GENERAL ELECTRIC REVIEW

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January, 1917—December, 1917

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GENERAL ELECTRIC REVIEW

A MONTHLY MAGAZINE FOR ENGINEERS

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Subscription Rates: United States and Mexico, $2.00 per year; Canada, $2.25 per year; Foreign, $2.50 per year; payable in advance. Remit by post-office or express money orders, bank checks or drafts, made payable to the *General Electric Review* Schenectady, N. Y.

Entered as second-class matter, March 26, 1912, at the post-office at Schenectady, N. Y., under the Act of March, 1879.

VOL. XX, No. 1
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JANUARY, 1917

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G. F. MORRISON

Recently Elected a Vice-President of the General Electric Company

GENERAL ELECTRIC REVIEW

THE PATHS OF PROGRESS

As a rule, we devote our editorial in the first issue of a new year to the scientific and technical progress of the year just completed, but on this occasion there seem even more important things to be considered, as most of us are thinking of the immediate future rather than contemplating the immediate past.

We publish in this issue an article by Mr. E. W. Rice, Jr., entitled "How Shall Manufacturers Contribute to American Industrial Progress," and one by Mr. Frank A. Vanderlip, President of the National City Bank, dealing with the "Relation of Banking to Industry." Both of these authors consider what we can do at this time to combat present evils to strengthen our future economic position. We believe that most thinking men, who will spare the time to look up from their desks, see danger signals for the future. With this condition in mind, we are particularly interested in the brief reference that Mr. Vanderlip makes to a conversation that he recently had with an eminent Frenchman—"He said he believed that democracy in its present form had been pretty well demonstrated to be a failure * * *." Here is the crux of all our present troubles—Is democracy a failure? To this, we would emphatically answer: No, democracy is not a failure. Again, Is democracy *in its present form* a failure? The answer to this, although perhaps less emphatic, is still no. Democracy may not be an entire success, but it certainly is not a complete failure.

If we look back into the pages of history, we can find many examples of democracies that rose, flourished and died; but this is no argument against democracy, because the same is true of every form of government.

But, if democracy in its present form is not an entire success, what is it that ails our present form of democracy? This is hard to determine, and a point on which there are sure to be disagreements; but there is one ailment that seems clearly discernable—Democracy—the government of the people, by the people, for the people—cannot bear its ripest fruit so long as the factor *by the people* is so incomplete.

This is not merely a national question; it is world wide. To again quote from Mr. Vanderlip's address where he is referring to his conversation with an eminent Frenchman—"It struck me particularly that in that analysis he put his finger on almost identically the things that we would say were weaknesses here with ourselves, more particularly perhaps that democracy seemed to throw up into legislative places at least, mediocrity almost invariably, that whenever there came into legislative place a man strongly representative of any interest, he was at once set down as a special pleader for that interest, was discounted and eliminated." It is certainly a matter of interest to note that some of the faults of democracy as developed in France are the same as those showing themselves in American democracy; it leads one to wonder if the same faults do not exist in all modern democracies.

The fault with our democracy is that we have let mediocrity represent us, and it would seem that this condition has arisen, mainly for two reasons: first, we are afraid of great men and they know they are distrusted; secondly, this has lead to our great men wrapping themselves up in personal and corporate business affairs to the exclusion of taking any interest in the government of their country.

Like every other state of affairs that we find in our economic, social and political lives, there is a reason for our present state.—We must look to broad fundamentals to find this reason. Many of the historic battlefields of the world have been drenched with blood to establish democracy. Democracy has been established, but in the process the people have learned to distrust not only despotic monarchs, but all men that were powerful, whether their power lay in brains, in money, or in lawful or unlawful combinations of men. It is unfortunate that this distrust of great men has been carried to the extent to which it has, but at the same time we cannot claim that the people were always wrong in their distrust.

These conditions have led to the democratic form of government being not truly representative, and the condition has been aggravated by selfishness and indifference which have been stimulated by prosperity.

We had this thought in mind when we wrote our last editorial pointing out the debt of gratitude that we owed Mr. E. W. Rice, Jr., for calling the attention of the young engineer to his broader duty as a citizen.

One of the fundamental necessities for good democratic government is that all sections of the community should be fairly represented in our various law making bodies. It is a recognition of the fact that the best brains of the country are, practically speaking, devoting their entire time to business, to the neglect of political considerations, that has led to the establishment of the National Industrial Conference Board, the object of this Board being to make the great business men of America articulate in government matters.

It is unfortunate that so many misrepresentations have been made in bringing the formation of the National Industrial Conference Board to the attention of the public. These very misrepresentations emphasize the distrust with which all big business men are held and emphasize the great difficulties that they must labor under in an effort to serve their country.

So far as we can learn nothing could be further from the truth than the statement that this Board was organized with a view of fighting labor; our impression is that the Board would be just as ready to fight for the legitimate ends of labor as for any other industrial ends, as labor is recognized as one of the most essential elements of our industrial life.

We wish the National Industrial Conference Board every success and hope they will be the means of securing the best brains of the country to help the government in framing and administering good laws which will be just and equitable to every element in the community.

We publish on page 38 of this issue an address by Dr. E. W. Rice, delivered at Boston on the occasion of the presentation of the Fritz Medal to Prof. Elihu Thomson; and by permission of the *New York Times* we reproduce here an editorial from their issue of December 10, which draws public attention to the debt the nation owes this most distinguished scientist.

A GREAT AMERICAN

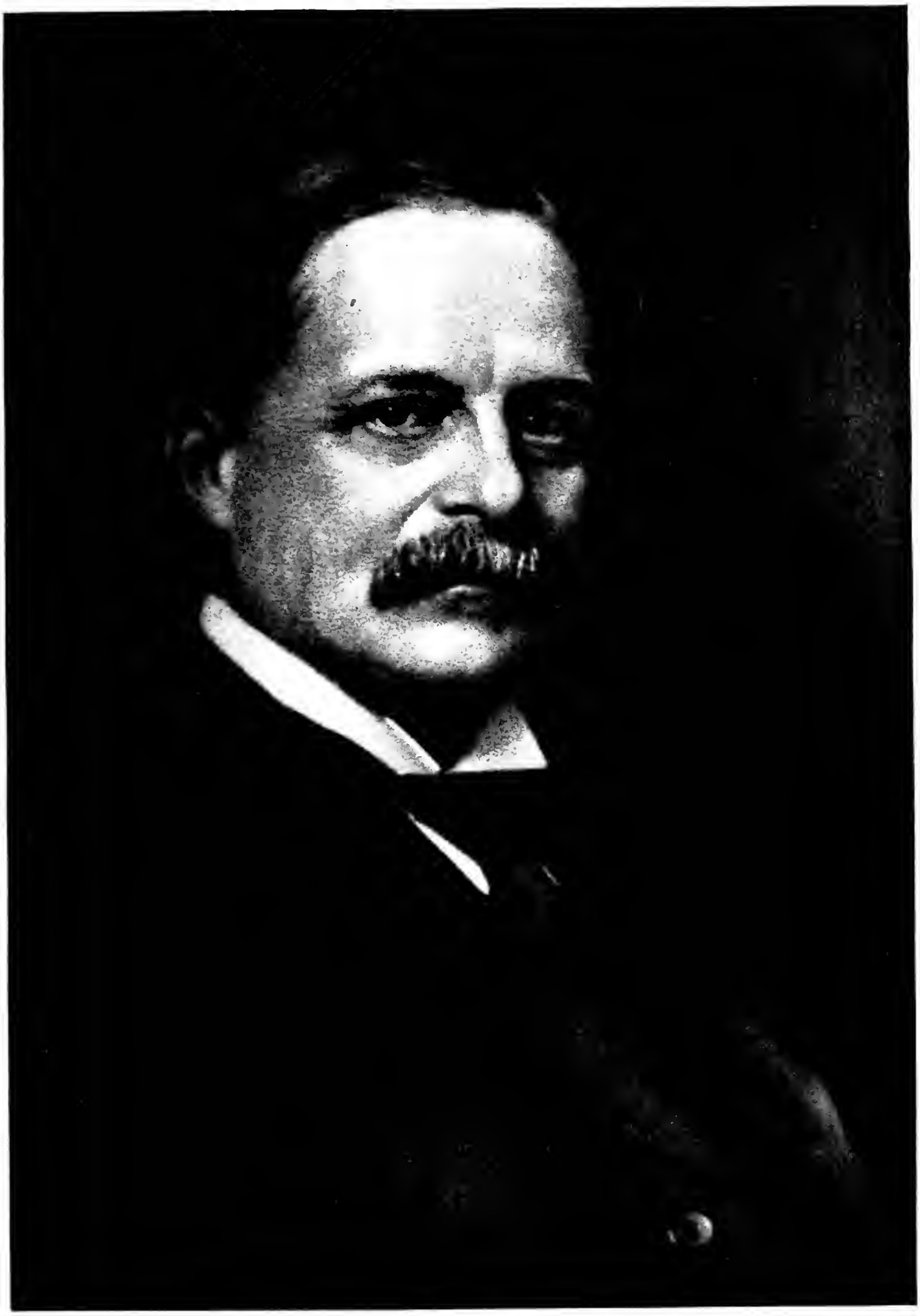
To how many hundreds of thousands of Americans is the name of Elihu Thomson even known, or if known does it connote anything more than some vague notion of science or invention? In a popular referendum where, say, the twelve most "famous" or "greatest" men in the country were to be selected, how many hundreds of thousands, how many thousands, of ballots would he receive? The quiet, fruitful labors of men of science pass unnoticed by the general in every nation. Elihu Thomson, English by birth, is an American citizen of whom the United States will boast hereafter. He is of the minds, few in every generation, that produce a great and lasting effect upon national welfare and industrial progress, that fructify civilization by the originality of their thought and their scientific achievement.

Only the other day Mr. Thomson, who wears modestly the laurels of we don't know how many native and foreign societies, received the medal of the Royal Society of London. On Friday night the Fritz medal was given to him. President Maclaurin of the Massachusetts Institute of Technology, of the corporation of which Mr. Thomson is a member, mentioned his five hundred-odd patents, "a large number of them embodying principles so wide in their application that they might almost be classed as physical laws," his master discovery of electric welding, "one of the great inventions of the last generation," and so on. Greater than the work, though, is the man; and not merely by the number and brilliance of his inventions, not merely because of his contributions to electrical engineering, the applied science perhaps most characteristic of this age, is Elihu Thomson great. He has not been content to dwell apart in that region of creative imagination which is the mathematician's, the astronomer's. The fact, uncommon, and one would have thought all but impossible, in this apotheosis of specialization, that his scientific interest and knowledge have the widest scope and range, has not engrossed him and confined him to the cultivation of his own powers. In his youth he was a teacher in the Central High School of Philadelphia. He has not ceased to teach, and more productively than he could hope to do in a university. In President Maclaurin's pondered estimation of the man this trait and habit are among the most significant:

> Throughout his life he has not only done great things himself, but shown an intense desire to help all who are struggling earnestly with scientific problems. He has proved an inspiration to an ever widening circle of engineers and others who have intrusted him with their secrets and sought his help in overcoming their difficulties. They have done this, knowing that they had only to ask in order to get the full benefit of his imagination and his power, and that they need have no misgivings that he would take any advantage of their confidence or any credit for their work, for he has no touch of selfishness.

Thus by helpfulness to others as well as by his own labors he furthers that scientific research the economic necessity and value of which the war is impressing upon this country laggard before it in spite of the shining example of Germany.

As we take leave of this honor to America, we like to think of him, as President Maclaurin let us see him, in his "laboratory built right into his house and an integral part of it," a man from whose mind "probably thoughts on scientific problems are never wholly absent," and "unselfish, generous, well-trained, well-rounded, well-balanced man of science."—*New York Times.*



ELIHU THOMSON

Recipient of the John Fritz Medal for "Achievements in Electrical Inventions, in Electrical Engineering, in Industrial Development, and in Scientific Research"

HOW SHALL MANUFACTURERS CONTRIBUTE TO AMERICAN INDUSTRIAL PROGRESS

By E. W. Rice, Jr.

President General Electric Company

This paper was read before the National Founders' Association at its annual convention on November 15th, in New York. The author points out the necessity of American Industries preparing to meet the changed industrial conditions which will inevitably follow the European war.—Editor.

There are many indications that when the great war ends our troubles in this country will begin. We have received ample notice that the principal actors in the present struggle will then begin what has been termed an industrial war. This industrial war will not permit us to remain neutral because it will be aimed to a large extent at us and we will become involved whether we like it or not. It is evident, therefore, that we as a people, and especially those directly interested in our manufacturing industries, will be faced with new, complex and even menacing conditions.

We read in a recent number of *Nature*, an English periodical, of the organization of a Federation of British industries which includes the leading manufacturing and producing industries of Great Britain. The objects of the Federation are—"The organization and development of the industry now and after the war in co-operation with labor and in conjunction with the Government and Government Departments. These and other signs show that our leading business men are prepared to do their part towards strengthening British industry and commerce for the competitive struggles of the future."

It is certain that the great industries of England have not only remained intact up to the present, but have been enormously enlarged and improved. England bitterly regrets her attitude of indifference towards science and the industries and is now headed in the right direction. She is certain to be a more powerful and efficient competitor in the world's industrial market than before the war. She is, moreover, copying as rapidly as possible whatever seems to be good in the German industrial system.

German industries also are unimpaired and are even improved and increased, and after the war, under the well-known system of governmental protection and assistance, will be in a position to compete more efficiently than ever before for the world's markets.

The men and women of industrial Europe, as a result of the war, are being trained in habits of discipline, economy and self-sacrifice, while we are being enervated by our great prosperity. The peoples of Europe are being taught by a life and death struggle the imperative necessity of co-operation in every detail of life. Their armies are now fighting, but after the war, even if they still continue the struggle commercially and industrially, the now contending groups will in effect be united to compete with us, not only in neutral markets but if possible in our own market.

Simple prudence, to say nothing of foresight, should impel us to take advantage of our present condition of extraordinary prosperity to prepare ourselves for the future. We should take an inventory of our resources and critically examine and compare them with the probable resources of our competitors, and exert ourselves to the utmost to remedy any deficiency that may be discovered. This is not an act of pessimism, but of wisdom.

It seems to be quite evident that the beginning of this great industrial struggle will find us well equipped financially as we are rapidly accumulating the gold of the world. We may also assume that we will have ample manufacturing plants, tools and equipment. These, however, are but the raw ingredients which must be skillfully and efficiently combined by human beings before they can be made useful to ourselves and to others, and thereby form a basis of permanent prosperity. We have, on the whole, good and skillful managers of our industries, but we must not be satisfied until we have the best and most efficient combination in the world.

It will not require a very exhaustive process of self-analysis to disclose that we are all relatively deficient in discipline and co-operation compared with the conditions which will exist in industrial Europe after the war.

The day of extreme individualism is past. The problems pressing for solution are so great that no single manufacturer, no matter how powerful, or group of manufacturers, no matter how numerous, is able to stand alone to the exclusion of other manufacturers or groups of manufacturers. The time has come when co-operation in the broadest sense is essential to the maintenance of our industrial prosperity.

All men and women engaged in industry, from the president and executive officers down to the humblest wage earner, must be brought into truly effective co-operative relationship. There is today a serious lack of mutual understanding between the manufacturer and the wage earner, and while considerable progress has been made in bringing about more harmonious relations, the situation leaves much to be desired. This lack of understanding and confidence is largely due to a lack of knowledge of each other, and this knowledge is lacking in the manufacturer as well as in the wage earner.

Employers are desirous to maintain good, healthful conditions of work and to provide fair treatment for their employees and to pay liberal but just wages, but the employer still needs to take an increased personal interest in his men as men.

On the other hand, if we are to have his effective co-operation, the employee must be convinced that all limitations of productive activity or restrictions of output are simply suicidal and as much an injury to himself as to his employer, in that such efforts only result in waste, inefficiency, high costs and poor business. He should get clearly in his mind that high costs restrict business and that the less of his product there is made and sold the less money there will be to divide. He should understand that although wages have the first claim on the earnings of any business, there must be a sufficient margin after payment for wages and material to pay for the use of capital, and, in addition, to set aside a reasonable reserve in good times to provide against bad times. But this is not all. Our governmental agencies, Federal, State and Municipal, must be won over to support proper industrial effort by sympathetic assistance. The manufacturers of other countries will have the great advantage of the intelligent and sympathetic help of their governments and of their people, and partiotism will be lifted to the highest plane. Our manufacturers, if we are to be successful in the coming struggle, must secure similar intelligent and sympathetic treatment from our Government and our people. We as manufacturers naturally think that we are entitled to such treatment and, in any event, we are making and shall continue to make an earnest endeavor to deserve it; furthermore, we intend to make continuous and, we hope, intelligent efforts to remove such defects in our business methods as may exist. In this process we will take the public and our employees into our confidence and deal with both in a spirit of absolute frankness and sincerity. We will endeavor to obtain constructive and helpful assistance from all sources, but we do not wish to encourage paternalism either in our relationship with our employees or on the part of our Government with us. What we want is intelligent, honest co-operation based upon simple justice and fair play. We want efficiency in every part of our country, but the only efficiency that is really worth while must be based upon a satisfactory treatment of the human factor in the problem.

We will indeed need to sharpen our wits to meet the future competition of foreign industrial nations with their industrial armies disciplined by co-operation, aided by their respective governments and with wages ruling at about one-half of those now prevailing in this country.

It is obvious that there must be unity of purpose and unity of action, not only among manufacturers but among all of our people, if we are to succeed in maintaining our position in the industrial world.

The National Industrial Conference Board, recently brought into action as a co-operative force among manufacturers throughout the country, is the type of agency which under wise and efficient leadership will be a potent factor in the solution of the many vexing problems herein briefly outlined and of many more that are constantly arising with changing social, industrial and political conditions.

THE RELATION OF BANKING TO INDUSTRY

By Frank A. Vanderlip

President, The National City Bank of New York

Mr. Vanderlip considers commerce as divided into three classes, production, transportation and banking, each of which is absolutely essential, and between which complete coöperation should exist. A strong plea is made for the American business man to take an active interest in government, to find time from his regular duties to work for better economic and social conditions, and for a closer coöperative relation between the government and the country's industries. The paper was read before the annual convention of the National Founders' Association, New York City, November 15th.—Editor.

It is a privilege that I very highly appreciate to meet you here. I am sorry that I am such a busy man that I have not had, on this particular occasion, the time to prepare, as Mr. Rice has prepared, a thoroughly thoughtful paper. I can only give you today, not a speech, but just a little face to face talk.

Your President assigned to me the subject of the relation of the banker, or of banking, to industry. Now commerce, it seems to me, falls in three classes; we have first, production, then transportation, and then banking. Each field contributes its important part and an equally important part to the whole of commerce; each is absolutely essential. Obviously, production by itself would not get far; it must have the aid of transportation, and I conceive that the business of banking plays as essential a part in the final make-up of commerce as do the other two fields of production and transportation. If that is so, the relation that must exist between banking and industry is a relation of complete co-operation; it is a relation that makes it evident that we must not look upon bankers in that narrow sense of men who for a time hold your money; who for a time loan it at a profit; and who are merely the parasites scraping off a bit of profit here and there. They are rendering, I believe, a service as essential, as absolutely necessary to society as that which either you, the producers, or the great transportation factors are rendering in the whole scheme of commerce. If, as I say, that is so, then their relations are relations of complete co-operation if the best results are to be obtained.

It seems to me that we are today peculiarly in a time when all of us, bankers, producers, and those who manage the great transportation interests, must do more than look on our desks, must do more than the work that normally flows by us. We are all of us so normally busy with that work that it pretty much consumes all of our time; it normally leaves us with little time to think, in broad, fundamental ways, of the problems that are affecting our business and are fundamentally affecting the society in which we live; but I conceive that those problems at the present time are more fundamental and in many ways more important than any we have had to observe before.

The fundamental problem of all is the problem of government. I had an interesting conversation a few days ago with a very eminent Frenchman, a great financier, who has spent the last two years at the front and was profoundly affected, as are all of the men who are going through that great drama. I asked him what he thought was going to come out of the war that would be fundamental to the future world, and he told me that he thought it not improbable that as great changes in the fundamental forms of government would come out of this great war as came out of the French Revolution. He said he believed that democracy, in its present form, had been pretty well demonstrated to be a failure, and he went on to analyze some of the weaknesses as they appeared in the French Government. It struck me particularly that in that analysis he put his finger on almost identically the things that we would say were weaknesses here with ourselves; more particularly perhaps that democracy seemed to throw up into legislative places, at least, mediocrity almost invariably; that whenever there came into legislative place a man strongly representative of any interest, he was at once set down as a special pleader for that interest, was discounted and eliminated.

Now if that is so, and it seems to me so with us as it is so in other countries, perhaps it is time that we did do some fundamental thinking, certainly not of returning to any former type of government, certainly not to changing fundamentally from democracy, but to considering whether there cannot be found some way whereby we are represented not by the mediocre men but by men in public life who do represent in an expert way the various interests of our society. Now I believe it is to such subjects as this that all of us must give some of our attention. I am merely citing this as a sort of a fundamental. The point that I want to emphasize is the necessity for all of us to have a broader vision than the consideration of the work of the desk.

One of the things that Mr. Rice referred to which I believe is going to be of vast importance to the business of this country and particularly to the productive energy of the country, is the co-operative relation between government and business, and we are going to see illustrations of that co-operative relation in European countries that will be something novel in business life. We are seeing now great experiments in state socialism; we are seeing co-operation in the way of subsidies; we are seeing the direction of great shipping interests by government and the control of shipping interests as recently illustrated in Australia, by government capital. We are going to meet in the future competition an entirely new relationship in the European countries, particularly, between the government and business, and a relationship that is going to increase your difficulties to meet that competition. Now, unless we can get something like similar co-operation between business and industry in this country, between government and industry in this country, unless we can get a sympathetic relation, a helpful relation of government to business, we are going to find ourselves very greatly handicapped in the competition of this new order of affairs which I believe will develop very much from its present state in the future development of European politics. So, there again, it is up to us to look at things in the large, to find time to look up from our desks, not to be absorbed with our day's work to the extent that we are not participating in the political life and the legislative decisions that are going to mean so much to the future of our development. We are no longer isolated; we are out in the world in spite of ourselves. What the world does is going to mean a vast amount in our lives, in our industrial affairs here, in our business, and it is up to us to take that interest in public affairs which will tend to make our voices heard and our wisdom have its influence in the shaping of that legislative relation to business which forms so great a part of legislative action. I think we will see the most adroit tariffs framed by the European countries, and those must be met, not by the log-rolling tariffs that we have heretofore had, but by equally scientific, equally adroit legislative measures which will serve to protect our industries. We are going to see the government ownership of utilities, particularly of shipping; we are going to see the influence of government in the shipping business to a larger extent than we have ever seen before.

The business in this country that has felt, more than anything else, the hand of government, has been the business of transportation. Railroads have been regulated—I believe, in many respects properly regulated—although I believe we have very foolishly applied two theories to the regulation of railroads, both of which cannot possibly be right, and when both are applied at the same time the result spells nothing but disaster. We have the one theory of minute regulation, starting with the regulation of rates, and embracing the regulation of bookkeeping of almost every act of the transportation company; then we have the other theory of the prevention of combinations, prohibition of pooling. Now both of these theories cannot be right and both of them are being worked side by side, both being applied to the railroads with resultant disaster. Now you may very readily say "Disaster? Where is the disaster to the railroads? They are doing more business than they ever did in their lives, their earnings are showing enormous increase; you are going a good way to talk about disaster in the railroads field." But I tell you any business that has become so hampered in the eyes of the investors that it will attract no money into partnership in the business, that it has only credit that will permit it to borrow, is in a bad way. Now that is really what the position of the railroads is today. They can borrow money, yes, they have still some credit. All last year the total amount of new money that went into railroads to buy stock for the construction of roads, that is, money that went in partnership in the business, was less than thirteen million dollars. So far this year there has not been a dollar of new railroad stock listed on the exchange here. Now there is something fundamentally wrong with that great branch of the industry, transportation, when we find that it occupies a place in the investor's mind such that he is willing to lend it money but not willing to go into partnership with it, not willing to put any fresh money in as a stockholder.

I believe that one of the troubles there lies in just this illustration of being busy with what is on your desk. Railroad men, too many of them, are good operators and too few of them statesmen; too few of them are looking at that problem in a broad way. I had an illustration happen at breakfast today. I had been talking to a railroad president a few days ago about what seemed to me the great economic waste in our present system of car ownership and control. We see empty cars traveling both ways at the same time. We see the great difficulties that roads are under because of this individual ownership of cars and the methods by which they get away from the owners and into other hands at busy times, and I said I believed the railroads must find some fundamentally different methods of handling the car situation. He said he was impressed with that same thing but had always been too busy really to think it out. I happened to meet him at breakfast this morning and he said "I sent you yesterday a plan for a national car pool that a very important railroad man has gotten up and sent me a copy of." "Well," I said, "Is it a good plan?" "Oh," he says, "I don't know, I didn't have time to read it, but I just passed it on to you." Well now that is illustrative not only of what I believe is one of the troubles with the railroad situation, but one of our troubles all around; we are too busy doing the thing we have got to do today to look after broadly some of those very fundamental things the correct solution of which is going to influence our future, the future of the business in which we are engaged.

Our problems are not all technical, by any means; a lot of them are economic, a lot of them are social; we have got to think soundly about principles of political economy; we have got to think soundly about social relationships, particularly in relation to labor; and have got to think, it seems to me, in a much more far-reaching way than to settle immediate difficulties, to avoid a strike today, or to hold the wage scale down to a reasonable point. Haven't we got to do a lot of educating of workmen themselves? Aren't they influenced by the fallacies of economics? Would they not, if they better understood the true principles of economics, take much more reasonable views of their rights and make much more reasonable demands? The great fallacy, one of the greatest of all that you find so general among many working men, the fallacy that a restriction of production is a benefit to their class, I believe could be rooted out if all of us would do our best towards education. It is that fallacy, restriction of production, that brought England to a very unfortunate point before the war. The clearing up of union restrictions as war measures have demonstrated what an enormously increased capacity follows the wiping out of those union restrictions, and I am inclined to think that it demonstrates probably to union men themselves in England that they can have a much greater share of prosperity if they will permit a freer production. I believe the tendency here at present is in the other direction. In some branches of industry with which I am familiar I have seen in these two years not only great advances in wages but an almost equal fall in efficiency. Now that is a fatal thing, and a tendency that will certainly make our position a very trying one when we come again to compete with a Europe that is free to enter into industry fully,—to continue advancing wages, and decreasing efficiency by permitting the fallacy to exist in many minds that a decrease of efficiency is helpful to the laboring class.

Well, in a word, the message that I would bring is that we want statesmen in business, that we want men who think broadly, fundamentally, on economic lines; and who think on social lines sympathetically but with clear vision. The man who is going to work 30 days in the month just at his business is not going to be left free to enjoy the fruits of that labor uninterruptedly. I tell you he has got to devote some of his 30 days to these broader fields of thought; he has got to devote some of them to sound citizenship, to bringing statesmanship into business. (Applause)

SOME DEVELOPMENTS IN THE ELECTRICAL INDUSTRY DURING 1916

By John Liston

Publication Bureau, General Electric Company

The great diversity in electrical apparatus and the wide field of power application which is affected either directly or indirectly by developments in the electrical industry make it difficult to include within the limits of a single article a complete description, even in outline, of all phases of the progress achieved during the year. However, by specific reference to typical equipments and installations, the author has in this article described the salient features of the more important developments in a manner which conveys a logical and comprehensive idea of their technical and commercial values, and also indicates their influence on both the designing and manufacturing trend throughout the industry.—Editor.

Notwithstanding the intensity of productive activity imposed on the electrical industry during 1916, by the demand for equipment to meet the needs of the unparalleled manufacturing business of the United States, a considerable number of important advances were achieved in the design and construction of various classes of electrical apparatus.

The phenomenal expansion of our seaborne commerce entailed a noteworthy increase in the use of electric auxiliaries on shipboard, and there was also a further acceptance and adoption of electric propulsion for naval vessels. Perhaps the most impressive development in marine work, however, was the radical increase in the use of geared turbine propulsion for merchant ships.

The unit capacity of steam turbine generator sets was carried well beyond the maximum of previous years, and many minor changes were introduced in the construction and methods of operation of apparatus for central station generation, distribution and control systems, and for the further safeguarding of industrial electrical equipment. These developments tended to enhance the value of electric service in widely diversified industries and to further extend the field of economical electric power application.

In railway work the regular operation of electrified trunk lines on a scale which was never before possible gave gratifying practical results and rendered possible the accumulation of detailed operating data which cannot fail to have a vital influence on the future trend of railway electrification, not only in the United States but throughout the world.

Due to the nature of this article the references to each class or type of apparatus must be necessarily limited in scope and fully detailed description which might be of interest to designing and operating engineers must perforce be abridged. Therefore the omission of specific mention of certain classes of machines does not imply the absence of improvements during the year, but merely indicates that the changes made were of a minor nature and did not involve elements of radical departure from previous practice.

The electrical apparatus and turbines referred to in the various sections of the article are all of General Electric manufacture, but the character and extent of the equipments cited permit their use as criteria of the advances made in the electrical industry as a whole, in a year replete with important engineering and commercial developments.

Turbines

The greatest advances of the past year in turbine work were along the lines of better economy and greater simplicity. The tendency toward the use of higher initial steam pressure which has become increasingly evident during recent years, led to the designing of units to operate at steam pressures as high as 300 pounds gauge. Most of the larger installations have taken advantage of improved condenser design and now operate regularly at vacua within one inch of perfect vacuum.

When we consider that the volume of each pound of steam is twice as great at 29 inches as at 28 inches vacuum, it is obvious that in utilizing such high vacuum with the resulting enormous volume of steam to be handled, the proportions of the turbine must be initially designed for such conditions if the full benefit of the high vacuum is to be obtained. This has been fully provided for in G-E turbine design.

Along the lines of greater simplicity, there were under construction self-contained single flow turbines of 35,000 kw. capacity and larger. These sets consist of a turbine enclosed in a single casing and operating with steam flow in one direction, the turbine driving a direct-connected generator mounted on a base integral with the turbine casing. This construction secures a maximum of simplicity and gives the smallest number of joints, connections and possible air leaks, thereby assuring sustained economical operation.

Fig. 1. S. S. Eurana, Equipped with Geared Turbine Propelling Machinery

In the size of the turbine generators being considered and built, the year showed notable progress when compared with previous practice. In this connection the order placed by the Detroit Edison Company for a 45,000-kw. turbine-generator is of interest. This set consists of a single turbine of single flow design, connected to a single generator rated 50,000 kilovolt-amperes at 90 per cent power factor.

To meet the demand for turbine driven exciters for the large installations, a line of geared direct-current sets (Fig. 2) was developed to supplement the smaller direct-connected sets which have been on the market for some time. Turbines and gears similar to those used in these sets are also used extensively for driving pumps, air compressors and similar apparatus. For high speed rotating machines these turbines are employed without the gearing. These turbines and sets are also used on ship board for driving various auxiliaries.

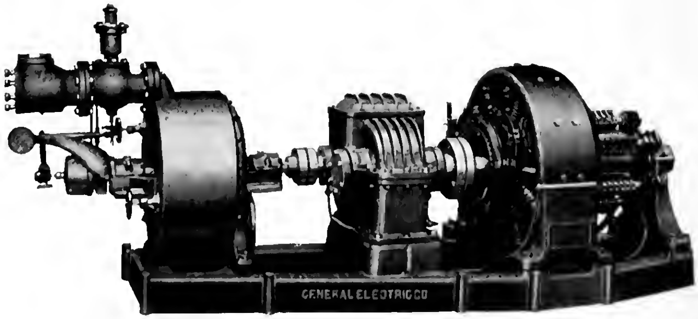


Fig. 2. Small Curtis Steam Turbine Geared to Direct-current Generator

A large number of geared turbine generator sets were built during the year; of which the greater part are direct current sets. The improved economy due to the higher turbine speeds made possible by the use of geared sets, combined with the advantage of the low speed direct current generator, explains this development. A number of alternating-current 25-cycle geared sets were built.

One of the most important applications of turbine and gear is for ship propulsion, and orders were received for a large number of such outfits for driving merchant vessels. These turbines range in output from 1800 to 4000 horse power. A typical ship of this class is shown in Fig. 1, while Fig. 3 shows the turbine and gear equipment that is used. Several larger sets are being built for high speed scout ships for the United States Navy.

Electric Drive for Auxiliaries on Ships

The equipment of the Union Oil Company of California's tank steamer "La Brea," which began its initial voyage on March 9, 1916, is of unusual interest due to the fact that induction motors were used throughout for driving the auxiliaries; in which service direct-current motors or steam drive had previously been used almost exclusively.

The "La Brea" is 435 ft. long, and is propelled by a steam turbine through reduction gearing. In addition to the main turbine, which is rated at 2600 h.p., two small turbo-generator sets, rated at 375 kv-a. and 125 kv-a., 3600 r.p.m., three-phase, 60 cycles, 240 volts, are installed for supplying current for the motor driven auxiliaries.

There are twenty-two cargo tanks in the hull of the ship, each served by a 4-inch vertical shaft rotary pump, individually driven through gearing by a 40-h.p., 600-r.p.m., 220-volt horizontal shaft induction motor. (Fig. 4) These motors are of the open type and are installed on the deck in cast iron gas-tight casings, the hand-hole covers of which are opened when the motors are in operation in order to secure the necessary ventilation.

On account of the nature of the cargo carried it was not considered advisable to locate the motor starting equipment where the circuit would be made or broken on the upper deck, and all of the 22 cargo pump motors are therefore started from the engine room switchboard through a single compensator. In order to accomplish this the control panels have running and starting buses, the former being energized direct from the generators and the starting buses through the compensator. With this arrangement and the use of triple-pole double-throw switches, the pump motors are put in operation in sequence so that only the one compensator referred to is required; a spare compensator is held in reserve.

In addition to the cargo pump motors a 60-h.p., 720-r.p.m. motor is direct-connected to the circulation pump for the main condenser, while the centrifugal boiler feed pump is direct driven by 50-h.p., 3600-r.p.m. motor, and a centrifugal ballast pump by a 35-h.p., 1800-r.p.m. motor.

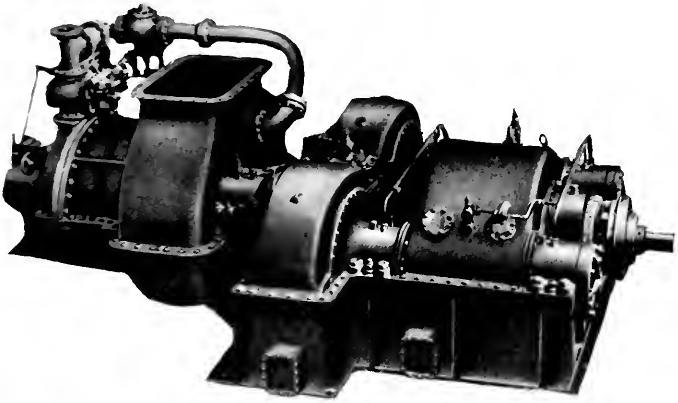


Fig. 3. Curtis Turbine and One Plane, Flexible Type, Speed Reduction Gear for Ship Propulsion

In order to avoid all possibility of the ignition of explosive gases, neither direct-current nor slip ring motors were considered, and the squirrel-cage type was adopted throughout.

Radio Apparatus

Electrical equipment more powerful than any previously installed for wireless telegraphy was produced for three high power radio stations, which, when completed, will give a service spanning the Pacific Ocean. These stations are located at San Diego, California, Pearl Harbor, Hawaii, and Cavite, P.I.

Fig. 4. Arrangement of Motor Drive for Cargo Pumps on S. S. La Brea

The apparatus supplied by the General Electric Company includes all power and auxiliary electrical equipment, except that immediately connected with the arc and its control and operation. Current for radio service will be furnished in each case by a motor-generator set, and two complete units were furnished for each station, one of which is held in reserve, and automatic starting, with both local and remote control, was provided for. The motor-generator sets are rated as follows:

Station	Motor	Generator
San Diego	300 h.p., 1200 r.p.m., 2200 volts	200 kw., 950 volts
Pearl Harbor	750 h.p., 900 r.p.m., 2200 volts	500 kw., 1430 volts
Cavite, P. I.	720 h.p., 900 r.p.m., 220 volts	500 kw., 1430 volts

The current supply at San Diego and Pearl Habor is secured from an outside source, and enters the former station at 11,000 volts, where it is then stepped down to 2200 volts; while at Pearl Habor it is received at 2200 volts, this being the operating voltage of the driving motors of the motor-generator sets in both stations. At Cavite. however, an independent generating plant supplies current for the radio service. This equipment consists of two G-E 150-kw., 220-volt high compression oil engine generating sets, used in conjunction with a 300-kw. storage battery. There is also a battery charging booster.

Each station is provided with a contactor panel for short circuiting the regulating resistance in series with the arc, and these contactors are operated in sequence by means of a single-pole multiple blade switch. The necessary resistance is mounted back of the panel on porcelain insulators, and the 125-volt control circuit is especially insulated to enable it to withstand the heavy surges which are imposed on the circuit when the arc is broken. On the back of this panel are mounted two specially designed direct-current high voltage contactors for the main arc circuit.

Electric Railways

In the railway field the year was marked by a trend toward standardization, indicating a general acceptance of existing types of electric equipment as eminently suited to the performance of various classes of service. Both manufacturers and operating companies, therefore, were more concerned with perfecting details and eliminating minor defects than in developing new types of apparatus.

Chicago, Milwaukee & St. Paul Railway

A conspicuous example of the ability of large manufacturers successfully to design and put in operation electrification projects of any magnitude, is the Chicago, Milwaukee & St. Paul Railway now operating 335 miles of route from Harlowton to Alberton, Montana, and with additional trackage nearing completion, making a total of 440 route miles. The unqualified success of this initial 3000-volt direct current electrification is a source of gratification to all concerned. The one feature of the project which stood out as new and untried was the use of regenerative electric braking in connection with standard direct-current series motors. After trials extending over a full year, it is most significant that this portion of the equipment is operating with entire satisfaction and practically without change from the original design.


Fig. 5. Chicago, Milwaukee & St. Paul, Canadian Northern and Butte, Anaconda & Pacific Locomotives on Test Track at Erie Works

Overload line construction and the remaining substations are practically finished for the entire electric zone and electric trains will be in operation over the entire 440 miles by the beginning of 1917. One feature of the motor-generator sets supplied on the last seven substations is worthy of mention. On these sets the ventilating fans used to cool the direct-current machines have been omitted and ventilation is secured by separate blower so controlled that it operates only above a certain temperature limit. This control is entirely automatic, depending upon the action of a thermostat suitably located. (See G. E. Review, November, 1916, page 908.)

Bethlehem-Chile Iron Mines Company

Three 120-ton, 2400-volt direct-current locomotives were shipped during the latter part of the year to the Bethlehem-Chile

Iron Mines Company for operating a 15 mile ore hauling road between Cruz Grande and Tofo, Chile. These locomotives are similar in many respects to a half unit of the Chicago, Milwaukee & St. Paul locomotive without the guiding trucks. Regenerative electric braking equipment is provided and will be used for lowering the ore trains for a distance of 14 miles down a continuous 3 per cent grade. (See G. E. REVIEW, Nov., 1916, page 995.)

Butte, Anaconda & Pacific Railway

In order to take care of greatly increased traffic, the Butte, Anaconda & Pacific Railway purchased six additional 80-ton locomotives which are duplicates of the original equipment, making a total of 28 locomotives. Two additional 1000-kw. synchronous motor-generator sets were provided for the substations, these being duplicates of the five sets previously purchased. An additional 20 miles of track were also electrified in the vicinity of Butte Hill.

Canadian Northern Railway

Work on the new tunnel and terminal of the Canadian Northern Railway entering Montreal, which had been held up on account of the European War, was resumed and partial shipment made of the 83-ton electric locomotives which will be used on this new 2400-volt electrification. Substation equipment was installed and the first electric locomotives will be used for construction work.

Fig. 6. Bethlehem-Chile 120-ton Locomotive

New York Central Locomotives

The electrical equipment of the New York Central Railroad operating on the New York Terminal Division will be augmented during the present year by ten additional 125-ton locomotives, which will be duplicates of those last furnished. Each of these locomotives is equipped with eight bipolar gearless motors designed for high speed passenger service.

Fig. 7. Canadian Northern 83-ton Locomotive

Automatic Substations

Since the first automatic railway substation was placed in operation about two years ago, twenty similar equipments have been sold in various parts of the country. About half of these are now in operation, and experience to date indicates that it is entirely practicable to operate a railway substation without attendants. Furthermore, operating data now available show that the saving in power due to the elimination of no-load losses and the reduced expenditure for attendance entirely justify the initial expenditure required.

One of the novel applications of this apparatus was the portable automatic substation built for the Interurban Railway of Des Moines, Iowa. Another adaptation of the automatic feature includes the control of two units in one substation, the control equipment being so arranged that one machine carries the load up to a predetermined figure and the second machine automatically cuts in on the higher peaks. The operation of both machines is automatic, the entire station being shut down under no-load conditions.

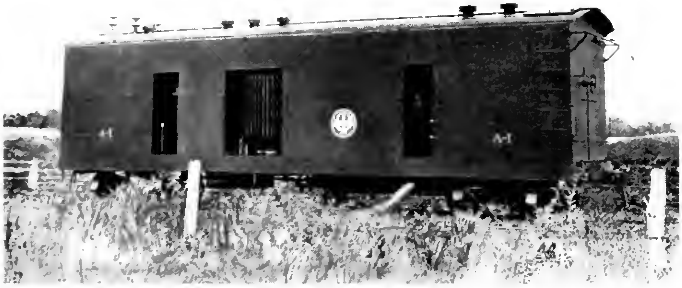


Fig. 8. Portable Automatic Substation

Car Equipments

Orders for car equipment indicated an unusual activity in light-weight motors including Types GE-258 and GE-247 rating 25 and 40 horse power respectively. More than 800 Type GE-258 motors were sold during the year for use both as two and four motor equipments. A large number of these motors were installed on light-weight frequent service cars designed to secure better service to the public and at the same time to return satisfactory earnings on the investment.

Large equipment orders were also taken for subway and surface lines, interurban properties and storage battery cars. The Interborough Rapid Transit Company and the New York Municipal Railways of New York City purchased more than 1200 motors for new subway and elevated equipment. The New York Railways have added to their storage battery equipment, and the surburban lines of the New York Central are installing new multiple unit car equipment Other large car equipment orders were received from Detroit, Minneapolis, Providence, Boston, Milwaukee, Buffalo, Baltimore and from the Public Service Company of New Jersey. Many of these orders included PC control. This type of control, which differs in many important features from previous systems of remote control, is fulfilling the requirements of operating companies in a most satisfactory manner. (Details of this type of control are given in the GENERAL ELECTRIC REVIEW of November, 1916, page 1015.)

Automatic Synchronous Condenser Substation

As a logical result of the success achieved with automatic substations in railway operation, the same principles were applied, with certain modifications, in a synchronous condenser substation installed toward the close of the year on a transmission line of the Interstate Light & Power Company, Hazel Green, Wis., in the vicinity of a low power-factor mining load located at a considerable distance from the generating station.

The installation comprises a 3000-kv-a., 4000-volt synchronous condenser and an automatic starting and control equipment, so that the substation does not require the attention of an operator except for periodical inspection and renewal of lubrication.

When the voltage at this substation drops, because of poor power-factor or increased load, a contact-making voltmeter automatically starts a motor-driven controller, which, through contactors and oil switches operating in proper sequence, effects the starting of the synchronous condenser, and connects it to the line with its field excited from the direct-connected exciter. A voltage regulator then holds constant voltage at the station, varying the kilovolt-ampere input to the condenser. As the need for the condenser becomes less and less (to hold the proper voltage) and the load drops to about 10 per cent of normal, a contact-making ammeter shuts down the equipment.

The condenser is prevented from being overloaded by means of a stop on the voltage regulator and the equipment is further protected against unusual internal disturbances by inverse time-limit overload relays.

Industrial and Mining Locomotives

In addition to meeting an unprecedented demand for standard forms of industrial locomotives, a considerable number of unusual types were developed during the year to take care of exceptional operating conditions, and a brief reference to certain of these special units will serve to demonstrate the great flexibility which is possible in the design of the electric type of tractor. This characteristic permits it easily and successfully to overcome operating limitations which would render the adoption or modification of other forms of locomotives a matter of great difficulty and expense.

Three 25-ton locomotives, one of which is shown in Fig. 10, were built early in the year for haulage service through a restricted tunnel over a 30-inch gauge road on the property of the Braden Copper Company in Chile. They are the heaviest locomotives operating on this gauge, and are of the trolley type.

Each unit is driven by four 45-h.p., 250-volt motors, and is equipped with Type M control and automatic air brakes. In order to secure sufficient vertical clearance while traversing the tunnel, the cab roof is only 7 ft. 6 in. above the rails.

A number of uncommon features are found in a 20-ton locomotive which was specially developed for coke oven service in steel mills. The locomotive is standard gauge and operates on a 220-volt direct-current metallic circuit, the feeders being two rails mounted vertically along one side of the track, as shown in Fig. 11. Two 85-h.p. driving motors are used with hand control and straight air brakes.

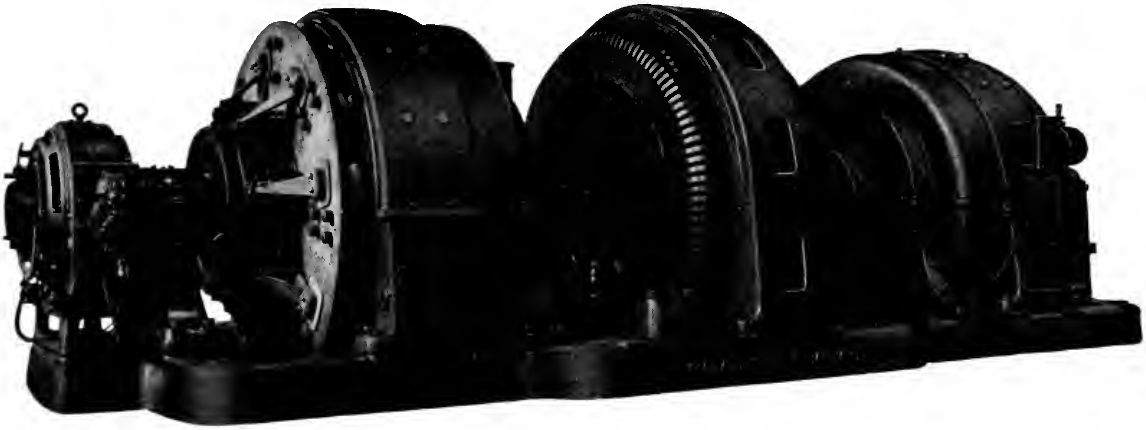


Fig. 9. Three-unit, 2000-kw. Synchronous Motor-generator Set Arranged for External Ventilation

The service cycle is as follows: The locomotive pushes long steel cars beneath the coke ovens, and while the coke is being discharged the car is moved slowly so that a broad ribbon of incandescent coke is evenly deposited along the bottom of the car. In order that this may be accomplished the locomotive has a two-story cab with the control centered in the upper section so that the motorman can overlook the length of the coke car and manipulate the locomotive so as to secure the required even distribution of the coke.

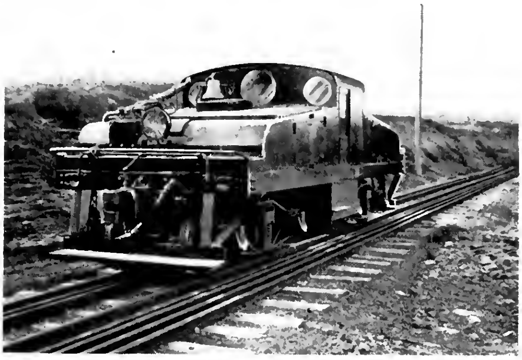


Fig. 10. 25-ton 30-in. Gauge Haulage Locomotive on Test Track

After being loaded the car is drawn to the quenching station where the motorman by stepping from the cab to the small platform, which forms part of the upper floor of the locomotive cab (Fig. 11), can easily reach the quenching valves. The car is thereafter brought to the coke wharf where the coke is discharged, as shown in Fig. 12.

The doors of the coke car are controlled by the motorman and are operated by compressed air, which is supplied by a CP-26 motor driven air compressor installed on the lower platform of the locomotive. At present fifteen of these coke oven locomotives are in service, and the completion of those now under construction will bring the total number above forty. They were designed for the H. Koppers Co. of Pittsburg, Pa.

Fig. 11. 20-ton Coke Oven Locomotive at Quenching Station

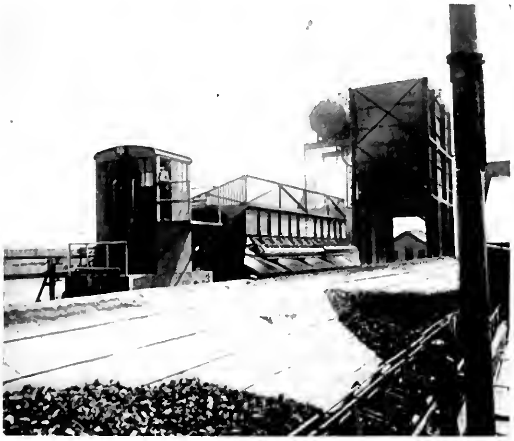


Fig. 12. Coke Car Discharging at Coke Wharf

Another special type, known as a "pusher" locomotive, was designed for handling coal trains and spotting cars at the plant of the Toledo Furnace Co., Toledo, Ohio. It is rated at 25 tons with two 125-h.p., 250-volt driving motors and has Type M control with straight air brakes.

The duty of this locomotive is limited to shuttle service on a single line of 42-inch gauge track (Fig. 13), centrally located between two standard gauge tracks on which the coal cars are run. Current is supplied by a metallic circuit consisting of two rails located between the running rails.

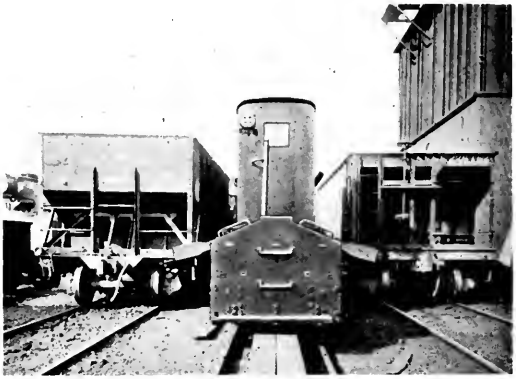


Fig. 13. 25-ton "Pusher" Locomotive with Both Pusher Arms in Operating Position

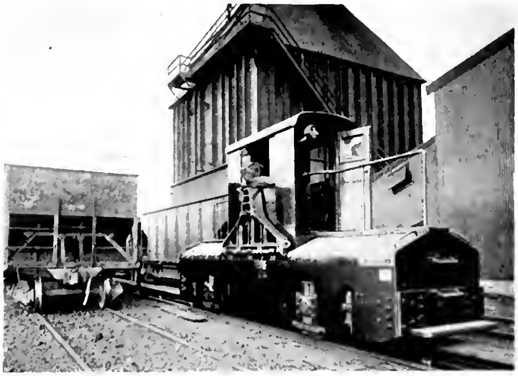


Fig. 14. Side View of "Pusher" Locomotive Showing Construction of Pneumatically Operated Pusher Arm

At the center of each side of the locomotive (Fig. 14) a hinged heavy metal arm or wing pusher is provided, these arms are raised or lowered pneumatically. The locomotive was placed in service in July, 1916, and has been in successful operation since that time.

Radically different conditions govern the service of four 12-ton standard gauge locomotives (Fig. 15) used in the plant of the Davison Chemical Company at Curtis Bay Md., for here the locomotive must, in addition to its work as a tractor, act as a movable air reservoir. Current is supplied through an over-running third rail at 250 volts to two 65-h.p. driving motors.

The exceptional equipment for each locomotive consists of two CP-30 air compressors of 35 cu. ft. capacity each, which supply air at 70 lb. pressure to four storage tanks, two of which are located on the locomotive deck and two below. The compressed air is stored rapidly in these reservoirs, so that while the locomotive is making a relatively short haul (Fig. 16) an ample supply of air is available for dumping the cars at the end of the run. This is accomplished by delivering air from the locomotive tanks to storage tanks on the cars, so that at the end of a run the locomotive may leave the cars, which can then be dumped pneumatically by means of their own supply of stored air. Combined straight and automatic air brakes are used.

Fig. 15. 12-ton Locomotive Showing Arrangement of Compressors and Air Storage Tanks

Fig. 17. 12-ton Industrial Gasolene-electric Locomotive

Fig. 16. Two 20-ton Locomotives Hauling Trips, Showing the Over-running Third Rail and Current Collectors

For yard switching and industrial railway haulage, a compact 12-ton gasolene-electric locomotive (Fig. 17) was built. It runs on standard gauge tracks and its power plant consists of a 25-kw., 560-r.p.m. gasolene-electric generating set which supplies current at 250 volts to two 25-h.p. driving motors. Like the large gasolene-electric passenger cars, its operating speeds are regulated by field control of the generator, and hand brakes are used. It has proven very successful in a variety of haulage service and as it is altogether self-contained (Fig. 18) with regard to its energy supply, it is especially useful where feeder wires or other electrical conductors would be objectionable, and for conditions involving long hauls and continuous service which might limit the usefulness of storage battery locomotives.

The entire weight is carried on the four driving wheels and speeds up to 16 miles per hour can be obtained on level track. When it is considered that the locomotive carries its own power plant, its overall dimensions are notably small; length 16 ft., width 6 ft., 6 in., and height between rails and top of cab 10 ft. 3 in.

Fig. 18. View in Cab of Gasolene-electric Locomotive Showing Self-contained Power Plant from Generator End

The advance made in the storage battery type of locomotive was typified by the construction of a double truck locomotive with the battery on a centrally located platform joining the two trucks, thereby minimizing the vertical dimensions of the locomotive and permitting its effective application for service in low coal seams and on the short radius tracks frequently encountered in mine haulage.

With a total weight of 8 tons, about 6 tons are imposed on the two pairs of driving wheels at either end of the locomotive. The two central pairs of wheels are not drivers. Each truck has a rigid wheel base of only 30 inches, while the overall height above the rails is 34 inches, indicating unusual compactness and flexibility for a locomotive of this capacity. It is the first double-truck storage battery locomotive built by the General Electric Company, and three others of the same type were under construction at the close of the year.

Toward the end of the year, the largest G-E locomotive so far built for main mine haulage was completed. The locomotive is rated at 25 tons, but the three 125-h.p., 500-volt motors with which it is equipped have ample capacity to permit the addition of sufficient weight to give a rating of 35 tons, if required. Its overall dimensions are: length over bumpers, 300 inches; width, 77 inches; and maximum height above rails, 54 inches. The wheel base is 120 inches, with 36-inch diameter wheels; it runs on a 48-inch gauge track, and develops a drawbar pull of 10,000 pounds at 8.8 miles per hour.

Both straight air and hand brakes are provided on this locomotive, and it is also equipped with Type M multiple unit control. Where additional haulage capacity is required, the design permits the coupling together of two of these units, so that if necessary the effective rating of a tandem locomotive of this type, operating within the working limits which regulated its design, can be raised to 70 tons with a control system as easily manipulated as that of the smallest and simplest form of mine locomotive. This 25-ton unit is intended for main haulage in the Caruthers coal mine of the H. C. Frick Co. at Maxwell Station, Fayatte County, Pa.

Electric Shovels

In the fall of 1915 the Piney Fork Coal Company, Smithfield, Ohio, placed in service a 250-ton electric shovel, and a year later a similar machine, rated at 300 tons, was installed by the Beech Flats Coal Company at Rush Run, Ohio. Both of these shovels are employed in stripping overburden from coal beds, and they are the largest electric shovels in existence.

In order to gain a comprehensive idea of the improvements embodied in the operation and control systems of the 1916 shovel, a comparison of the equipment of both shovels is necessary.

The 1915 machine has a six yard dipper, and is equipped with a 300-kw., 250-volt synchronous motor-generator set having a 4000-volt, 60-cycle motor, switchboard control panel, two 170-h.p. hoisting motors, one 63-h.p. swinging motor, one 60-h.p. crowding motor, and three contactor control panels. The motors are of series mill type construction, while the control is automatic and reversible with current limit acceleration, "notching back" and plugging features.

The hoisting control, although not strictly of the reversible type, has a hoisting and lowering position corresponding to the forward and reverse positions on any reversible controller; but the lowering position is utilized for regeneration, and the energy given up by the falling dipper is in this way applied in the operation of the swinging motor on its return trip.

Magnetically operated air valves are used in conjunction with each control for releasing the friction band brakes, the air being supplied by a small self-contained motor-driven compressor. This shovel requires two men for its operation. At the time of its installation it was not only the largest electrically equipped shovel, but it embodied certain features hitherto untried on this type of machine. The 1916 shovel is not only of greater capacity than its prototype, but is so designed that its unique control system permits the carrying on of all operations by one man.

The dipper of the new shovel is of eight yard capacity, and the operator controls the entire equipment as follows:

The hoisting master controller is manipulated with one hand, and the crowding master controller with the other, while the swinging motor is started and stopped by means of two foot-operated push buttons. The dipper trip, instead of being manually operated, as in the 1915 machine, is opened and closed by a small motor, controlled through a push button in the handle of the crowding master controller.

In other details the electrical equipment of the two shovels is identical. The power is supplied in both cases from a three-phase, 60-cycle high potential line from which the current is stepped down to 4000 volts in the field in which the shovel is operating, after which it is transmitted directly to the shovel through a three-phase armored cable and taken into the cab through a three ring collector. Slack cable is wound up on a large reel mounted on the shovel frame, as shown in Fig. 19.

Some idea of the exceptional size and service capacity of the 1916 shovel may be gained from the following data:

Radius of cut at bottom, approximately 60 ft.
Center rotation to center of dump, approximately 95 ft.

Fig. 19. 250-ton Electric Stripping Shovel in Coal Field at Smithfield, Ohio

Height of dump above rail, 65 ft.
Maximum radius of cut, 103 ft.
Length of boom, approximately 90 ft.
Length of dipper handle approximately 45 ft.
Weight of dipper and handle, 45,000 lb.
Average length of cycle, 45 sec.

As an evidence of the fact that these machines have fully met the service test in a class of work which imposes the severest strains and jars on the operating mechanism, a third shovel of the "one man" type, similar to the 1916 machine above described, was nearing completion at the end of the year, and at an early date will be applied for removing overburden on coal fields near Zanesville, Ohio.

Mine Hoists

That considerable progress was made in the application of electric drive to mine hoists during the year is indicated by the fact that in that period there were installed seventy-nine equipments, aggregating more than 30,000 h.p., the average unit size being about 380 h.p. This does not include any hoisting set rated at less than 100 h.p. Of this total approximately 24,000 h.p., or about 80 per cent of the rated capacity, consisted of induction motors, the remainder utilizing direct-current equipments with flywheel motor-generator sets and the Ward Leonard system of control.

Among the more notable direct current outfits is that for the Cleveland Cliffs Iron Mining Company, provided for hoisting iron ore at the Athens Hoist, Ishpeming, Mich. The equipment here comprises a 900-h.p., 300-volt direct-current motor (Fig. 20), direct coupled to a double drum, balanced hoist, operating at 71 r.p.m. In service the equipment hoists 12,000 pounds of iron ore per trip through a shaft having a maximum depth of 2700 ft., at a hoisting speed of 1800 ft. per minute; this duty requiring from the motor a maximum output of approximately 1700 h.p. Current is supplied to the hoist motor by a motor-generator set (Fig. 21) consisting of an 850-h.p., 2200-volt, three-phase, 60-cycle induction motor direct connected to a 675-kw., 300-volt generator. This set operates at 720 r.p.m., and is provided with a 30-ton flywheel which functions to limit the demand from the power system to approximately 960 h.p.

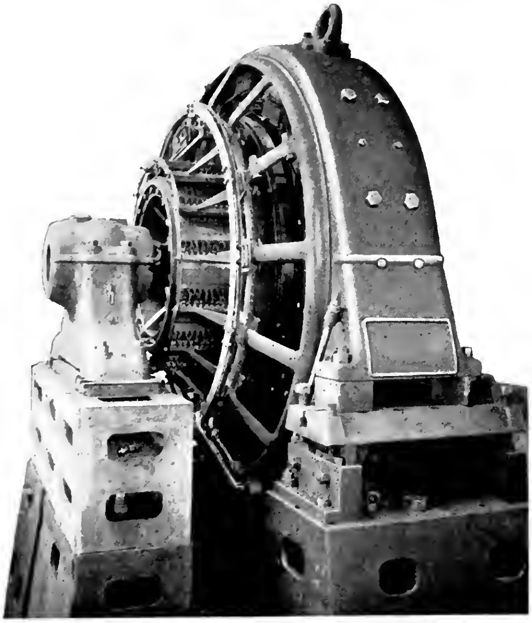


Fig. 20. 900-h.p. 300-volt 71-r.p.m. Motor for Direct Connection to Mine Hoist

Another shaft hoist, for handling copper ore at a maximum depth of 3500 ft. with a rope speed of 2500 ft. per minute and a weight of 10,000 pounds per trip, was installed at the Elm-Orlu Mines at Butte, Mont. This is a balanced double drum hoist driven by an 1800-h.p., 80-r.p.m. direct current motor. It is a first motion hoist with the motor coupled directly to the hoist drums. It is of importance in connection with this motor to state that the rating of 1800 h.p. is for continuous operation with a temperature rise not to exceed 40 deg. C. The installation of this equipment was completed toward the end of the year and includes a flywheel motor-generator set having an output of 1300 kw. for supplying the hoist motor; the flywheel weighing approximately 45 tons.

About the middle of the year an induction motor driven mine hoist was put in service by the Tennessee Coal & Iron Company at Slope 4, Muscoda, Ala. This included an 1800-h.p., Form M induction motor geared to a single hoist drum through single reduction gearing, and the outfit is the largest induction motor driven mine hoist ever installed in America. The control of this hoist is secured through primary reversing air break contactors with liquid rheostat for secondary control, the primary voltage being 2200.

This equipment superseded a steam driven hoist, and the drums of the original equipment have been retained. It is utilized for hoisting iron ore on a 23 deg. slope, one mile in length, with a load of 26,880 pounds per trip, and with a rope speed of 2700 ft. per minute. The operating results obtained have been so satisfactory that a number of similar equipments are being considered for other properties of this Company.

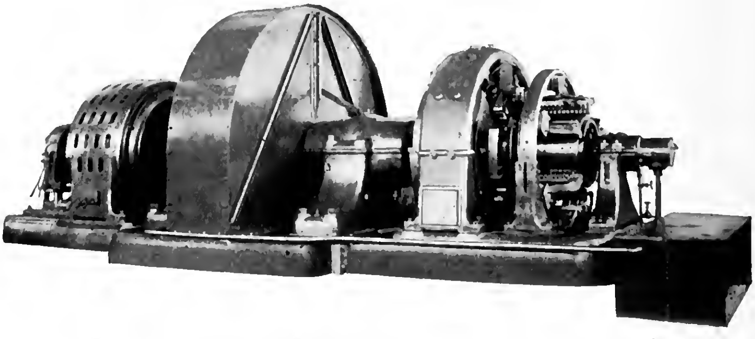


Fig. 21. Flywheel Motor-generator Set which Supplies Current to Hoist Motor Shown in Fig. 20

Another outfit having the same system of control as the above has been applied in the operation of a water hoist at Lansford, Pa., by the Lehigh Coal & Navigation Co. The induction motor in this case is rated at 1200 h.p., it is geared to a double drum balanced hoist, and is controlled by means of a liquid rheostat. Each bucket carries a load of 30,000 pounds of water, and the hoist delivers at the rate of 200,000 gallons per hour.

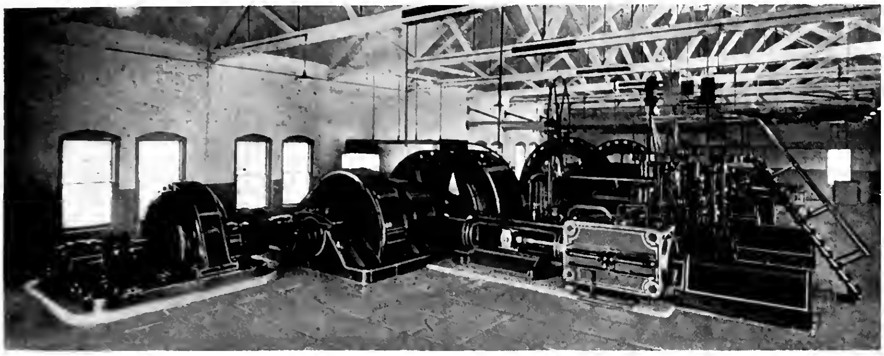


Fig. 22. 1800-h.p. Induction Motor Driving Converted Steam Hoist

Among the larger orders received by the General Electric Company during the year, was one for the Oliver Iron Mining Company, Ironwood, Mich., covering five 875-h.p. and five 400-h.p. motors with liquid rheostat secondary control. In connection with this order it may be stated that these hoists, together with compressor and turbine equipments, will form the first extensive mine electrification in this district.

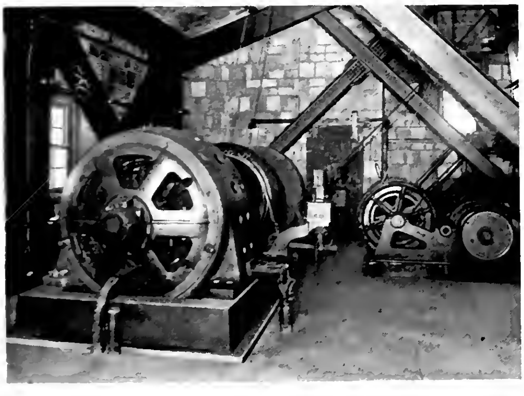


Fig. 23. 350-h.p. Induction Motor Driving High-speed Coal Hoist

Coal Tower Hoist

Prior to 1916, steam driven coal hoists were used exclusively where extremely high rope speeds were required, but the development of an electric motor with exceedingly light flywheel effect in its armature made it possible to secure the desired rapidity in starting, stopping and reversing a motor-driven hoist, so that the benefits of electric operation were at once rendered available for this particular class of power application.

A coal tower hoist of this type was installed at the Essex Street Station of the Public Service Electric Company of New Jersey, to give a rope speed of 1260 feet per minute, with a lift of 180 ft. The bucket capacity is two tons of coal and two round trips per minute are made (see illustration on cover).

The equipment consists of a 350-h.p., 200-r.p.m., 440-volt, three-phase, 60-cycle motor, (Fig. 23) coupled direct to the hoisting drums and capable of bringing the load from rest to full speed in 2½ seconds. Solenoid brakes and magnetic controls are used, and for the trolleying a 75-h.p., 900-r.p.m. motor is geared to drums to give a speed of about 450 feet per minute.

This initial installation was placed in service early in the year, and has given entire satisfaction in operation. It is the first direct-connected motor-driven hoist designed for such high speeds and rapid acceleration as were required in this instance, and its successful application opens up a wide field of usefulness for motors having rotors with very light flywheel effect.

Mine Pumps

The mine pumping sets produced included two vertical shaft, centrifugal sinking pumps for the Iron & Silver Mining Co., Leadville, Colo., which are each direct driven by a 150-h.p., 440-volt, 1845-r.p.m. induction motor.

These pumps are used for unwatering service and deliver 1000 gallons per minute, against heads varying from 0 to 315 ft. The motors are totally enclosed and water-cooled, and are the first totally enclosed motors of this capacity to be applied to this particular class of service.

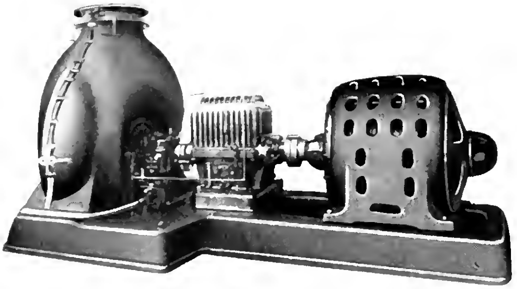


Fig. 24. Centrifugal Compressor Driven by Induction Motor Through Increasing Gears

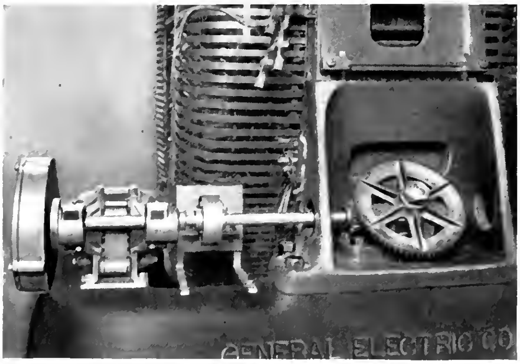


Fig. 25. Motor Driven Phase-shifting Device for Frequency Changers

Motor Driven Centrifugal Compressors

The development in this class of apparatus can be indicated by reference to three distinct classes of service for which motor-driven centrifugal compressor sets were built. In all three outfits the necessary high speeds for the rotating element of the compressors is obtained by means of increasing gears between the motor and the compressor, and in the cases cited Alquist gears, which were originally developed for reduction gearing on steam turbine equipments, were used.

The first set consists of a 25,000 cu. ft. five-pound single stage compressor employed by the Inspiration Consolidated Copper Company at Miami, Ariz., in connection with their flotation process of ore concentration. This compressor is driven through gearing by a 720-h.p., 6600-volt, three-phase, 25-cycle, 750-r.p.m. induction motor, the speed of the compressor rotor being 3850 r.p.m.

A similar motor equipment is utilized for a 20,000 cu. ft., two-stage, five-pound gas exhauster (Fig. 24) installed at the River Furnace Company's Plant, Cleveland, Ohio. The motor and compressor speeds are respectively 750 and 3850 r.p.m. and the outfit is provided with an automatic constant volume governor.

These two compressor sets were completed and shipped during the year, while two larger sets, each having a capacity of 40,000 cu. ft. of air per minute at a pressure of 30 pounds per square inch, were under construction at the close of the year. They are five-stage compressors, and are intended for use in connection with the operation of Bessemer converters by the Bethlehem Steel Co. The driving motor for each unit is rated at 5150 h.p., 6600 volts, 25 cycles, and operates at 490 r.p.m., the increasing gears giving a compressor speed of 3200 r.p.m.

Alternating-current Machines

While numerous alternating-current machines of unusual size were produced, their individual capacities did not in any case exceed the maximum of previous years. There were under construction, however, three vertical shaft generators of a higher rating than any machine of this class heretofore built. These alternators are intended for waterwheel drive and have a normal rating of 18,000 kw., 13,200 volts at 154 r.p.m. They will have a safe maximum capacity of 22,500 kw. These machines will be installed by the Aluminum Company of America, at Whitney, N. C.

Another large equipment which was not completed at the close of the year consisted of a frequency changer set for the Applachian Power Company of West Virginia. It is intended to tie in a three-phase, 13,200-volt, 60-cycle system with a single-phase, 11,000-volt, 25-cycle system. The motor is rated at 9375 h.p., and the single-phase generator has a normal rating of 10,000 kw., with a maximum capacity of 11,500 kv-a. at zero power-factor. The set is started by means of a 25-cycle repulsion induction motor which can be disconnected from the set when the set is running. This equipment represents the maximum capacity so far adopted for frequency changer sets.

A device which is unique in American power station practice was constructed early in the year. It consists of a phase shifting device for use on frequency changers and is illustrated by Fig. 25. It will be noted that the motor operates through gearing, to rotate the frame of one element of the frequency changer set, and this renders it possible to change the load on the set while it is in operation. This method has a decided advantage over the previous practice of rotating the frame of the machine by hand, which is feasible only when the set is at standstill.

Synchronous Converters

Machines of this class were built in both larger and smaller sizes than had previously been constructed in complete commercial lines, and important advances were made, particularly in the use of 60-cycle machines. The smaller 60-cycle units were designed for the transformation of current for direct-current mine industrial service.

With a previous low limit of capacity of about 150 kw., the newly developed line (Fig. 26) which has been practically standardized, included 25, 50 and 75-kw. units, operating at 1800 r.p.m., 250 volts, and 100, 150 and 200-kw. sizes at 1200 r.p.m., 250 volts; with a line of 125-volt machines up to and including 75 kw. With these machines higher efficiencies were secured than with corresponding types brought out in previous years and commutating poles were provided for all 100-kw. units and larger.

For the larger 60-cycle converters the maximum capacity represented by individual machines was more than twice that of preceding years, and some very large units were produced for use in zinc refining. Five of these have an effective output of 5800 kw. at 580 volts, 225 r.p.m., the current rating being 10,000 amperes (Fig. 27). They are provided with separate motor driven boosters to secure necessary variations in the direct-current voltage. When it is understood that the rating of the largest machines of this class built in former years did not exceed 2500 kw., the advance made during 1916 can be appreciated.

For frequencies lower than 60 cycles some very large units were completed and installed, and others were nearing completion at the close of the year. An order was received which included eleven converters, rated at 6825 kw., 525 volts, or an aggregate capacity of 75,075 kw. for this one type of machine, for a single installation.

This is the largest order for synchronous converters ever placed, and the individual machines are of record size.

Transformers

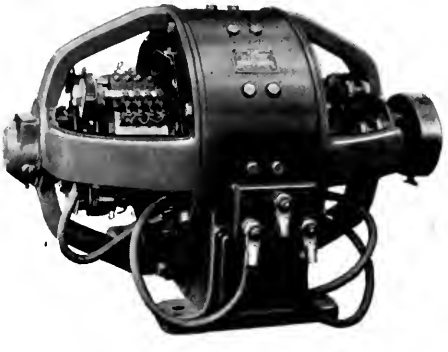


Fig. 26. 100-kw. 1200-r.p.m. 250-volt Three-wire Synchronous Converter

Circular coil transformers were built for larger capacities than any heretofore constructed, and reference to some of the more important units will serve to indicate the nature and extent of the advances made.

In the self-cooled type (Fig. 28) there were three-phase, 25-cycle, 4000-kv-a., 44,000Y-2300-volt circular coil transformers which, because of the low frequency for which they were wound, had considerably larger physical dimensions than the three-phase, 60-cycle, 5000-kv-a., 23,000–11,000-volt circular coil units built during 1915. There were also under construction single-phase, 25-cycle, 8000-kv-a., 44,000–6600-volt circular coil units to give a bank output of 24,000 kv-a. These are by far the largest G-E transformers of the self-cooled type.

In the development of the water-cooled type (Fig. 29) there were single-phase, 60-cycle, 10,000-kv-a., 120,000–24,000/6600-volt circular coil units, and three-phase, 60-cycle, 11,500-kv-a., 26,400Y-13,200-volt units, these capacities being nearly twice as great as that for any of this type previously built.

A three-phase water-cooled, 60-cycle auto-transformer is being constructed to give an output of more than twice that of any previously built transformer or auto-transformer of any type. It is a three-phase, water-cooled, core-type auto-transformer, stepping up from 12,200 volts, three-phase, to 24,400 volts three-phase. It has a normal output of 50,000 kv-a. at 55 deg. rise, and is to be used to double the voltage of a 45,000-

kw., 50,000-kv-a. turbo-generator. It is capable of withstanding momentary short circuits limited only by its own reactance. Its guaranteed efficiency is 99.1 per cent at ¼ load, and 99.4 per cent at all other loads.

Current-limiting Reactors

The largest reactor built before 1916 had a rating of 25 cycles, 720 kv-a., 1200 volts, 600 amperes, which was for use in a three-phase, 9000-volt, 9375-kv-a. circuit. This rating was carried to 25 cycles, 1135 kv-a., 610 volts, 1860 amperes in 1916 by the construction of three reactors for giving 8 per cent reactive drop in a three-phase, 13,200-volt, 42,500-kv-a. circuit.

Steel Mills

The polyphase induction type of motor, already long familiar to and in high favor with the steel mill engineer, had its usefulness still further increased by the development of an efficient and commercially practical means of obtaining strictly adjustable speed control under varying load for speed ranges above as well as below the normal synchronous speed of the motor.

This "double-range" speed-regulating set was the result of several years investigation of previous unsuccessful attempts to secure an efficient shunt speed characteristic for the polyphase induction motor, and is the only successful double-range system yet devised.

Fig. 27. 5800-kw. 225-r.p.m. 580-volt Synchronous Converter

The "double-range" system is, except for certain important details, practically a duplicate of the well known "single-range" system placed on the market several years ago by the General Electric Company. Briefly, the following principles are involved:

The polyphase induction motor with phase wound rotor, when excited with normal primary potential and frequency, has a secondary or slip ring frequency and voltage proportional to its speed either above or below synchronism. At synchronism, the secondary voltage and frequency are zero, and above synchronism the phase rotation is reversed. The secondary current is proportional to the mechanical load.

The secondary energy of the motor of which the speed is to be controlled is utilized at varying frequency and voltage to drive a polyphase commutator motor with shunt speed characteristics. This commutator motor forms one unit of a two-unit motor-generator, the second unit of which is a squirrel-cage induction motor wound for line frequency and voltage. When the speed of the main motor is to be adjusted below synchronism the commutator motor drives the squirrel-cage motor slightly above its synchronous speed, causing it to function as an asynchronous induction generator, thus returning to the power system, at line frequency and voltage, the secondary energy of the main induction motor.

When the speed of the main motor is to be adjusted above synchronism, the squirrel-cage motor performs its normal function as a motor, driving the commutator machine as a generator and thus supplies energy at the necessary frequency and voltage to the secondary of the main motor. The speed of the main motor is therefore the result of the algebraic sum of the primary and secondary frequencies.

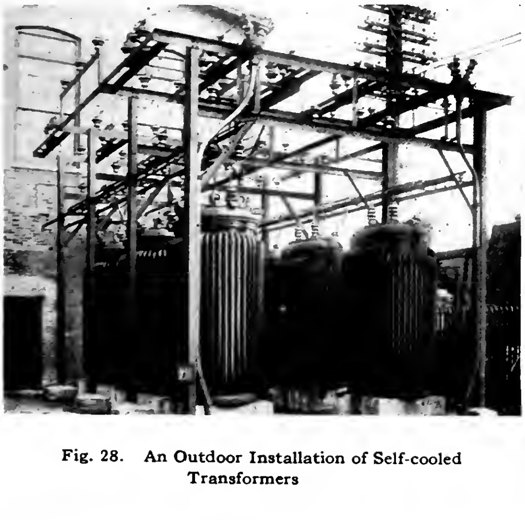


Fig. 28. An Outdoor Installation of Self-cooled Transformers

Adjustment of speed is secured by varying the excitation of the commutator machine which normally is excited from the slip rings of the main motor. Since, however, this source of excitation fails at synchronism as noted above, it is necessary to supply suitable excitation while passing through synchronism. The device for accomplishing this purpose is the essential requirement to make the single range equipment operate successfully on double range. It consists of a small winding with slip rings and commutator mounted on the main motor shaft. Suitable voltage at primary frequency is impressed on the collector rings and from the commutator is taken the necessary current for excitation of the commutator machine while the main motor is running at and near its rated synchronous speed.

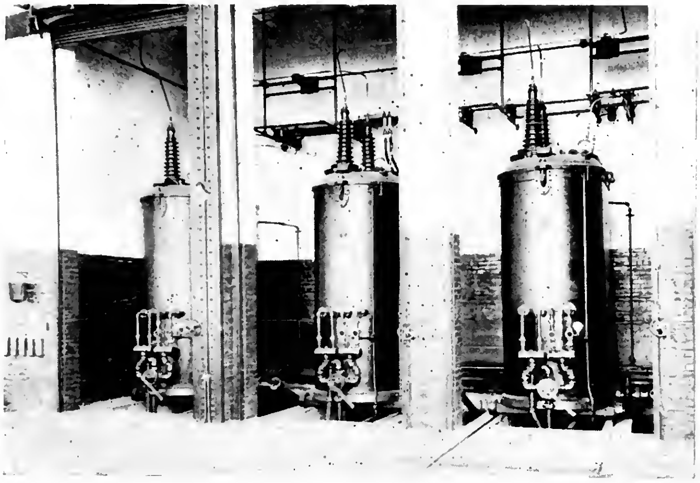


Fig. 29. An Indoor Installation of Water-cooled Transformers

The double-range system increases the range of available motor speeds at high efficiency, and for a given capacity of auxiliary equipment gives practically twice the range of adjustment of the single-range system.

The first equipment of this character was sold to the Bethlehem Steel Company in January (Fig. 30) and by the end of the year orders had been received for twenty-two equipments with an aggregate normal rating of 34,500 h.p.

The largest single installation of adjustable speed main roll drives was that for the McDonald Bar Mills of the Carnegie Steel Company, which includes nine separate and complete equipments. Construction work was in progress for other important equipments of similar character for the following companies:

Keystone Steel & Wire Co., Peoria, Ill.
Wickwire Steel Company, Buffalo, N.Y.
Donner Steel Company, Buffalo, N. Y.
Lackawanna Steel Company, Buffalo, N. Y.
Trumbull Steel Company, Warren, Ohio

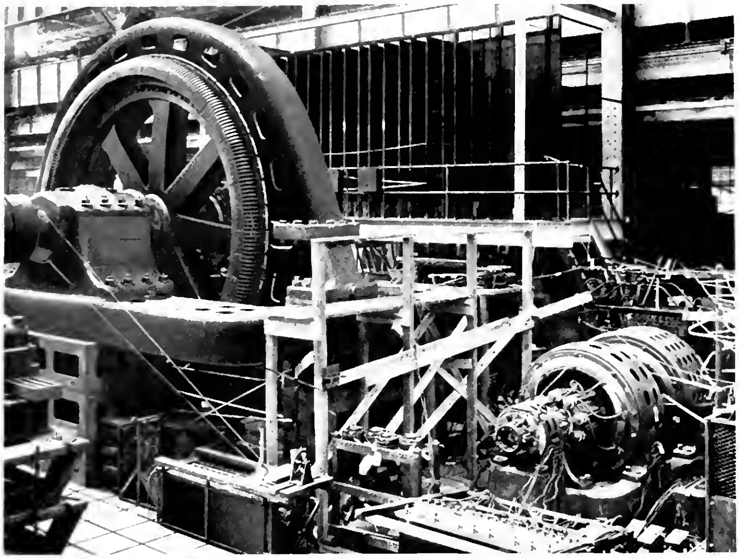


Fig. 30. 2000-h.p. Motor and Regulating Set for Steel Mill Drive

The growing demand for the reversing motor drive for blooming and plate mills, with necessary flywheel motor-generators for the equalization of widely fluctuating peak loads, was indicated by the receipt of orders for four such equipments, viz.,

34 in. Bloomer Mill, Ashland Iron & Mining Co., Ashland, Ky.
34 in. Bloomer Mill, Keystone Steel & Wire Co., Peoria, Ill.
36 in. Bloomer Mill, Trumbull Steel Company, Warren, Ohio.
40 in. Bloomer Mill, Bethlehem Steel Company, So. Bethlehem, Pa.

Rubber Mills

A new automatic push button control equipment was produced for the speed control of rubber calenders, the object being to secure a slow-down feature which would permit the operation of the calender (Fig. 31) at minimum speed for threading in new rolls of fabric without the necessity for disturbing the field rheostat setting for normal operating speed.

These equipments are designed for both single-voltage two-wire, and two-voltage three-wire circuits. By the manipulation of a push button contactors are energized and the motor is automatically decelerated until it is running at the minimum speed of which it is capable, and it continues to operate at this speed until the button is restored. The motor then accelerates to the speed at which it was previously operating.

This relatively simple arrangement has proved of considerable value in this industry, due to the fact that the operator is merely required to press the button, and can then continue the threading in operation work without giving further attention to the motor.

Shoe and Leather Industry

From time to time the use of electrically heated devices has been extended in this industry, but in many plants steam and gas heat were largely used even when part of the heating was accomplished electrically. During the year 1916, however, there was a marked increase in the number and relative importance of the electrically heated units, due to the demonstrated value of the electric system of heating and to improvements in the heating devices themselves; so that in certain of the newer plants fuel heating for manufacturing purposes was entirely avoided and the required heat was generated exclusively by electricity.

Fig. 31. Motor-driven Rubber Calender Equipped with Automatic Push Button Control

Among the more important of these heating operations are those involved in embossing, sole drying, wax heating or stitching, and the heating of the heads of lasting machines; and in these newer factories, even where the direct application of the heat is accomplished by steam, the steam itself is produced by means of electrical heating units.

The year has also seen in this industry a very marked growth in the adoption of individual drive for all classes of shoe machinery. In preceding years a limited number of individual machines had been equipped as self-contained motor-driven units, but in most of the shoe factories the group method of driving was retained to a very large extent. However, as the extreme flexibility of individual motor drive became better understood, machines were re-located solely to facilitate production, regardless of the location of shafting, and it was demonstrated that only relatively slight mechanical changes were required for individual motor drive on machines which had previously been driven only in groups.

A considerable number of these independently driven machines have already been produced by the manufacturers of shoe machinery, and equipped with individual motors ranging in capacity from 1/50 h.p. to 7½ h.p., and among those which have already been subjected to exhaustive tests in actual service are clicking machines, gearless sole cutters, eyeletting machines, agitators, etc.

This same evolution has already been completed in a number of other industries in which extremes of power consumption for individual machines are met, and during the past year the growth of the individual drive system in shoe factories followed the same logical lines as similar developments had previously done, as for example, in machine shop practice and in the equipment of textile mills. For in both of these industries the original method of electric drive developed in successive stages from large groups to segregated groups and, finally, to a practically universal system of individual motor drive for a large percentage of the machines in all modern installations.

Switching Apparatus

It can be safely asserted that during the year 1916 more progress was made in the improvement of this class of apparatus, with regard to securing immunity from injury to the apparatus or danger to the operator, than in all the preceding decades of electrical manufacture.

The slogan "safety first" became, to an unprecedented extent, the dominating factor in the design and construction of two new types of lever switches, and in the development of a unique sectionalized, removable panel, compartment type of switchboard.


Fig. 32. Enclosed "Safety First" Lever Switch, 2-pole, 30-amp. 250-volt, Switch Locked Open, Fuse Compartment Locked Closed

Some of these "safety first" devices are illustrated here and their distinguishing features may be briefly outlined as follows:

The enclosed lever switch is made up of a standard lever switch mounted in an iron box (Fig. 32) so constructed that all current carrying parts, including fuses, are inaccessible while alive. The lid to the fuse chamber can be opened when the switch is "off," and the switch cannot be closed while this lid is open. Provision can be made for locking the switch in the "off" position.

The second type is known as the low tension dead front switch, and consists of standard knife switch and fuse clip parts mounted on a slate base (Fig. 33) which is in turn supported on iron studs at the back of a sheet steel panel. The operating handle is arranged so that it is in an upright position when the switch is "on," and at an angle of 60 deg. to the panel when the switch is "off." A sheet steel door, which opens upward, gives access to the fuses from the front of the panel, but cannot be opened while the switch is "on," and conversely, the switch cannot be closed while the door is open. Air circuit breakers of the carbon type are mounted on these panels in the same manner. These switches and circuit breakers are for use on circuits of 600 volts and under.

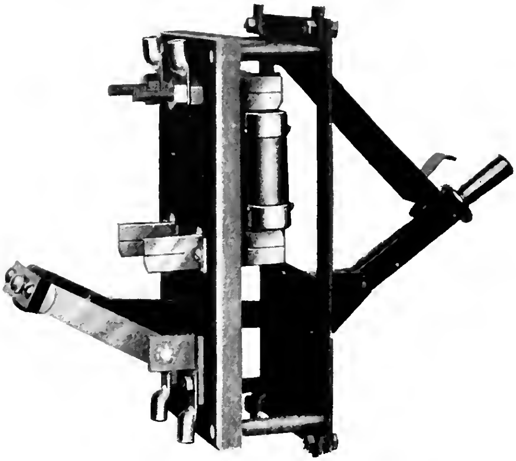


Fig. 33. "Safety First" Panel Switch Unit, 200-amp., 250-volt 2-pole

For circuits up to 300 amperes at 2500 volts a pedestal type switching unit is used, which has a standard oil circuit breaker and disconnecting switches so interlocked that the switch cannot be opened while the circuit breaker is closed, nor can the circuit breaker be closed while the switch is open. The disconnecting switch is operated by means of a key, which may be removed when the switch is open, thus locking the circuit breaker in the open position.

A steel switching cabinet utilizing the interlocking principle of the pedestal type switching unit in a modified form was developed for capacities up to 500 amperes on 6600-volt circuits.

Each complete unit of the "safety first" truck type switchboard panels consists of two elements (Fig. 34), viz., the truck or movable element carrying the panel, oil circuit breaker and instrument transformers, and the stationary or housing element which encloses the truck when it is in the operating position, and also contains the buses and the terminals of the incoming and outgoing cables.

The truck is mounted on wheels and can readily be withdrawn for inspection, repair or replacement; but an interlock is provided so that the truck can neither be withdrawn nor replaced in the housing while the oil circuit breaker is closed. When in operation all live current carrying parts are completely enclosed and the buses are isolated from the remainder of the housing by a heavy metal partition. The action of withdrawing the truck automatically opens the disconnecting switches.

The panels are interchangeable within reasonable ranges, and new units can be easily and quickly added to a group of panels already installed, or an extra truck held in reserve will insure a minimum interruption to service if it should be necessary at any time to withdraw a panel from the switchboard for inspection or repair. When required the oil circuit breakers may be of the electrically operated type.

In connection with switchboards and switchboard apparatus, the tendency toward further standardization of parts continued. One indication of this is the universal insulator made in 3500-volt and 15,000-volt sizes, which can be used interchangeably for the same voltage ratings on any standard busbar support, T. D. fuses, switch mountings or on pipe supports. The caps, tops, and bottoms of these insulators are interchangeable (Fig. 35), and in this way a great variety of fittings can be used with a single form of insulator.

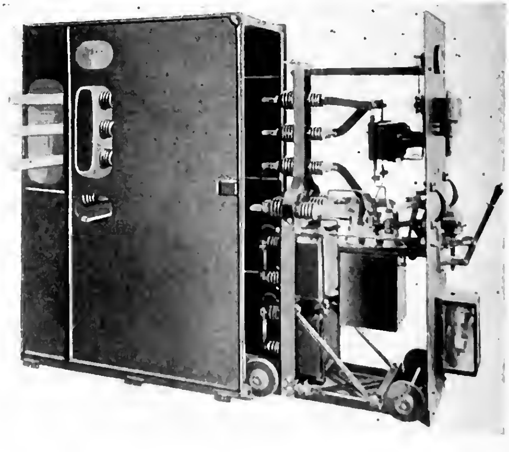


Fig. 34. Truck Type "Safety First" Switchboard Unit, Showing Truck just Entering Compartment

A further advance in the standardization of high tension insulators comprehends the eventual use of the same insulators for a given potential on different classes of apparatus, such as oil switches, lightning arresters and transformers.

It is obvious that the further this method of standardization can be safely and effectively carried, the greater will be the economies in manufacturing and operating costs, and a reduction in the number of spare parts which will be required for any power system.

In order to produce a time-limit overload relay which would be immune from the disturbing influences of heavy fluxes set up in the magnetic circuit during the operating period, a relay of entirely new design, operating on the induction principle, was developed.

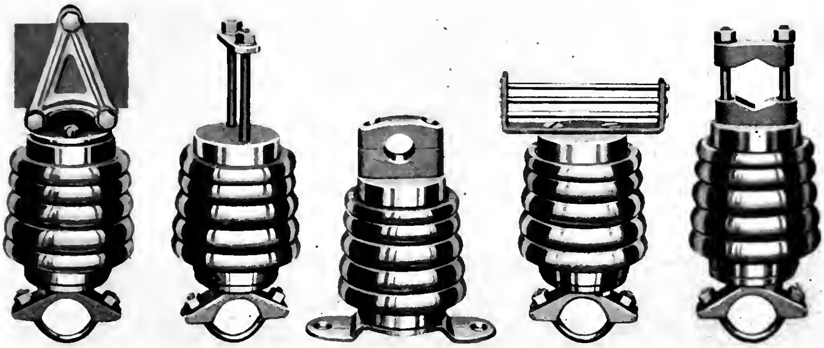


Fig. 35. Universal Insulator Used with Various Fittings

A reverse phase relay was perfected (Fig. 36), the function of which is to afford protection against the accidental reversal of motor rotation. It operates on the same principle as the squirrel-cage induction motor, the operating coils corresponding to the stator, and a hollow almuinum cylinder, connected to the contacts, to the rotor. The relay is made in both circuit-opening and circuit-closing forms. The cylinder does not rotate, but moves in a straight line, either up or down, depending on the phase rotation, and in the event of one of the phases of the line being reversed the movement of the cylinder operates the circuit-closing or circuit-opening contacts, depending on the form of the relay used.

Fig. 36. Instantaneous Circuit-opening Reverse Phase Relay with Hand Reset Contacts

It is made as a single-pole, circuit-closing device, for frequencies of 25 to 60 cycles, with a continuous rated capacity of 5 amperes, and is suitable for operation from current transformers. Its characteristics are such that selective action of two or more relays is assured when settings are made with due regard to the time element inherent in the mechanism of the circuit breaker controlled.

Changes in surrounding temperature will cause the ordinary induction time-limit relay to act with a large variation in its time delay, if uncompensated for such changes. This relay, however, is provided with an efficient temperature compensating device which keeps time delay variations within reasonable limits.

Electrically Heated Industrial Ovens

At present more than fifty different manufacturers are using G-E electrical heating equipment with automatic control for ovens for baking japan, drying paint, and other similar manufacturing purposes. It is interesting to note that more than 80 per cent of these concerns adopted the electric oven during 1916, and that while the initial installations were practically all for japanning work, their use has been extended to a great variety of other drying and baking processes which require accurate application of heat and close control of temperature.

The electric ovens already installed represent a total connected load of about 45,000 kw., and one manufacturer alone is utilizing several batteries of ovens aggregating about 20,000 kw. in capacity (Fig. 37). The remaining installations consist of one or more ovens requiring a current supply of from 25 kw. to 250 kw. each.

While not of such great commercial importance as the ovens above referred to, the use of electric furnaces for heating gun tubes and gun jackets, preparatory to inserting the lining or to shrinking on the jacket, is of considerable interest as it demonstrates the possibilities of electric heat for securing a uniform and positively controlled temperature in the manufacture of heavy ordnance. The original equipment for this work was supplied several years ago, and consisted of two sections, each 5 ft. high with about 4 ft. internal diameter, and each having a current consumption of about 30 kw. These sections were at first used in connection with oil heating for boosting the temperature at the top of the heating pits, where great difficulty had been experienced in securing the necessary high temperature with fuel heating. The electrical sections, however, proved so successful in operation that the use of fuel was entirely abandoned, and at the close of the year there were under construction for one of the large steel companies five gun furnace sections of approximately the same dimensions and with the same current consumption as the original sections.

A new development for the year consisted of an air oven for tempering steel, by the use of which more accurate results could be secured than by the previous processes of oil or fuel tempering, due to the fact that the positive control of the temperature, made possible by the use of electrical heating units, enabled the results obtained to be accurately predetermined.

Fig. 37. Electrically Heated Japanning Oven in Automobile Manufacturing Plant

Domestic Electric Heating Appliances

Improvements in the design of electric ranges, increased sales of these appliances, and a notable growth in the adoption of electric cooking, were the outstanding features in the development of domestic heating devices.

The National Electric Light Association recognized the importance of this section of the heating device industry by appointing an electric range committee to investigate conditions and to determine the possibilities of the future. The results of this investigation have been of great value to the manufacturers, central stations and the user, as it secured valuable data regarding merchandising, costs of installing and operating, heating rates, effect on day load, power-factor, etc. Many practical and useful suggestions were gathered from those who have had extended experience in the electric range business, and these will assist in the standardization of this appliance.

The rapidly increasing demand for electric ranges stimulated many central stations to establish special cooking rates, and this service gave adequate returns in increased income, added day load and a better load factor. It was demonstrated that electric cooking is thoroughly practical and economical where reasonable service rates are available, and experience indicated that an average heating rate of 5 cents or less would more than double the demand for electric service.

Statistics on cooking rates granted by the central stations throughout the country, showed that 3350 communities had heating and cooking rates of 5 cents or less per kw-hr. Approximately 60 per cent of these had rates of 4 cents or less, while 30 per cent had rates of 3 cents or less. About 65 per cent of all the communities on which data were secured are located in the eastern half of the country, and it is interesting to note that, contrary to the general impression, low rates for cooking are largely confined to the Western States.


Fig. 38. Shipment of 611 G-E Electric Ranges

The production of electric ranges exceeded all previous records. The largest single order ever placed for electric ranges was filled last May by the Pittsfield (Mass.) plant of the General Electric Company. The shipment comprised 611 ranges packed in eight freight cars, (Fig. 38) and had a listed value of approximately $53,000. But this enviable record was far surpassed by the receipt of another single order last November for 2000 electric ranges. This represents a listed value of $222,000, and will require approximately 25 cars when packed for shipment.

Rectifiers

It has been known for some time that a vacuum tube containing a hot and a cold electrode would act as a rectifier. This principle is utilized in the kenotron, which is a high voltage rectifier, and also in the Coolidge X-ray tubes; these devices depending on the emission of electrons from an incandescent filament. In the kenotron and Coolidge tubes there is the highest possible vacuum, so that the electrons themselves are the only current carriers, and the tubes operate at low currents and very high voltages. The voltage drop across the kenotron will be from 100 to 500 volts, from which it will be seen that it would be impractical to operate these on the usual commercial circuits of 110 and 220 volts.

In the recently developed Tungar rectifier bulb there is an inert gas, at low pressure, which is ionized by the electrons emitted from the incandescent filament. This ionized gas acts as the principal current carrier, with the result that the bulb operates with a much lower voltage drop (from 5 to 10 volts), and is capable of passing currents of several amperes, the current limit depending on the size of the tube.

The Tungar bulb rectifies because, on the half wave when the tungsten filament is negative, the emitted electrons from the incandescent filament are being pulled toward the anode by the voltage across the tube, colliding with the gas molecules, ionizing them, and making them conductive in the direction of anode to cathode. On the other half cycle, when the filament is positive, any electrons that are emitted are driven back to the filament, so that the gas in the bulb is non-conductive toward that half cycle; or, in other words, during the half cycle when rectification does not take place, ionization of the gas dies out, but immediately builds up on the next half cycle which the Tungar rectifies. The filament of these rectifiers is constantly excited.

At the present time this rectifier is made in three sizes for charging storage batteries: 2 amperes, 7.5 volts (Fig. 39) (which also delivers 15 volts at 1 ampere); 6 amperes, 7.5/15 volts; 6 amperes, 7.5/75 volts (Fig. 40).

Lighting

With an increasing efficiency of Mazda lamps there was evidenced a marked tendency toward taking advantage of the increased light available, for the purpose of improving the effect of diffusion, or otherwise making the light more suitable for particular purposes, rather than endeavoring to secure extreme economy. This was first apparent through the rapidly increasing popularity of the indirect methods of lighting. More recently it was indicated by the demand for modified color of light. It was therefore found desirable to use lamps with tinted bulbs, either natural or dipped, as, for example, the Mazda C2 (white light) lamps, Mazda C photographic lamps, and the Mazda yellow bulb lamps.

Fig. 39. 2-amp. 7.5-volt Tungar Rectifier

The Mazda C2 lamps are intended for use in stores, store windows and certain manufacturing processes where an approximately white light is advantageous. The natural blue glass bulb absorbs the excess of red and yellow light which is minimized by operating the filament at a higher temperature than normal. The shortened life of the lamps is justified by their relatively high efficiency, which is only 25 per cent or 30 per cent below that of the corresponding clear bulb lamps. These lamps are now made in 100, 150, 300 and 600-watt sizes.

The Mazda C photographic lamp also has a blue bulb, but of different color from the C2. The function is to reduce the visible light without appreciably affecting its photographic value. This avoids a bright light in the eyes of the subject. It has no value in photographing inanimate objects. Economy has made it desirable to force this lamp also, so as to produce a high percentage of actinic rays. A 1000-watt unit is made. The yellow or amber bulb Mazda lamps, most of which have so far been produced by dipping, found application in the lighting of residences and other artistic interiors, where it was desired to reproduce the warm glow of fire and lamp light. They have been extensively applied in a few cities. The 60-watt size is usually employed.

The efficiency and approximation of the "point source" obtainable with Mazda C lamps have very largely increased the possibilities of incandescent lamps in projection, i.e., searchlights, headlights, floodlights, and stereopticons. Small moving picture machines were so equipped, and developments are now under way that promise to extend the application in the near future to the machines used in moving picture theaters. Such lamps are of low voltage and high current, thus being most economical on alternating-current circuits where the arc is least effective.

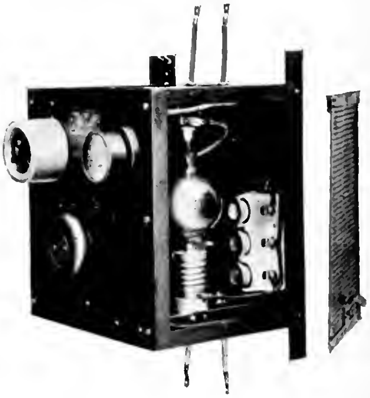


Fig. 40. 6-amp. 7.5/75-volt Tungar Rectifier

A 75-watt Mazda C lamp was brought out for use on 105 to 125-volt circuits. This lamp can be used in sockets with shades where the ordinary lamp has heretofore been used. It gives nearly as much light as a 100-watt Mazda B (vacuum) lamp, about four times as much as the 50-watt Gem, and five times that of the 50-watt carbon lamp.

A 50-watt Mazda B lamp was also developed for operation on 105 to 125-volt circuits. It is largely used by central stations previously supplying 50-watt Gem and carbon lamps, the new lamp giving the customer about two and three times, respectively, the amount of light previously obtained from the Gem and carbon lamps for the same current consumption.

Figs. 41 and 42 show the number of lamps sold by the Edison Lamp Works since its beginning. In 1906, carbon lamps attained their greatest sale, being then about thirty-millions as compared with 1916 (estimated) sales of two and one-half millions. Gem lamps reached the height of their popularity in 1912, with about twenty million lamps sold as compared with 1916 (estimated), seven and one-half millions. Mazda lamps have been increasing in popularity every year, the 1916 (estimated) sales being about forty-seven and one-half millions, and about twenty-two and one-half millions miniature Mazda lamps. The latter is largely a result of the increase use of automobiles, only Mazda lamps being used for this class of lighting.

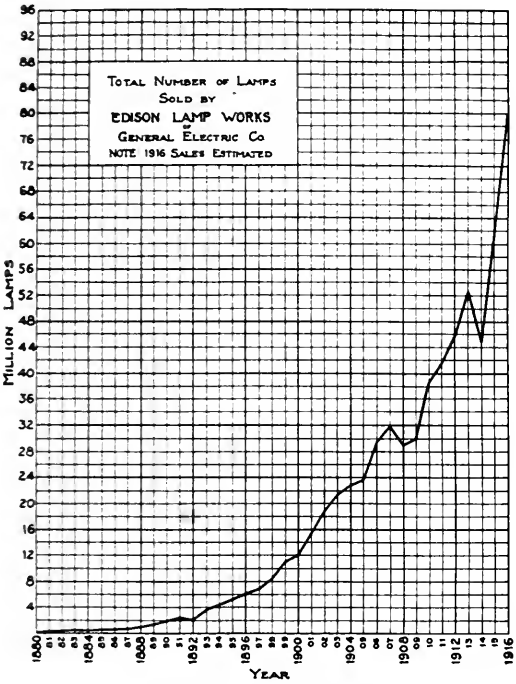


Fig. 41. Lamp Sales Chart

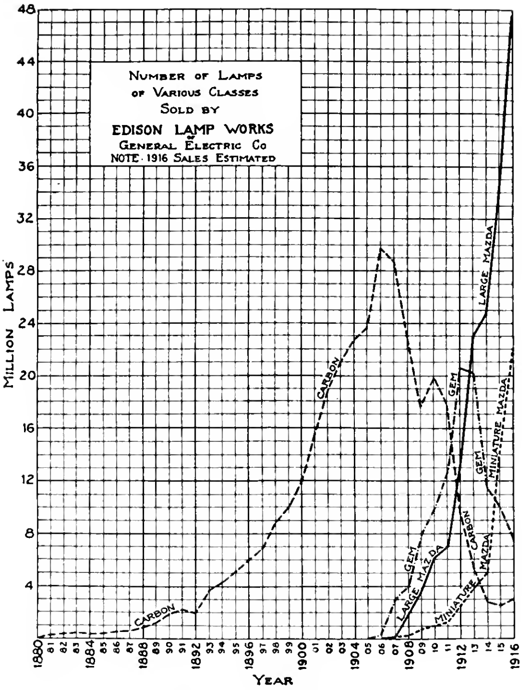


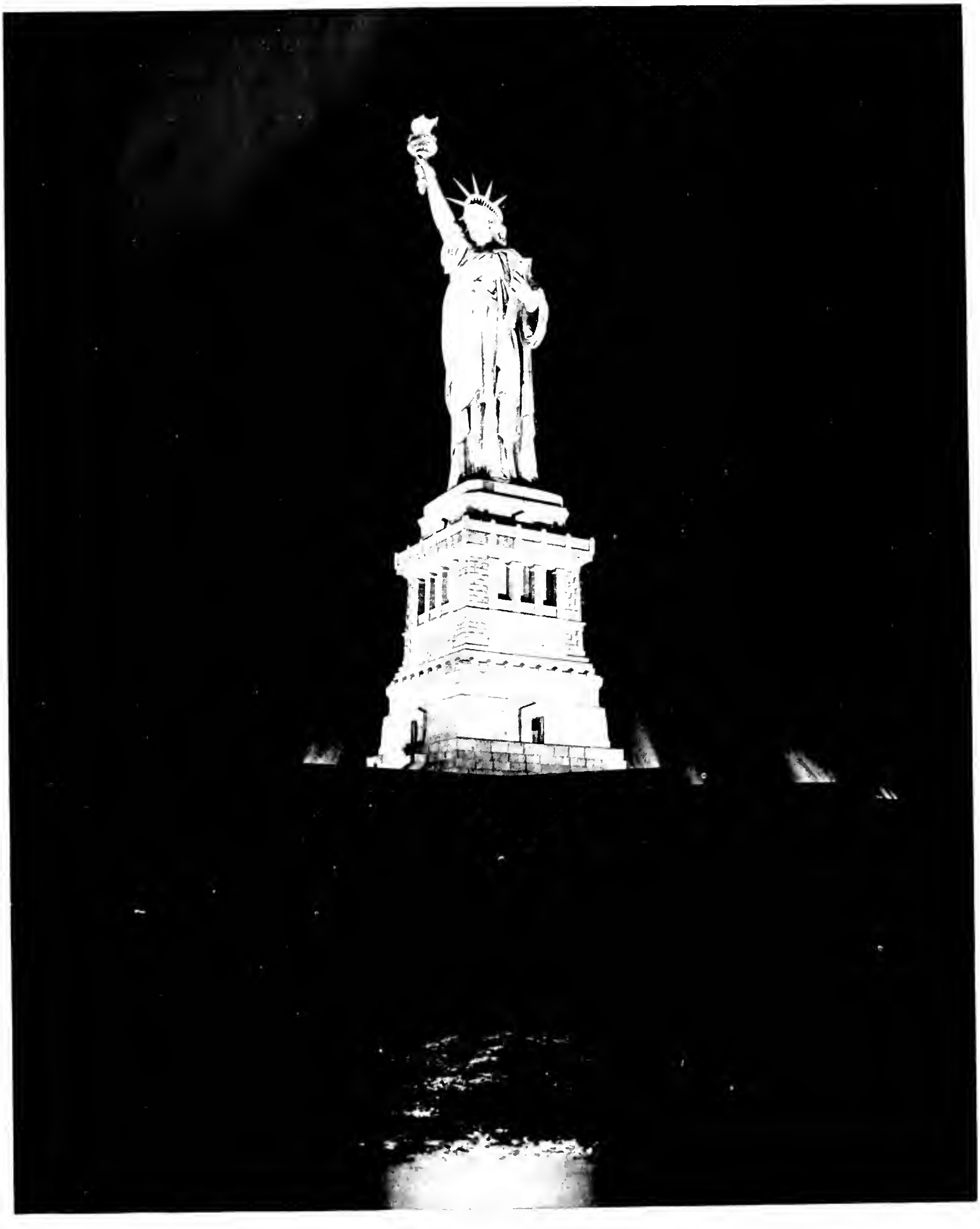
Fig. 42. Lamp Sales Chart

The increase in the average candle-power of Mazda lamps used for street lighting during the past few years is as follows:

Year	Average Candle-power
1908	35
1909	45
1910	47
1911	48
1912	56
1913	62
1914	78
1915	108
1916	125 (estimated)

The relative popularity of series circuits of different amperes, compared by the number of lamps sold, is as follows:

Amperes of Circuit	Proportion of Lamps Sold (1915)
6.6	50
4.0	20
5.5	15
7.5	10
Miscellaneous	5
	100



Flood Lighting of Statue of Liberty

The more logical rating of incandescent lamps by lumens, rather than candle-power, was adopted by the Illuminating Engineering Society, American Institute of Electrical Engineers, National Electric Light Association Lamp Committee, and the various lamp manufacturers.

The arc lamp assumed the role of strictly street lighting unit and the tendency in its construction was toward the development of a more ornamental exterior and higher efficiency electrode. That this was successfully accomplished and was received with favor is evidenced by the installations at Salt Lake City, Utah and San Francisco, California. The latter city deviated from the stereotyped "white way" system and introduced color into its street lighting equipment, creating what has been called the "Path of Gold," in which a higher intensity of illumination was secured than had ever before been attempted for street lighting.

Fig. 43. "Path of Gold" Street Lighting in San Francisco

This installation (Fig. 43), consisting of 439 lamps, commences at the Ferry Building and extends along Market Street to 7th Street, taking in 15 business blocks on the north side of the street and 13 blocks on the south side, a distance of approximately 7500 feet, and including the Ferry Building Plaza, 1.5 miles.

G-E luminous arc lamps, the same as those used for the Exposition, were adopted. They operated at 6.6 amperes, but their appearance is greatly enhanced by the addition of a new sectional globe and special glassware, which has a yellowish tint that is visible in daytime, but not at night, when it prevents glare.

These lamps are mounted in the form of a triangle, with the plane of the lights at right-angles to the direction of the street, and have a combined candle-power of 4500 as compared with 225 candle-power, the capacity of the lamps previously used. The poles average 110 feet apart, and are 32 feet high, including the ornamental triangular tops.

The growing recognition of the importance of adequate lighting as a factor of safety in industrial work was indicated by the adoption of a code of lighting for "factories, mills and other work places," by the Industrial Board, Department of Labor and Industry, State of Pennsylvania. These rules and regulations went into effect June 1, 1916, and similar action was later taken by the State of New Jersey.

This resumé of achievements for the year, in the field of electric lighting, would be incomplete without reference to the flood lighting of the Statue of Liberty on Bedloes Island in New York Harbor.

While this statue has occasionally been lighted in outline by means of incandescent lamps, this lighting was of a temporary nature, and during the past thirty years only the rays from the torch in the hand of the statue could be clearly discerned in the night by those watching on the shore or from ships; but on the evening of December 2, at a signal given by the President of the United States, the entire statue was instantly bathed in a flood of light (Fig. 44) which rendered it more conspicuous, by reason of the contrast with the surrounding darkness, than when seen by daylight.

This effect was accomplished by means of 15 batteries of flood-lighting projectors, totaling 246 units, each utilizing a 250-watt Mazda lamp. Each projector was provided with an individual compensator through which the incoming line potential of 220 volts was stepped down to 35 volts for the lamps. The current supply is transmitted to the Island by submarine cable.

By this means the statue, which stands as the epitome of our national aspirations, is made perpetually visible, glowing with enhanced beauty throughout the night, until with the coming of dawn the man-made illumination is gradually superseded by the light of day.

AN ADDRESS BY E. W. RICE, JR. ON THE OCCASION OF THE PRESENTATION OF THE JOHN FRITZ MEDAL TO ELIHU THOMSON, DECEMBER 8, 1916

This address will be full of interest to every engineer. Prof. Thomson's life's work has been as varied as it has been useful. Few know the scope of his work.—EDITOR.

The medal which was awarded in January 1916 to Dr. Elihu Thomson, and which is to be presented tonight, is for "Achievements in Electrical Inventions, in Electrical Engineering, in Industrial Development and in Scientific Research."

It would be impossible in the brief time at our disposal to adequately describe the achievements of our medalist in these various fields, as it would involve describing the life work of one of the world's most prolific and industrious inventors and scientists. The impossibility of performing such a task can perhaps best be indicated by the statement that in the field of electrical inventions alone Prof. Thomson has been awarded something over 550 United States patents, and in other fields, notably mechanical work, about 150 patents, making a total of some 700 U. S. patents; that he has made contributions to the world's scientific and technical literature, set forth in several hundred articles describing not only his own discoveries and inventions but making remarkably interesting contributions to scientific speculation and thought. The range of such contributions may be indicated by some of the titles taken at random:

Nature of the Lightning Discharge
Conditions Affecting Stability in Electric Lighting Circuits
Wireless Telegraphy
Electric Welding Process
Experimental Research
Properties of Carbon in Electrical Work
Simple Steam Engine with Remarkable Economy
The Possibilities of Liquid Air in Electrical Work
An Unjust Patent Statute
The Light of the Fire Fly
Cosmic Electrical Phenomena
Safety and Safety Devices in Electrical Installations
Lightning Rods
Sterescopic Roentgen Pictures
Oil Insulation for High Tension Transformers

and so on through a long and suggestive series of subjects.

Prof. Thomson's electrical work began about 37 years ago with the invention of the 3-coil arc dynamo, which, with its automatic regulator and other novel features, formed the basis of the successful lighting system put out by the Thomson-Houston Company, beginning in 1880. This machine was remarkable for its extreme simplicity, ruggedness, flexibility and general efficiency. It was designed to operate a series of arc lamps and was the first machine to be entirely automatic in its operation. It was so constructed that it would maintain a constant current flowing in a series circuit over the extreme range from full load of, say 25 lights, down to one light or even to a complete metallic short circuit; a feature possessed by no other arc light machine at that time. This feature of automatic regulation together with its general reliability and fool-proofness were the basis of its great technical and commercial success. This 3-coil dynamo was, of course, designed for direct current and therefore provided with a commutator of only three segments.

You will be interested to learn that the original application for a patent for this 3-coil machine showed that it could also be used to produce alternating currents. As the armature coils were spaced 120 degrees apart the application showed a structure identical with that now known as a three-phase alternator. Prof. Thomson, writing some years ago, referred to this in the following language:

> "It is not generally known that the original application for our three-coil armature showed it with a common joint and three collector rings, a veritable three-phase, Y-connected alternator, but that alternating currents were then of so little importance that we were persuaded to limit the case to a three-segment commutator as facilitating the grant of the patent."

This alternating-current feature was but one instance of many where Prof. Thomson's ideas were years in advance of the world's readiness for their reception.

The next important electrical invention was the utilization of a magnetic field to mechanically propel an electric arc. This idea took many forms and was first applied some time in 1881 in connection with a lightning arrester for his arc light system. This is an interesting example of Prof. Thomson's foresight. He had often observed the powerful inductive effects of lightning on telegraph wires and knew that such effects would be present in extended circuits used in connection with arc lighting, and, to forestall trouble, decided that it would be necessary to use lightning arresters for the protection of such circuits. Lightning arresters had been used, as stated, with telegraph lines, but such arresters could not be employed with a dynamo because the dynamic current would follow any spark to earth and produce an arc which would be maintained with disastrous consequences. It was necessary to provide some means for interrupting the flow of the dynamic current. Prof. Thomson made use of the fact that an electric arc was a conductor which could be moved by a properly disposed magnetic circuit. His first lightning arrester took the form now well-known as the horn lightning arrester, the gap between the horns being surrounded by the poles of a magnet. Any high potential discharge from lightning induction would cross the gap of the lightning arrester at its narrowest point, a resulting arc would follow and be impelled upwards by the magnetic field, gradually increasing its length until it broke at the tips of the horns. The first model of this lightning arrester was immediately put into commercial use and was manufactured without alteration for many years.

This important principle was immediately extended to the construction of switches in which the magnetic field was used to interrupt the arc formed upon breaking a circuit. All these devices are known as "magnetic blowout" devices and are used on a very extensive scale at the present time; notable applications being found in the controllers for electric street cars, on electric trains for elevated roads, and on large electric locomotives.

Prof. Thomson was one of the earliest workers in the field of alternating currents. As I have stated, his first 3-coil dynamo was also intended to be used as an alternator. The modern transformer system with transmission at high potential and reduction of the potential in the secondaries of the transformers was worked upon at the Franklin Institute in Philadelphia in 1879, and in February of that year he ran two transformers by an alternating dynamo with the fine wire primaries connected in parallel to the dynamo line and the secondaries doing the local work. Later on, this pioneer work was taken up (especially after safety devices had been produced), and in 1885 a patent was applied for and went through the fire of interferences with others here and abroad and finally was issued with broad claims The whole history of the multiple arc distribution system with transformers may be found in the Patent Office record and the interferences and procedures in which it was involved. It was issued, after a long contest, in 1902.

A patent granted in 1883 for a reactive coil points out very clearly the distinction between a resistance and a reactance, and sets forth the practical value of the reactive coil in regulating and controlling alternating-current circuits. I think I am correct in stating that in this patent the name of "reactive coil" first appears in literature.

While, as stated, Prof. Thomson had confidence in the commercial value of alternating current at a very early date, he objected to its commercial exploitation because he believed that no insulation could be devised which would make it impossible for the high-pressure alternating current to occasionally come into contact with the low-pressure circuits, with fatal results to the unsuspecting users. It was not until he conceived the idea of grounding the secondary circuit, which eliminated this danger, that he was willing to push the development of alternating current for commercial purposes. This idea of grounding the secondary circuit, in order to insure safety, is first disclosed in one of his patents granted in 1885, and from that time on his contributions to alternating-current work were renewed in earnest. I would mention incidentally that the patents in this general line were dedicated to the public by the owner, on the ground of public safety, so that there should be no difficulty in applying them universally. In the same general class are safety devices for cutting off high tension lines from secondaries, such as described in a patent of 1885, a pioneer patent in this field.

The year 1886 is notable for the invention of the art and process of electric welding which has already gone into very extensive use and which perhaps constitutes one of his most notable achievements, as by this invention he has contributed an entirely new art to the world. In electric welding by the Thomson process alternating-current is essential because of the extremely large current which is required.

In 1887, 1888 and 1889 Prof. Thomson first proposed the method of using oil for insulating and cooling transformers—a method universally used at the present time; and invented the constant current transformer, a device in which a constant potential alternating-current in the primary is turned into a constant alternating-current in the secondary, being used for all purposes where a constant alternating-current is required, such as for arc lights and incandescent lamps in series.

The alternating-current induction regulator, in which a movable secondary or primary is used to vary the mutual induction and thereby control the current and voltage in an alternating-current circuit, was devised in 1888.

About this time Prof. Thomson made a large number of brilliant discoveries in connection with so-called alternating-current repulsion phenomena, and patented the first alternating-current single-phase repulsion motor, the basis of the existing single-phase motor. It is interesting, in this connection, to quote from an editorial appearing in the Electrical World of May 28, 1887, commenting upon this work:

> "It is, as yet, too early to assign to its proper place and limit the part which the alternating current will take in the electric arts. It has started on its career with most rapid strides, and it now only remains to devise means for its accurate measurement, regulation and distribution. Certain it is that Prof. Thomson's brilliant paper cannot fail to act as a powerful stimulus to those whose attention is now absorbed in the direction indicated, and the fruits of which will soon be noted. We hope that at a later meeting of the Institute Prof. Thomson will give to the world his practical results, which he has only hinted at in the present paper."

The wish which was expressed in this editorial was promptly realized. Following the principles first shown in this interesting experimental apparatus, Prof. Thomson rapidly devised instruments for the accurate measurement of alternating-current and other apparatus needed in its regulation and distribution. As already stated, these experiments formed the basis for the single-phase alternating-current motor, of which hundreds of thousands are in daily use; an interesting and rather useful example is found in the fan motor, which contributes so much to our comfort in hot and humid weather.

He also made the first very high frequency dynamo. This was constructed in 1890 to give 4000 cycles, a frequency from 30 to 40 times higher than that hitherto produced in a dynamo electric machine. Shortly after the introduction of this high frequency dynamo he originated the method of producing a high-frequency alternating current from a direct-current arc by shunting the arc with inductance and capacity. He published at the time a full description of this beautiful apparatus and the theory of its operation. To Prof. Thomson, therefore, must be given the credit for discovering and originating this interesting method of producing an alternating current which has since been developed by Poulsen and others in connection with wireless telegraphy. About this time also he produced his high-frequency transformer, made a series of brilliant investigations and developed apparatus of extreme scientific interest which form the basis of wireless telephone and telegraph work.

In this same decade, 1885 to 1895, we find Prof. Thomson busily engaged with electric meters, and as an outcome various meters known by his name were designed, of which over 4,000,000 have been sold and are now in operation. These meters are used for measuring the electrical energy consumed by electric lights, motors and other industrial appliances. He also invented the electrical switch operated from a distance, which forms the basis of the switching devices used on electric elevators, trolley cars, electric locomotives, and electric trains on elevated and suburban roads—the essential features of the so-called multiple unit system.

If time permitted it would be interesting to tell you of the notable discoveries and inventions which were made in connection with the Roentgen or so-called X-rays: of his static electric machine, which makes it possible to obtain from the ordinary low tension supply high tension discharges suitable for work with vacuum tube apparatus: of the countless arc lamps: of chain making machinery: of electric forging and brazing: of novel types of lightning arresters, such as the multi-gap and those with polarizing cells: of the film cutout, of time limit switches, and the resistance electric furnace. I think I should mention that the first stereoscopic X-ray pictures were made by him in 1897. The growing importance of this kind of work in X-ray applications, sometimes called "radiography," justifies mention of this matter, which is believed to be a pioneer development.

In addition to this great list of electrical inventions and contributions to electrical engineering, Prof. Thomson's active mind has found time to make valuable contributions in other lines. Among the earliest patents is a joint patent with Prof. Houston on a centrifugal creamer, filed in 1877 and issued in 1881. This patent was issued with broad claims to the continuous separation of cream from milk and was the first example of a continuously operating centrifugal machine with ducts for the separation of the new charge and ducts for the exit of the separated constituents. During the life of the patent all centrifugal creamers were manufactured under this patent coupled with another of De Laval, famous for his early steam turbine work; but the pioneer patent was one to Professors Thomson and Houston to which I have referred. In 1899 he produced a steam engine of remarkable efficiency, which has since become known to the world as the "uni-flow" engine. The inventor's description of the principle upon which this engine was based is as follows:

> "The conditions are such that there is no re-traversing of passages, no re-traversing of even the cylinder portion. The steam enters, goes forward and out, keeps running steadily forward, so that we do not have any of those inter-actions that use up energy. We have a temperature gradient from one end to the other of steam cylinder."

In this connection may be mentioned the electric air drill, in which an electric motor drives an air pulsator which compresses air for operating an ordinary air drill. This method was patented in 1895, and is now being extensively used.

In 1894 he devised a muffler for automobiles a form of muffler which embodies a silencing principle which is remarkable for its effectiveness, and interesting because it employs the method of dividing up an impulse and lagging certain parts of it behind others so as to prevent an explosive shock and spread the impulse over a considerable time. It antedates the Maxim silencer, and in some respects may be said to be similar in principle. He also devised numerous gas and oil engines, and developed a method of manufacturing fused quartz by electrical means, which gives every evidence of being the best yet devised.

It may not perhaps be generally known that our medalist is as much at home in the science of optics, in the practical application of its laws and in the design and use of its apparatus, as he is with those of electrical science. As early as 1878 he published an account of a method of grinding and polishing glass specula, or mirrors, such as are used in reflecting telescopes. His method was ridiculous in its simplicity, requiring no tools and yet capable of yielding optically true surfaces. He has a well equipped optical workshop at his laboratory at home and has originated many ingenious tools for the working and figuring of optical glass. He has found great delight in constructing with his own hands a large number of lenses, prisms, mirrors and other optical pieces for use in various apparatus. In his observatory is a 10-inch achromatic telescope in which all the optical parts, including the object glass and the spectroscopic attachment, were made with his own hands. If he had not chosen electrical engineering as his profession, but that of optics, he probably would have made a reputation in that field comparable with that which he has made in electricity.

He is equally at home in the science and practice of acoustics. Back in 1875 he constructed a pipe organ with several banks of pipes and with electropneumatic key action; many of the features of which have been adopted in the industry.

Prof. Thomson's scientific researches have been largely associated with his inventions, as his inventions are not those of the happy-go-lucky kind but are the result of careful and thorough research.

It must be remembered that he started in his early scientific career as a teacher, and has never been content with superficial knowledge, but has mastered fundamental principles so thoroughly as to be able to impart his knowledge to others. Such study has invariably led to original observations which have added to our scientific knowledge.

One of the earliest wireless experiments, of which I have knowledge, was made by Professors Thomson and Houston at the old High School in Philadelphia, in the Winter of 1879–80, by using an induction coil with one terminal connected to a water pipe through a wire of some length to a tin vessel on a glass stand. Sparks passing between the secondary terminals of the transformer set up ethereal vibrations all around which could be detected all over a large building containing numerous rooms. The detector was a sharpened lead pencil point in a dark place held close to a metallic object. Minute sparks would pass between the pencil point and the metallic object. Prof. Thomson has stated to me that he recognized at that time that a system of signalling could be based upon this phenomenon.

His first important research covered a study into the nature of and the electrical laws governing the operation of the electric arc. The results of this investigation were published in the Franklin Institute Journal in 1879. The research disclosed, among other things, the important fact that the resistance of the electric arc varied inversely with the current, and accounts for the instability of an arc unless operating from a circuit having constant-current characteristics. The important facts learned in this research undoubtedly put Prof. Thomson in a position to understand the characteristics of the electric circuit which were necessary to produce a satisfactory arc lighting system.

In February 1896 was published the results of a careful research conducted several years previously as to the dielectric strength of insulating oils under alternating-current potentials; he points out for the first time the interesting and important fact that with high frequencies; that is, frequencies of the order of 50,000 to 100,000 cycles per second, the insulating power of oil always is, as measured by the striking distance in air relative to that in the oil, far in excess of the insulating power for low frequencies, such as from 50 to 125 cycles, the usual commercial frequencies then employed. In this research attention is called for the first time to the extremely deleterious effect upon the insulating power of oil of an exceedingly minute quantity of moisture, and points out the necessity for the thorough drying of oil when used as an insulator in high pressure electrical apparatus.

As I have already stated, his inventions were so largely the result of and accompanied by original scientific research that it is impossible to separate them, and the information, therefore, which we may obtain as to his various scientific researches will be largely found in the descriptions of his inventions and discoveries.

I hope that this sketch of Prof. Thomson's work, brief and imperfect as it is, will serve to illustrate the extent and variety of his knowledge and the range of his mental activities and the ingenuity and great practical value of his work. He has not been content to make some one astonishing discovery or invention and then lapse into comparative quietude, but during his entire life has been a "continuous performer" and succeeded in turning out an amount of work astounding in quantity and equally remarkable for its high quality.

As a close observer of Prof. Thomson's activities for over 36 years I may be able to say something of interest as to his method of work. A skilled workman, he is always able to himself do the work which he asks others to perform. He prefers to make his own drawings, freehand sketches, to which he adds dimensions and a short written description. He selects his own materials, supervises the work, quickly makes such modifications as may be needed during its progress and stands constantly ready to give just the advice necessary to help over difficult places and turn failure into success. His inventions are the result of such profound and accurate knowledge, and developed with such skill that they almost invariably work on the first trial in accordance with expectation. One of the most extraordinary things about his experimental work is its low cost. I am certain that if a prize were to be given for the inventor or engineer who could make a dollar go the furthest, and produce the greatest results, that Prof. Thomson would have no worthy competitor in this or any other country. He seems to possess an almost intuitive insight into Nature and her ways, probably because of the quickness and accuracy of his perception combined with the most remarkable depth and range of scientific knowledge, all helped by a marvellously retentive memory. In fact, Prof. Thomson perhaps more than any other inventor since the days of Henry or Faraday, combines in his person profound and accurate scientific knowledge with extraordinary technical skill.

You may be interested in learning from this great master of experimental research something as to his own views of the field to be covered and the method of attack. I therefore take the liberty of reading a few short quotations from an address delivered in August 1899 before the American Society for the Advancement of Science on "The Field of Experimental Research."

"The development in the field of research by experiment is like the opening of a mine, which, as it deepens and widens continually yields new treasure but with increased difficulty, except when a rich vein is struck and worked for a time. In general, however, as the work progresses there will be needed closer application and more refined methods. In most fields of research the investigator must be ready to guide the trained mechanic and be able himself to administer those finishing touches which often mark the difference between success and failure. There must be in his mental equipment that clear comprehension of the proper adjustment of means to ends which is of such great value in work in new fields. He must also learn to render available to science the resources of the larger workshops and industrial establishments.

"The obstacle of increasing costliness of equipment, which in some fields might act as a bar to further progress, can only be overcome by more liberal endowments of laboratories engaged in advanced work. Even those in a community who can only understand the value of scientific work when it has been put to practical use may find in the history of past progress that many discoveries in pure science, which had not, when made, any commercial importance or value, have in the end resulted in great practical revolutions.

"Scientific facts are of little value in themselves. Their significance has a bearing upon other facts, enabling us to generalize and to discover principles, just as the accurate measurement of the position of a star may be without value in itself, but in relation to other similar measurements of other stars may become the means of discovering their proper motion. We refine our instruments, we render more trustworthy our means of observation, we extend our range of experimental inquiry and thus lay the foundation for future work with the full knowledge that although our researches cannot extend beyond certain limits; the field itself is even within those limits inexhaustible."

The address is one which could be read with profit by everyone having to do with experimental research. While it points out certain apparent limitations in research due to the impossibility of producing the range of temperatures and pressures which exist in nature, it is, nevertheless, full of suggestions as to method of overcoming difficulties. It points out the gaps in our knowledge and makes fascinating suggestions as to the possibilities of filling these gaps in future.

It is difficult to restrain our enthusiasm for one who has given the world so much, who has been and still continues to be such an inspiring example to all workers in science and industry. If I have failed to use superlatives it is not because they are undeserved, but in deference to his well-known modesty and because of a conviction that a plain statement of the facts would be most impressive. His technical and scientific work has met with the enthusiastic approval of his fellowmen as evidenced by the honors of all kinds that have been showered upon him; but I think those who know him best prize not only his technical skill and scientific attainments but those qualities—ethical if you please—with which he is so generously endowed; those qualities which make the personality of the man we delight to honor, so sincere, so full of sympathy with all that is good in life; that character which commands our confidence and respect and wins and retains our affection. He has certainly made generous additions to the world's material wealth, but he has added almost infinitely more to its intellectual treasures.

It strikes me as a particularly happy and sensible thing to do, to honor such a man while he is in the prime of life; it gives double pleasure, to those who join in the fortunate event and to the one who receives the token of appreciation. While our friend perhaps considers the joy which he has had in his work as a sufficient reward, let us hope that that joy and satisfaction may be increased by the many evidences of appreciation of a grateful world, of which the medal to be bestowed tonight is the latest but by no means the least or the last.

EFFECT OF BAROMETRIC PRESSURE ON TEMPERATURE RISE OF SELF-COOLED TRANSFORMERS

By V. M. Montsinger

Transformer Engineering Department, General Electric Company

A standard rating applies only when an electrical machine is installed in a temperate location and at a moderate altitude. For service in a tropical climate or at a great altitude, an electrical machine must be re-rated, as otherwise the temperatures attained may exceed approved values. The author's paper deals with the influence of altitude.

Section 308 of the 1916 Edition of the A.I.E.E. Rules contains the recommendation:

> "That when a machine is intended for service at altitudes above 1000 meters (3,300 ft.), the permissible temperature rise at sea level, until more nearly accurate information is available, shall be reduced by 1 per cent for each 100 meters (330 ft.) by which the altitude exceeds 1000 meters. Water cooled oil transformers are exempt from this reduction."

The recommendation in the British Rules (Report No. 72 of the Engineering Standards Committee) reads as follows:

> "For a machine intended for service at an altitude above 3,300 feet (1,000 meters approximately), the observable temperature rise, if tested near sea-level, shall be reduced 2½ per cent for each 1,000 feet above sea-level at which the machine is intended to work in service. The correction shall not be applied for altitudes below 3,300 feet."

The author discusses the effect of altitude upon the temperature rise of oil-immersed transformers without water cooling and describes tests made successively at Pittsfield, whose altitude is 305 meters; at Boulder, Colorado, where the altitude is 1830 meters and at Leadville, where the altitude is 3360 meters. For some kinds of transformer tanks the temperature rise at this greatest altitude exceeded that at Pittsfield by some 12 per cent. It is quite evident that a variation of so considerable magnitude cannot be ignored. Formulæ are developed by the author which will enable the effect of altitude to be accurately taken into account and he recommends their inclusion in the American Rules. The present recommendations concerning altitude in the American and British Rules are shown by the author to be inapplicable for transformers immersed in oil in tanks of the types which were employed in the tests at Pittsfield, Boulder and Leadville.—Editor.

General

Although it is generally recognized that an increase in altitude has the effect of increasing the temperature of electrical apparatus, the extent to which such apparatus is affected by changes in atmospheric pressure has never been accurately determined.

While the 1915 A.I.E.E. rule (Section 308), which specifies that the same correction be made for all types of air-cooled apparatus, may be correct for certain types, an analysis of the modes in which heat is dissipated and of the effects of atmospheric pressure on these modes indicates that there are other types of apparatus for which this correction is much too large. This latter type comprises principally self-cooled stationary apparatus where the cooling is not as dependent on the volume of air passing through or over the cooling surfaces as is the case with forced ventilating systems. All self-cooled transformers, of course, fall within the self-cooled class, and air-blast transformers (and rotating machinery to a greater or less extent) fall within the forced ventilating class.

The purpose of this article is to present a short discussion* on the dissipation of heat from self-cooled transformers in order to show how barometric pressure affects the heating and to give the results of experimental observations conducted on transformers at different altitudes. The results of the tests are then compared with calculated values, making use of the principal laws of cooling and of the effect of barometric pressure on these laws.

MODES OF HEAT DISSIPATION

The loss of heat from the surface of a tank takes place by radiation and by convection, the relative amounts depending to some extent on the color and the height of plane, but principally on the shape of the contour.

Radiation is dependent upon the envelope surface or outer perimeter of a tank, while convection is dependent upon the total developed surface, providing free circulation of air is allowed.

While the nature or form of the laws of radiation and convection are fairly well understood, it is almost impossible in practice to separate the two and obtain absolutely correct values for the empirical constants. For the present discussion, however, the writer has used for radiation the empirical constant that is given by the best authorities. For convection, the constant was determined by subtracting from the total, or supplied losses, the calculated loss by radiation.

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* For a more comprehensive treatment of this subject, see Proc. A.I.E.E. Apr. 1916, by V. M. Montsinger.

The loss of heat from a self-cooled transformer may be expressed as follows:

$$W = W_r + W_c \qquad (1)$$

where

W = total losses supplied to transformer.

W_r = loss by radiation.

W_c = loss by convection.

Radiation

The Stefan-Boltzman law that radiation is proportional to the difference of the fourth powers of the absolute temperatures is generally expressed in the form

$$W_r = K\,E\,(T^4_2 - T^4_1) \qquad (2)$$

where

W_r = watts dissipated by radiation per sq. in. of surface.

K = constant = 3.68×10^{-11}.

E = relative emissivity which depends upon the nature and color of the surface.

T_2 = absolute temperature of the radiating surface.

T_1 = absolute temperature of the room.

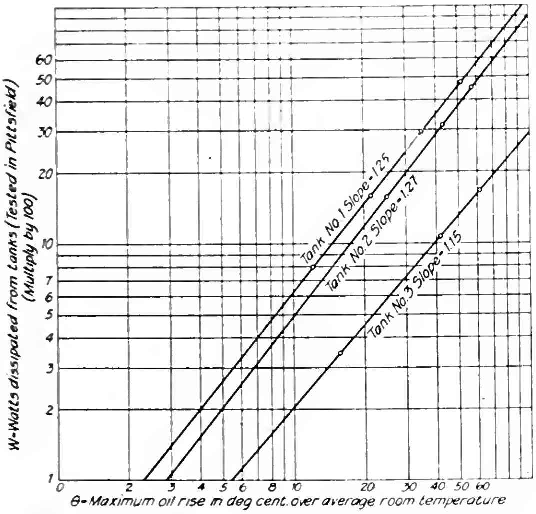

Fig. 1. Watts Dissipated in Test from Tanks 1, 2 and 3 at Various Temperatures above Room Temperature

Convection

Practically all Physicists have found that loss by convection varies very nearly as the 1.25 power of the temperature rise. For example, Lorenz (An. d. Physik. Vol. 13. P-582, 1881) by making certain arbitrary assumptions proved that the convection of heat from vertical plane surface varied as the 5/4 power of the temperature rise. Also in 1817 Dulong and Petit announced that

"The velocity of the cooling due solely to the contact of a gas is proportional to the excess of temperature in degrees centigrade to the power 1.233."

The following equation then is no doubt fairly accurate and for practical purposes may be used for the loss of heat by convection from vertical surfaces of tanks.

$$W_c = K\,\theta^{1.25} \qquad (3)$$

where

W_c = watts dissipated per sq. in. of developed surface.

and

K = constant for any one tank.

θ = temperature rise of surface above room temperature.

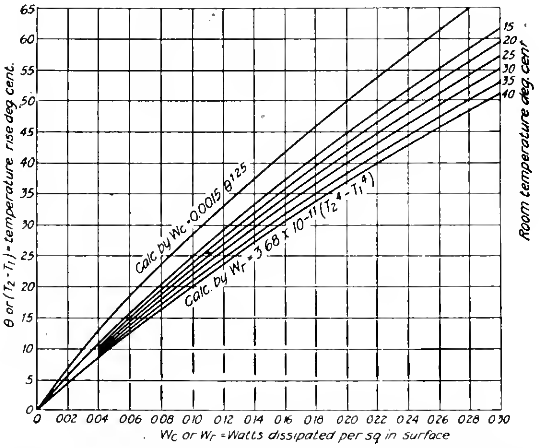

Fig. 2. Watts Dissipated per Square Inch Surface at Various Room Temperatures and Degrees Rise above Room Temperature

MAXIMUM OIL RISE *VS.* TOTAL LOSS SUPPLIED TO TANKS

Referring to Fig. 1 in which the maximum oil rise (θ) is plotted on logarithmic scale against total watts (W) supplied to the three different tanks as shown in Figs. 3 and 4, it will be seen that the test points for each tank fall in a straight line. Since the slope of the lines for the tanks having irregular contours, and consequently dissipating the greater part of their losses by convection, is close to 1.25, this also indicates that the loss of heat by convection for various temperature rises of the surface follows this same law, i.e., the loss varies as the 1.25 power of the temperature rise. The reason the line for tank No. 3, having a plain surface, has a slope (1.15) less than 1.25 is no doubt due to the fact that radiation plays a more prominent part in the loss of its heat than it did for the other tanks. The relative amounts of loss of heat from the plain tank were approximately 60 per cent radiation and 40 per cent convection.

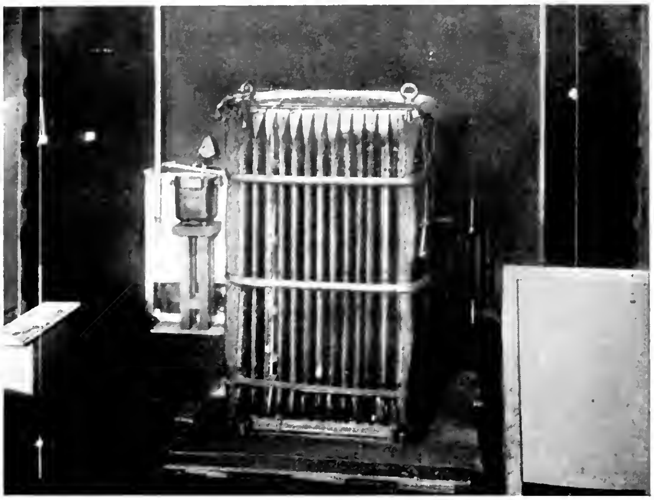

Fig. 3. Tank No. 1 on Heat Run

If we plot on logarithmic paper the Stefan-Boltzman equation for radiation, we obtain, between the limits of 10 and 50 deg. cent rise above a 30 deg. room temperature, a line whose slope is about 1.12. The slope of 1.15 for the plain surface as given in Fig. 1 (for approximately equal losses by radiation and by convection) then looks reasonable. In practice, however, the slopes may vary slightly from 1.15 for plain and 1.25 for complicated surfaces, due to the fact that the height of oil which affects to some extent the surface effective for loss of heat, may change, due to expansion of the oil as the temperature increases. Again if the viscosity of the oil is such as to cause an appreciable change in the temperature gradient along the surface of the tank, the maximum oil rise when plotted on logarithmic paper against loss may not fall in a straight line.

The error due to change in oil height is usually small. The error due to change in viscosity of oil may be considerable with oils having a high viscosity at low temperatures, but the present day oils used in transformers do not change in viscosity to a great extent between about 40 deg. and 100 deg. C. In practice then the maximum oil rise vs. total loss supplied to self-cooled transformers should generally follow very closely the formula $W = K\ \theta^n$, where n has a constant value for any given tank but varies from 1.15 to 1.25 for different tanks, depending upon the shape of the surface.

Effect of Shape and Height of Surface on Convection

For the plain and for the corrugated surface having corrugations 3½ in. in depth and 2¼ in. pitch, the experimental tests indicated that K has about the same value, i.e., 1.5×10^{-3}, while for the surface having corrugations 9 in. in depth and 2⅜ in. pitch, the value was 1.32×10^{-3} or 88 per cent of the value for the less complicated surfaces. This is shown in tabulated form in Table I.

The reduction in the value of K for the 9 in. corrugations is no doubt due to a greater resistance offered to movement of the air through the deep vents. As surfaces become more and more complicated the value of K no doubt would be further decreased. Also for surfaces of this nature the height no doubt would prove to be an important factor, whereas for ordinary plain and simple corrugated surfaces, practice has shown that the effect of height usually has very little if any effect on the thermal efficiency.

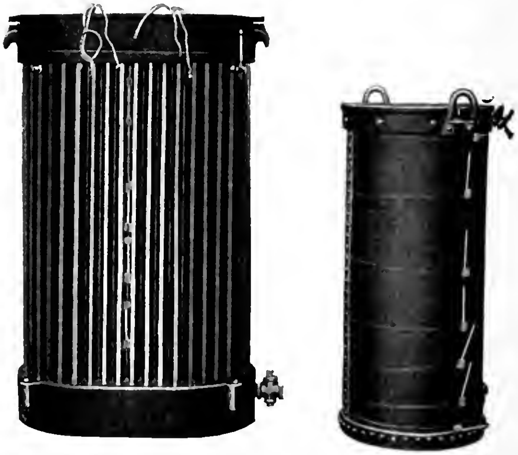

Fig. 4. Tanks Nos. 2 and 3

EFFECT OF BAROMETRIC PRESSURE ON RADIATION AND CONVECTION

Radiation

Radiation is not affected by changes in air density.

Convection

In 1817 Dulong and Petit found that the velocity of cooling in a gas was proportional to the pressure raised to the power of

0.45 for atmospheric air
0.38 for hydrogen
0.517 for carbonic acid
0.501 for olifiant gas.

Messrs. Kennelly and Sanborn* in an investigation on "The Influence of Atmospheric Pressure upon the Forced Thermal Convection from Small Electrically Heated Platinum Wires" found that the linear convection is nearly proportional to the 0.5 power of the atmospheric pressure.

According to Lorenz, convection varies as the 0.5 power of the pressure. It seems, therefore, that if we use 0.5 power of the pressure, the result should be fairly accurate.

CALCULATION OF THE EFFECT OF PRESSURE ON COOLING

Assuming that the loss by convection W_c varies as the 0.5 power of the pressure and as the 1.25 power of the temperature rise, letting B represent the barometric pressure in inches of mercury, the general equation for convection becomes

$$W_c = K\,\Theta^{1.25}\,B^{0.5} \tag{4}$$

transposing

$$\Theta^{1.25} = \frac{W_c}{K\,B^{0.5}}$$

or for temperature rise compared with rise at sea level

$$\Theta = \left(\frac{W_c}{K}\right)^{0.8} \times \left(\frac{29.9}{B}\right)^{0.4} \tag{5}$$

For a constant loss the temperature rise therefore varies inversely as the 0.4 power of the barometric pressure. Assuming, then, a constant loss the expression reduces to

$$\Theta = \left(\frac{29.9}{B}\right)^{0.4} \tag{6}$$

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* Proc. Am. Phil. Soc., Vol. LIII, 1914.

TABLE I

COMPARISON OF CALCULATED LOSS WITH TESTS (LOSS) CONDUCTED AT PITTSFIELD

Test	Max. Oil† Rise Deg. Cent.	Total‡ Watts Input	Convection or Input Watts less Calc. Radiation	WATTS LOSS BY CONVECTION CALCULATED BY EQUATIONS $W_c =$	
				$\frac{1.32\theta^{1.25}}{10^3}$	$\frac{1.5\theta^{1.25}}{10^3}$
			Tank No. 1		
1	21.1	1564.5	1268.0	1245.0	
2	34.6	2910.0	2370.0	2380.0	
3	50.9	4721.0	3811.0	3830.0	
			Tank No. 2		
4	24.9	1550.0	1023.4	......	1005.0
5	42.3	3114.0	2114.0	......	2041.0
6	56.7	4500.0	3026.2	......	3129.0
			Tank No. 3		
7	15.6	347.5	186.5	......	100.0
8	41.9	1064.5	478.0	......	446.5
9	60.2	1657.5	704.5	. ....	722.3

†Based on the following average ambient temperatures:

For tests No.	1	2	3	4	5	6	7
Room (deg. cent.)	30.0	30.1	32.1	30.0	32.0	32.0	29.9
Test No.	8	9					
Room (deg. cent.)	30.2	30.1					

‡Avg. of volt x ampere and wattmeter readings.

According to the Smithsonian Institute formula for altitude *vs.* pressure.

$$log_{10} B = log_{10} 29.9 - \frac{A_1}{62584\,[1+0.00367\,(T-10°\,C.)]} \qquad (7)$$

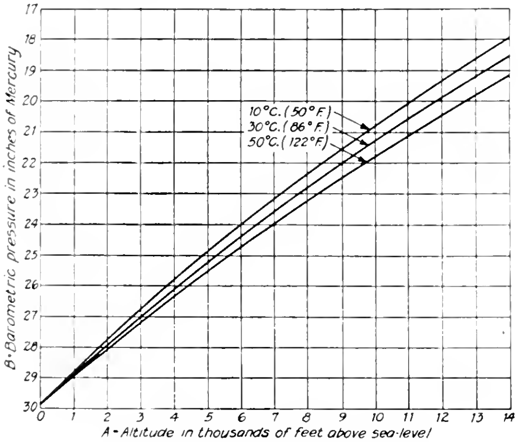

Fig. 5. Curves Calculated by Formula 7

where

B = barometric pressure in inches of mercury.

A_1 = altitude in feet.

T = temperature in deg. cent.

Values of B for different values of A, when $T = 10$, 30 deg. and 50 deg. are plotted in Fig. 5.

Substituting in equation (6) the values for B as found for different values of A_1 in equation (7), and letting Θ_x represent temperature rise when $B = 29.9$ (at sea level), we have (when $T = 30$ deg.)

For

$$A_1 = 2000,\ 4000,\ 6000,\ 8000,\ 10{,}000,\ 12{,}000,\ 14{,}000$$

$$\frac{\Theta}{\Theta_x} \Big\} = 1.028\ \ 1.057\ \ 1.0862\ \ 1.115\ \ 1.147\ \ 1.1786\ \ 1.212$$

Letting

$$\phi_1 = \left(\frac{\Theta}{\Theta_x} - 1\right)100$$

and expressing altitude A in thousands of feet, we again have

For

$$A = \ 2 \quad 4 \quad 6 \quad 8 \quad 10 \quad 12 \quad 14$$

$$\frac{\phi_1}{A} = \Big\{ 1.4\ \ 1.425\ \ 1.436\ \ 1.44\ \ 1.47\ \ 1.49\ \ 1.51$$

Since the above values of $\frac{\phi_1}{A}$ are so nearly the same, we may take an average (1.46) of these values and only a small error is introduced at the lowest and highest altitudes. The equation then becomes

$$\phi_1 = 1.46\,A \qquad (8)$$

where ϕ_1 is the percentage increase in temperature rise for a constant loss and A is the difference in altitude between lower and upper elevations expressed in thousands of feet (that is, for 1000 ft. $A = 1$).

Equation (8) is true only for a surface dissipating all its loss by convection when naturally cooled. However, this condition seldom exists in commercial transformers*. For a plain surface the percentage of loss by convection is probably from 40 to 45 per cent of the total loss, whereas for surfaces with very complicated contours the loss by convection may approach more nearly 100 per cent. It is evident, therefore, that the effect of altitude will be very different for different styles of surfaces—each one requiring special consideration.

This effect may be expressed in terms of the percentage of loss by convection to the total loss. For example, if only 50 per cent of the loss is by convection and the remaining by radiation (unaffected by pressure) the effect of pressure will be approximately one-half that expressed by equation (8). Letting ϕ_2 equal the percentage increase in temperature rise for surfaces having both radiation and convection, we have

$$\phi_2 = 1.46\,A \times \frac{\text{loss by convection}}{\text{total loss}} \qquad (9)$$

or substituting for loss their equivalent values given in equations (1) and (3) and assuming that $E = 1$

$$\phi_2 = 1.46\,A \times \frac{W_c}{W_c + W_r}$$

$$= \frac{1.46\,A}{1 + \frac{W_r}{W_c}} \qquad (10)$$

Since the ratio of $\frac{W_r}{W_c}$ does not remain quite the same when the altitude changes, equation (10) is not quite correct. For instance, when the apparatus is taken to a higher altitude the radiation increases while the convection may decrease. However, the error is small especially for surfaces with irregular contours, such as corrugations, etc., where the greater part of the loss is by convection, and since it is

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*Natural draft transformers would come under this condition where the total RI^2 loss is dissipated by convection.

a positive error, i.e., it makes the estimated temperature rise slightly higher than it should be, it may be neglected for practical purposes. An attempt to make a correction for this error would require an equation too cumbersome to handle.

If we assume a standard room temperature and a standard temperature rise, we can, for practical purposes, express, W_c and W_r in terms of the developed and envelope surfaces reduced to equivalent values of loss per unit area. This makes it more convenient for practical application. For example, referring to Fig. 2, we find that for a 50 deg. rise above 30 deg. room temperature, the calculated watts dissipated per sq. in. of surface are approximately in the *ratio* of 1.0 for convection to 1.3 for radiation. If we let

$$R = \frac{\text{Envelope area of surface}}{\text{Developed area of surface}} =$$

equation (10) may be written

$$\phi_2 = \frac{1.46\,A}{1+1.3\,R} \qquad (11)$$

DERIVATION OF GENERAL EQUATION FOR EFFECT OF BAROMETRIC PRESSURE ON TEMPERATURE RISE

We have seen that for temperature rises between 0 deg. and 75 deg. cent., the general equation of temperature rise *vs.* loss is $\Theta = KW^n$ and that the equation of temperature rise *vs.* altitude is

$$\phi_2 = \frac{1.46\,A}{1+1.3\,R}.$$

If we let Θ = temperature rise at some high altitude and let

W_o = loss at room temperature Θ_o for given load conditions on the transformer.

W = loss at temperature rise Θ.

$$r = \frac{\text{copper loss}}{\text{(iron+copper) loss}}$$

We may put

$$W_o = W_o\,(1-r) + r\,W_o$$

Since iron loss is practically unaffected by temperature (see Proc. A.I.E.E., Oct. 1912, MacLaren) at temperature Θ (for temperature coefficient or resistivity of copper of 0.00427 per cent per deg. cent.) the copper loss

$$= r\,W_o\left(\frac{234+\Theta_o+\Theta}{234+\Theta_o}\right)$$

Then

$$W = W_o\,(1-r) + r\,W_o\left(\frac{234+\Theta_o+\Theta}{234+\Theta_o}\right)$$

$$= W_o\left(\frac{234+\Theta_o+r\Theta}{234+\Theta_o}\right)$$

The temperature rise (say Θ_x) for this loss at sea level will be

$$\Theta_x = K\,W_o{}^n\left(\frac{234+\Theta_o+r\,\Theta}{234+\Theta_o}\right)^n$$

If taken to a high altitude the temperature rise, with this loss, will be increased ϕ_2 per cent. i.e.,

$$\Theta = \Theta_x + \frac{\phi_2}{100}\Theta_x = \Theta_x\left(1+\frac{\phi_2}{100}\right)$$

$$= K\,W_o{}^n\left(1+\frac{\phi_2}{100}\right)\left[\frac{234+\Theta_o+\Theta_r}{234+\Theta_o}\right]$$

Let

Θ_s = temperature rise at the lower altitude for the given load conditions.

$$\Theta_s = K\,W_s{}^n$$

$$= K\,W_o{}^n\left(\frac{234+\Theta_o+r\,\Theta_s}{234+\Theta_o}\right)$$

then

$$\frac{\Theta}{\Theta_s} = \left(1+\frac{\phi_2}{100}\right)\left[\frac{234+\Theta_o+r\,\Theta}{234+\Theta_o+r\,\Theta_s}\right]^n$$

Which may be written in the form

$$\frac{\Theta}{\Theta_s} = \left(1+\frac{\phi_2}{100}\right)\left[\frac{234+\Theta_o+r\Theta_s+r(\Theta-\Theta_s)}{234+\Theta_o+r\Theta_s}\right]^n$$

Putting

$$\left(1+\frac{\phi_2}{100}\right) = B$$

and

$$(234+\Theta_o+r\,\Theta_s) = D$$

$$\frac{\Theta}{\Theta_s} = B\left[1+\frac{r\,(\Theta-\Theta_s)}{D}\right]^n$$

Expanding by the binomial theorem

$$\frac{\Theta}{\Theta_s} = B\left[1+n\frac{r\,(\Theta-\Theta_s)}{D}+\frac{n\,(n-1)}{2}\cdot\frac{r(\Theta^2-\Theta_s)^2}{D_2}+\ldots\right.$$

The terms after the second may be neglected without any appreciable error, then

$$\frac{\Theta}{\Theta_s} = B\left[\frac{D-n\,r\,\Theta_s}{D-B\,n\,r\,\Theta_s}\right]$$

$$= B\left[\frac{1}{1-\dfrac{\dfrac{\phi_2}{100}\,n\,r\,\Theta_s}{D-n\,r\,\Theta_s}}\right]$$

or with an error of less than 1 per cent

$$\frac{\Theta}{\Theta_s} = B\left[1+\frac{\frac{\phi_2}{100}\,n\,r\,\Theta_s}{D-n\,r\,\Theta_s}\right]$$

which reduces to

$$\frac{\Theta}{\Theta_s} = \left(1+\frac{\phi_2}{100}\right)\left[1+\frac{\frac{\phi_2}{100}\,n\,r\,\Theta_s}{234+\Theta_0+r\,\Theta_s\,(1-n)}\right] \qquad (12)$$

While equation (12) may be used for calculating the temperature rise for various altitudes and for various ratios of copper to iron loss, it is not in a convenient form, and for commercial transformers conditions are usually such that we can assume definite values of r, Θ_0, Θ_s and n and the error introduced for other conditions is permissible.

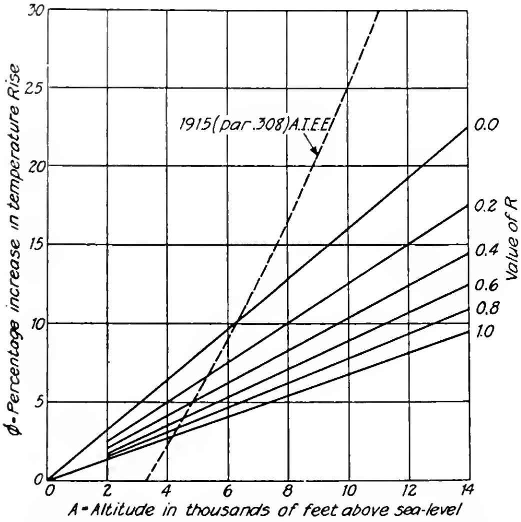

Fig. 6. Curve showing Effect of Altitude on Heating of Different Shape Tank Surfaces, Calculated by Formula 13

Assuming a difference in altitude of 1000 ft., that is, when $A=1$ and letting $R=0$, $n=0.8$, $\Theta_o=30$, $\Theta_s=50$ deg. cent., and $r=0.6$, and substituting these values in equation (12) we have $\left(\frac{\Theta}{\Theta_s}-1\right)100=1.6\,A$; that is, we have increased in equation (11) the value $1.46A$ to $1.6A$ due to the fact that 60 per cent of the total loss is in copper windings.

Then

$$\phi = \frac{1.6\,A}{1+1.3\,R} \qquad (13)$$

Curves calculated from equation (13) for different values of R are shown in Fig. 6, together with a curve representing the present A.I.E.E. (para. 308) Rule.

Table II shows a comparison between observed temperature rises and calculated temperature rises by equation (11) using the data shown in Tables III, IV and V giving complete data on observations conducted at Pittsfield, Mass. Boulder, Colo. and at Leadville, Colo.

An inspection of Table II shows that the calculated and observed temperature rises for all tests on tank No. 1, which is the most important of the three (because the effect is greatest), agree very well. Also there is only a slight difference, the observed being lower than the calculated values, for the Leadville tests on tanks Nos. 2 and 3. Why the observed and calculated values for the Boulder tests on tanks Nos. 2 and 3 do not agree any better is not clearly understood. This difference is no doubt mostly due to the fact that the room temperatures were from three to six degrees higher at Boulder than at Pittsfield, which as seen before, has the effect of increasing the tank's effectiveness for radiation. The difference is largest for the plain tank where radiation plays the more prominent part. Also it will be noted that the humidity of the air at the former place was somewhat higher, but in general this has been shown to have very little effect. (See Proc. A.I.E.E. Feb. 1913. Frank and Dwyer)

Fig. 7. Pressboard Housing used for Making Tests

EXPERIMENTAL OBSERVATIONS

Observations were made under exactly the same conditions, with the above exceptions, at

Pittsfield, Mass. approx... 1000 ft. above sea level
Boulder, Col.* approx..... 6000 ft. above sea level
Leadville, Colo. approx...11000 ft. above sea level

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* It is desired here to acknowledge indebtedness to Prof. H. S. Evans of the University of Colorado, who had charge of and conducted the observation at Boulder at the expense of the University Eng. Dept. Also the writer wishes to acknowledge the excellent aid given by Messrs. C. D. Fawcett and T. M. Victory in carrying on the observations at Boulder and at Leadville.

The writer had charge of the observations at Pittsfield and at Leadville.

The housing, Fig. 7, consisted of pressboard walls made up into sections so it could be easily assembled and disassembled. A view of the arrangements on the inside of the housing is shown in Fig. 3. The room temperature was controlled by means of sliding covers. In a few instances when the supplied loss was small, in order to keep the room temperature from falling below the desired value, it was necessary to use a small electric heater.

Two 16-in. desk fans were operated in a vertical position in opposite corners of the room, with pressboard screens placed between the fans and the tank to prevent breezes from striking the surface of the tank. Tests made in this manner at different outside temperatures showed that under all conditions, the difference in air temperature (approx. 35 in. from the tank surface) level with the top and bottom of tank did not in any case exceed 2 deg. cent., whereas without the fans sometimes as much as 6 to 8 deg. cent. difference was observed. The room temperature used as a base was taken as the average of the four thermometers placed on a level with the center of the tank, in each corner of the room as shown in Fig. 3. In addition to the room temperature being used as the base, the temperature of a small lighting size transformer tank, filled with oil, set with its center on a level with the center of the tank under test, was also used. The percentage of humidity of the air, during

TABLE II

Test No.	Approx. Average Surface Rise Deg. Cent. at Pittsfield	TEMPERATURE RISE IN PERCENTAGE ABOVE RISE AT PITTSFIELD					
		Tests at Boulder			Tests at Leadville		
		Calculated by Equation (11)	Rise above		Calculated by Equation (11)	Rise above	
			Average Room	Idle Tank		Average Room	Idle Tank
Tank No. 1							
1	17.5	6.2	6.83	8.32	12.0	10.0	11.0
2	29.7	6.1	5.5	7.0	12.6	13.5	14.6
3	44.4	5.7	6.7	7.5	11.0	12.6	13.3
Mean values..........		6.0	6.34	7.6	11.9	12.0	12.9
Mean value obtained by formula*..........					11.05		
Tank No. 2							
4	15.8	4.6	0	0	9.5	6.06	7.40
5	31.4	5.0	3.3	1.85	10.7	8.75	9.50
6	44.4	4.8	1.95	1.78	9.6	8.65	9.95
Mean values..........		4.8	1.42	1.27	9.95	7.82	8.95
Mean value obtained by formula*..........					9.3		
Tank No. 3							
7	9.85	3.1	0	0	6.4	5.77	5.6
8	31.5	3.55	−3.34	−3.34	6.6	3.82	4.05
9	48.3	3.43	−2.82	−3.26	6.4	4.32	5.0
Mean values..........		3.36	−2.08	−2.2	6.45	4.6	4.88
Mean value obtained by formula*..........					5.85		

* $$\varphi = \frac{1.46A}{1 + \frac{W_r}{W_c}}$$

NOTE.—Instead of using here a constant value for $\frac{W_r}{W_c}$ for different temperature rises, the values are based upon actual watts dissipated as given by equations (1) and (3) for surface temperature rises shown in second column above. Since the values for W_c and W_r change in opposite directions for change in altitude, the calculations are made for the proper values at an average altitude of Pittsfield and Boulder (5000 ft. above sea-level).

TABLE III

RECORD OF TESTS ON TANK No. 1 (CORRUGATIONS 9 IN. IN DEPTH)

Test	Volts	Amperes	WATTS (1) OBSERVED BY		TEMPERATURE IN DEG. CENT.					Observed Barometric Pressure in Inches Hg.	CALCULATED ALTITUDE IN FEET ABOVE		Humidity of Air in per cent of Saturation	Grains of Moisture Per Litre of Air	Date of Test
							AVERAGE MAX. OIL (3)								
								RISE ABOVE							
			Volts × Amp.	Wattmeter	Oil in Idle Tank	Avg. (2) Room	Actual	Oil in Idle Tank	Avg. Room		Sea Level	Pittsfield			
Pittsfield															
1	110	14.35	1565	1564	30.3	30.0	51.1	20.8	21.1	28.7	1200	0	21	0.106	3–27–15
2	110	26.6	2913	2907	30.4	30.1	64.7	34.3	34.6	28.9	1000	0	16	0.086	3–26–15
3	110	43.1	4728	4707	32.4	32.0	82.9	50.5	50.9	28.6	1300	0	17	0.95	3–23–15
Boulder															
1	110	14.5	1583	1538	36.0	36.0	58.5	22.5	22.5	24.2	6200	5000	21	0.132	5–14–15
2	110	26.7	2925	2908	37.3	37.4	74.0	36.5	36.7	24.4	5900	4900	18	0.130	5–12–15
3	110	43.5	4773	4688	37.2	37.2	91.5	54.3	54.3	24.4	5900	4600	20	0.140	5–10–15
Leadville															
1	110	14.35	1565	1564	29.9	29.8	53.0	23.2	23.1	20.6	10900	9700	25	0.122	7–24–15
2	110	26.4	2891	2897	30.0	30.0	69.3	39.3	39.3	20.4	11150	10150	20	0.099	7–23–15
3	110	43.1	4728	4727	30.9	30.9	88.2	57.3	57.3	21.1	10200	8900	22	0.106	7–22–15

(1) Less instrument losses.
(2) Avg. of 4 thermometers.
(3) Avg. of 3 thermometers.

TABLE IV

RECORD OF TESTS ON TANK No. 2 (CORRUGATIONS 3 IN. IN DEPTH)

Test	Volts	Amperes	WATTS (1) OBSERVED BY		TEMPERATURE IN DEG. CENT.					Observed Barometric Pressure in Inches Hg.	CALCULATED ALTITUDE IN FEET ABOVE		Humidity of Air in per cent of Saturation	Grains of Moisture Per Litre of Air	Date of Test
							AVERAGE MAX. OIL (3)								
								RISE ABOVE							
			Volts × Amp.	Wattmeter	Oil in Idle Tank	Avg. (2) Room	Actual	Oil in Idle Tank	Avg. Room		Sea Level	Pittsfield			
Pittsfield															
4	110	14.25	1554	1547	30.5	30.1	54.9	24.4	24.8	28.6	1300	0	16	0.081	3–19–15
5	110	28.4	3111	3117	32.3	32.0	74.3	42.0	42.3	28.7	1200	0	14	0.081	3–18–15
6	110	41.0	4493	4507	32.4	32.0	88.7	56.3	56.7	28.5	1400	0	14.5	0.078	3–16–15
Boulder															
4	110	14.25	1554	1556	31.5	31.1	55.9	24.4	24.8	24.3	6000	4700	34	0.176	5–20–15
5	110	28.8	3163	3117	36.4	35.5	79.2	42.8	43.7	24.1	6300	5100	29	0.188	5–18–15
6	110	41.5	4552	4573	38.8	38.3	96.1	57.3	57.8	24.1	6300	4900	22.5		5–17–15
Leadville															
4	110	14.1	1548	1547	30.2	30.0	56.4	26.2	26.4	20.5	11000	9700	21	0.110	7–27–15
5	110	28.4	3111	3117	31.8	32.0	78.0	46.2	46.0	20.4	11150	10950	24	0.130	7–26–15
6	110	41.3	4517	4517	31.7	32.0	93.6	61.9	61.6	20.4	11150	9750	24	0.116	7–25–15

(1) Less instrument losses.
(2) Avg. of 4 thermometers.
(2) Avg. of 3 thermometers.

all tests, was determined by means of wet and dry mercury bulb thermometers. The barometric pressure was observed with a mercurial barometer. Particular care was taken to see that the oil height was the same for similar tests at all three altitudes.

Tanks

The dimensions of the three tanks used are given in Fig. 8.

The covers for the three tanks were insulated thermally from the tanks proper. Also for tank No. 1 the two plain sides were covered each with two 1 in. thicknesses of hair felt, so as to make the loss by radiation a minimum. However, in order to determine the amount of heat passing out through these blanketed sides, the blanketing material was covered with a sheet iron casing of black color. By observing the temperature of these insulated sides and covers it was possible to calculate the amount of heat lost.

The following tabulation gives the estimated loss by these blanketed areas in percentage of input loss on each tank for the tests conducted at Pittsfield.

Tank No.	Run No.	Estimated Loss by Blanketed Areas in Percentage of Input Loss
I	1	2.5
	2	2.2
	3	2.9
II	4	1.32
	5	0.75
	6	0.70
III	7	1.5
	8	1.8
	9	1.9

Since the above losses are so small, we can neglect these surfaces in calculating *R*. However, in making calculations for comparison of dissipated with input losses, these blanketed areas were considered.

The developed surfaces effective for convection were as follows:

Tank No. I (24 corrug. 9 in. in depth)	
Corr.—24 × 19.14 in. × $55\frac{3}{4}$ in.	25,600 sq. in.
Space above corr. not blanketed. . . .	500 sq. in.
	26,100 sq. in.

TABLE V

RECORD OF TESTS ON TANK No. 3 (PLAIN SURFACE)

Test	Volts	Amperes	WATTS (1) OBSERVED BY		TEMPERATURE IN DEG. CENT.					Observed Barometric Pressure in Inches Hg.	CALCULATED ALTITUDE IN FEET ABOVE		Humidity of Air in per cent of Saturation	Grains of Moisture Per Litre of Air	Date of Test
							AVERAGE MAX. OIL (3)								
								RISE ABOVE							
			Volts × Amp.	Wattmeter	Oil in Idle Tank	Avg. (2) Room	Actual	Oil in Idle Tank	Avg. Room		Sea Level	Pittsfield			
							Pittsfield								
7	110	3.28	348	347	29.4	29.9	45.5	16.1	15.6	28.8	1100	0	18	0.092	3- 2-15
8	110	9.79	1066	1063	30.1	30.2	72.1	42.0	41.9	29.2	700	0	17	0.092	3- 4-15
9	110	15.2	1658	1657	30.4	30.1	90.3	59.9	60.2	29.0	900	0	18	0.092	3- 6-15
							Boulder								
7	110	3.23	354	342	33.6	33.6	49.0	15.4	15.4	24.3	6000	4900	40	0.24	5-25-15
8	110	9.87	1073	1067	33.9	33.9	74.4	40.5	40.5	24.1	6300	5600	24	0.148	5-23-15
9	110	15.6	1703	1637	33.7	33.2	91.7	58.0	58.5	24.1	6300	5400	32	0.190	5-22-15
							Leadville								
7	110	3.26	346	313	29.5	30.0	46.5	17.0	16.5	20.4	11150	10050	18	0.105	7-29-15
8	110	3.78	1063	1066	29.8	30.0	73.5	43.7	43.5	20.4	11150	10450	19	0.113	7-28-15
9	110	15.2	1658	1667	30.0	30.1	92.0	62.9	62.8	20.5	11000	10100	19	0.105	7-27-15

(1) Less instrument losses.
(2) Avg. of 4 thermometers.
(3) Avg. of 3 thermometers.

Tank No. II (43 corrug. 3½ in. in depth)
Corr.—43×7.81 in.×51 in. . . . . 17,200 sq. in.
Plain bands at top and bottom
16 (29 in.+24.8 in. π) . . . . 1,710 sq. in.
18.910 sq. in.

Tank No.III (Plain sides)
23.25 in.×π×51.25 in. . . . . 3,750 sq. in.

The envelope surfaces (not blanketed) effective for radiation were:

Tank No. I—24×2.375 in.×62.5 in. . . 3,560 sq. in.
Tank No. II—67(4×7.24 in.+24.8 in.π) 7,160 sq. in.
Tank No. III—23.25 in.×π×51.25 in. 3,750 sq. in.

The values of *R* (envelop divided by developed surface) for the above tanks are as follows:

Tank No.	*R*
I	0.137
II	0.378
III	1.0

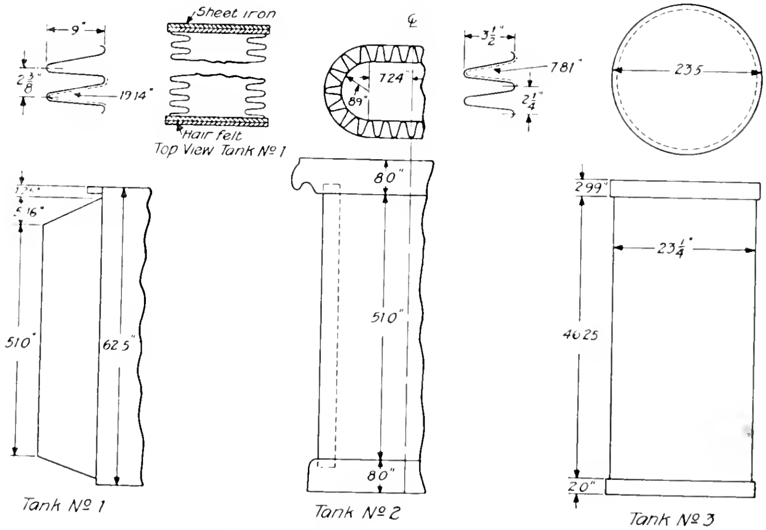

Fig. 8. Dimensions of Tanks 1, 2 and 3

Method of Loading

Each tank was fitted with tubes wound (non-inductively) with resistance wires of zero temperature coefficient, and so arranged that by connecting in parallel various combinations proper losses were supplied, at 110 volts pressure, to give three maximum oil rises ranging from about 20 to 60 deg. cent. These tubes were so grouped that for each test the loss was uniformly distributed over the tank. By means of a diagrammatic record the same grouping was used at Pittsfield, at Boulder and at Leadville. The tubes were supplied at Pittsfield and at Boulder with current from an a-c. generator, and at Leadville from an a-c. circuit of the Colorado Power Company. The regulation was within one per cent under all conditions. In fact, at Leadville the regulation was better than one per cent.

The instruments consisted of

One 150-volt voltmeter
One 5-ampere ammeter.
One 600-watt, 15-ampere, 150-volt wattmeter.
One 10:1 ratio current transformer.

The wattmeter was used to obtain a check on the input losses as found by the voltammeter method (volts × amperes). The same instruments were used at both Pittsfield and Leadville. At Boulder the meters were furnished by the University of Colorado. All the thermometers were of the mercury bulb type and only those reading accurately within ½ deg. cent. by calibration were used. The four used for room read in 1/5 deg. divisions. The three used for the maximum (top) oil read in ½ deg. divisions.

In order to obtain the temperature gradient along the surface of the tanks (for checking input against dissipated losses), thermometers were placed at short intervals from top to bottom on both the outside and inside bend of the corrugations. Small felt pads and putty were placed over the bulbs to protect them from the influence of the room. At Pittsfield thermocouples were welded to the tank surface adjoining five of these thermometer bulbs to obtain a check on the temperatures. The thermocouples and thermometers read together, in almost all cases, within 1 deg. cent., showing that the felt pads were not causing hot spots from a blanketing effect.

For each test the run was continued at least 8 or 10 and in some cases 15 hours after conditions became constant, and an average of these readings (observed hourly) was taken as the final value.

Summary

Within a limited range of temperature, namely from about 40 deg. to 80 deg. C. loss by radiation varies approximately as the 1.12 power of the temperature rise.

Loss by convection varies as the 1.25 power of the temperature rise. For self-cooled transformers having tanks with irregular contours, the total loss dissipated usually varies as the 1.25 power of the top oil rise. For transformers having smooth surfaces the loss varies close to the 1.15 power of the top oil rise.

Radiation is not affected by barometric pressure.

Convection varies approximately as the 0.5 power of barometric pressure. Or stated in another way, for a constant loss, the temperature rise varies inversely as the 0.4 power of the barometric pressure.

For a constant loss supplied to tanks having different shaped surfaces, the effect of altitude on the temperature rise of top oil is expressed by the formula;

$$\phi_2 = \frac{1.46A}{1 \times 1.3R}$$

in which

ϕ_2 = Increase in temperature rise of top oil* in percentage of rise at lower altitude.

A = Difference in altitude in thousands of feet.

$R = \dfrac{\text{Envelope area of tank surface.}}{\text{Developed area of tank surface.}}$

For transformers having 40 per cent core loss and 60 per cent copper loss (which is increased with an increase in temperature due to higher altitude) the effect is to increase the constant 1.46 in the above formula to 1.6 so that we have

$$\phi = \frac{1.6A}{1+1.3\ R}$$

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*Same correction, i.e., same number of degrees to be added to temperature rise of windings.

PRACTICAL EXPERIENCE IN THE OPERATION OF ELECTRICAL MACHINERY

PART XXI (NOS. 82 AND 83)

BY E. C. PARHAM

CONSTRUCTION DEPARTMENT, GENERAL ELECTRIC COMPANY

(82) ABNORMAL INTERNAL LOSSES

The total loss of a generator includes the core losses, the copper losses, the friction losses, and the windage losses. The core losses are composed of the hysteresis losses and the eddy current losses. The hysteresis loss depends on the quality of the iron involved and on the magnetic density at which it is worked; and the eddy current loss depends on the thickness of the laminations and on the effectiveness of the insulation between them. The poorer the quality of the iron and the greater the density of the magnetic lines, the greater will be the hysteresis loss. The thicker the laminations, the greater will be the eddy current loss; also, if the laminations should be burred over from one to another, as the result of mechanical injury, or of an electrical short-circuit, or of failure to remove the original burrs incident to punching, the effective thickness of the laminations is thereby increased and the eddy current loss will thereby be increased. The various losses can be separated but on a completed unit it is seldom necessary to do this.

In a certain instance, however, an approximate idea was wanted of the combined no-load losses of a large alternator. In order to get this, the machine was brought up to synchronism by means of the connected waterwheel, then it was thrown on the line, the water cut off, and the machine permitted to operate as a synchronous motor. Under this condition the power absorbed by it was measured by means of suitable meters and current and potential transformers. The result obtained should have represented the no-load losses at rated speed and specified field excitation, but it proved to be much greater than there was any reason to expect. As the calculated result was about ten times what it should have been, a misplaced decimal point or a current transformer or a potential transformer of the wrong ratio was suspected and these possibilities were carefully checked; but nothing irregular was found. As a check on the method used, the machine was then subjected to a retardation test: Briefly, this consists in bringing the machine up to a little above synchronous speed, then cutting off the driving power and permitting the rotor to slow under the influence of only the losses, and measuring the rate at which it slows. Normally, the rate of slowing of large rotors will be low; in this particular case, however, as soon as the driving power was removed, the rotor slowed as if a powerful brake was being applied.

The testers had thought that conditions warranted the assumption that there was no water in the penstock at the time of taking the readings; it developed, however, that there actually was considerable water and it was the rotating of the wheel in this water that produced the apparently abnormal internal losses.

(83) RESISTANCE AT NEGATIVE TEMPERATURE

Given the resistance R_o of a copper winding at a temperature of zero deg. C., the resistance R_t of that winding at a temperature of t deg. C. can be derived from the formula

$$R_t = R_o\ (1+0.0042\times t) \qquad (1)$$

This formula holds good for all values of t met with in ordinary electrical practice (that is, the formula fails for very wide and unlimited temperature ranges); therefore the resistance R_s corresponding to a temperature s would be

$$R_s = R_o\ (1+0.0042\times s) \qquad (2)$$

Usually the measured resistance R_t at a certain temperature t is known, and the resistance R_s at another temperature s is desired.

From equation (1),

$$R_o = \frac{R_t}{1+0.0042\times t}$$

From equation (2),

$$R_o = \frac{R_s}{1+0.0042\times s}$$

These two values of R_o must be equal, therefore,

$$\frac{R_s}{1+0.0042\ s} = \frac{R_t}{1+0.0042\ t}$$

Whence,

$$R_s = R_t \frac{1+0.0042\ s}{1+0.0042\ t}$$

This formula does not involve R_o; consequently, the resistance R_s at any temperature s can be derived from the measured resistance R_t corresponding to any other temperature t. It is assumed in the formula that the resistance is 100 per cent at zero deg. C.; therefore, the resistances corresponding to negative temperatures will be less than 100 per cent. It follows, then, that where negative temperatures are involved, due reversal of algebraic sign must be observed in using the formula, otherwise misleading results will be obtained. To illustrate:

In a locality where the temperature frequently dropped to −40 deg. C. a field coil was measured at −20 deg. C. and it was desired to know what would be the resistance at +20 deg. C. because that was the average room temperature during the season which the machine was operating. The resistance R_t as measured at −20 deg. C. was 91.6 ohms. The quantities to be incorporated in the formula were $t = -20$, $R_t = 91.6$, and $s = +20$. However, the negative sign of t was omitted, which gave

$$R_s = 91.6\times\frac{1+0.0042\times 20}{1+0.0042\times 20} = 91.6\times 1 = 91.6$$

ohms a result which indicated the −20-deg. resistance to be the same as the +20-deg. resistance. The operator realized the absurdity but as he did not know exactly how to modify the formula he brought the whole machine into a room which he then maintained as nearly as possible at +20 deg. all day. He then measured the resistance and got 107 ohms as the result, which was very close.

If in applying the formula, however, he should have modified it thus

$$R_s = 91.6\times\frac{1+0.0042\times 20}{1-0.0042\times 20} = \frac{1.084}{0.916}\times 91.6 = 108.4 \text{ ohms.}$$

OPERATION OF CURTIS STEAM TURBINES AND ALQUIST REDUCTION GEARS IN THE PROPULSION OF CARGO SHIPS

By W. J. Davis, Jr.

Pacific Coast Engineer, General Electric Company

The unprecedented demand for more cargo ships has vigorously raised the question as to what form the power plant shall take—reciprocating engines, direct-connected turbine, or turbine with reduction gears. In the following article certain limitations of the first two forms for cargo ships are pointed out, and the merits of the turbine reduction-gear drive are explained. The construction and arrangement of Curtis "ahead" and "astern" turbines with Alquist reduction gears is described and illustrated. Attention is particularly called to Tables I and II which are valuable in that they furnish directly comparable operating figures for two identical ships, one equipped with reciprocating engines and the other with a turbine and reduction gears.—Editor.

The present activity in American ship yards due to the extraordinary demand for cargo ships is of especial interest to engineers by reason of the large number of such ships which are to be driven by steam turbines with reduction gears. Although only a very few large steel freight carrying ships were being built in this country before the war, within the past two years the Pacific Coast yards alone have built, or contracted for, sixty-five steel ships of 8000 to 10,000 tons cargo capacity, of which more than fifty are to be equipped with geared turbines.

The first commercially successful steam turbine driven freighter, the S. S. "Vespasian," built in England and equipped with a 1000-h.p. Parsons turbine with reduction gear, was placed in service in 1909, but it was not until November, 1915, that the first American built turbine freighter was commissioned. It is evident, therefore, that the steam turbine is now making substantial and rapid progress in a field in which the reciprocating engine has for many years been strongly entrenched.

The distinction of being the first cargo ship built in the United States to be equipped with the new drive belongs to the S. S. "Pacific," built by the Union Iron Works Company at San Francisco, and propelled by a 2400-h.p. Curtis turbine with Alquist flexible gears, manufactured at the Schenectady Works of the General Electric Company.

For twenty years and more, there has been little progress made in the way of improvements in the operating characteristics of steam power plants used in driving slow and moderate speed merchant vessels, in spite of the fact that during this period the steam turbine has been developed to its present high state of perfection, resulting in extraordinary reductions in cost of producing power for manufacturing and industrial purposes.

The initial cost of a moderate sized electric power plant built today under normal conditions would be less than half the cost of an equivalent plant of fifteen or twenty years ago, the fuel consumption per hp-hr. would be reduced by 35 to 45 per cent and the total cost of generating power by 50 to 60 per cent. It is well known that these improvements in central station construction and operating costs have been due almost entirely to the use of high speed steam turbines direct connected to electric generators, by which combination it has been made possible to greatly increase the steam economy and reduce the weight and cost of the prime mover.

As an illustration of the gain in economy effected, it may be of interest to mention an installation with which the writer was connected in which eight 1500-kw. reciprocating engines direct connected to electric generators were replaced by a 12,000-kw. turbo-generator. Whereas it required twenty-four boilers to supply steam for the engines, only eleven of these boilers were sufficient to enable the turbine to carry the same load.

The steam turbine being essentially a high speed machine, while the propeller of a ship must run at a low speed, it is obvious that an attempt to connect the turbine directly to the propeller shaft must result in a compromise in which the efficiency of both turbine and propeller must be sacrificed. In the case of very high speed ships, such as destroyers, certain classes of passenger vessels, etc., it has been possible to make such a compromise which would possess certain advantages in the way of increased speed, reduction in vibration and saving in weight which would over-balance the failure to give the best attainable economy in fuel. These advantages, however, would not apply to slow speed freight carrying vessels, due to limitations of propeller speed.

As an example illustrating this condition, we may consider a freighter or tanker of 8000 to 10,000 tons capacity with a speed loaded of 11 knots. Such a ship will require about 2500 h.p. to drive it. The most economical speed for the propeller would be about 90 r.p.m., while that for the turbine would be not less than 3000 r.p.m. It is impracticable in this case to attempt a direct connection by increasing the speed of the propeller and reducing that of the turbine, as such an arrangement would prove so greatly inferior in economy to a reciprocating engine as to outweigh any claims for other possible advantages.

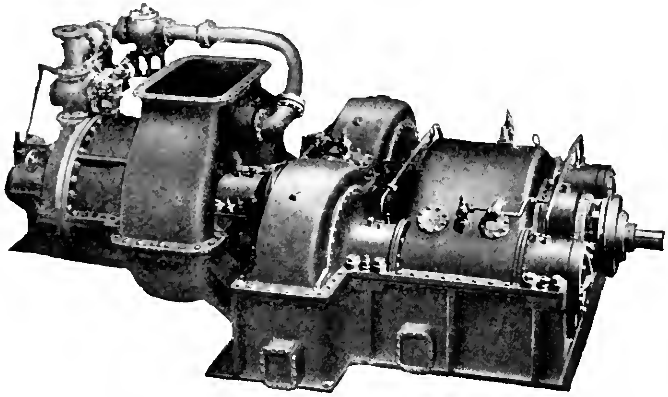


Fig. 1. Curtis Turbine Connected to Alquist One-plane Flexible Type Speed Reduction Gear for Ship Propulsion

It is this difficulty accompanied by lack of experience and knowledge in the design and construction of high speed gearing of capacity suitable for the purpose which has until recently prevented the general adoption of the steam turbine drive in the propulsion of cargo vessels.

For eight or ten years a number of able and experienced engineers have been studying the problem of designing and cutting helical gears which would operate successfully under the conditions of high speed and large powers required of them for marine work. Several successful designs of gears and gear cutting tools have been recently perfected and tried out in England on turbine propelled ships with excellent results in the way of economy and reliability.

The Alquist flexible gear as manufactured by the General Electric Company is particularly interesting amongst high speed reduction gears in its mechanical features. The wheels for this type of gear are made up of rolled steel plates or disks rigidly bolted together near the center and keyed to the shaft. Each disk is reduced in thickness between the hub and the rim sufficiently to give a small amount of flexibility in an axial direction, and to permit this movement a clearance of about ten thousandths of an inch is provided between the disks at their rims. As the gears are of the double helical type, this construction insures equal distribution of pressure along the face of the teeth. It will readily be seen that if the pressure applied by a pinion tooth at any point should exceed the normal pressure, the axial component will cause a slight axial flexure of the disk. Experience has shown that changes in alignment or slight inaccuracies in tooth cutting or assembly of the gears which would cause objectionable noise, loss in efficiency, high temperature and excessive wear of the teeth of solid gears have little effect on the operation of the flexible disk type.

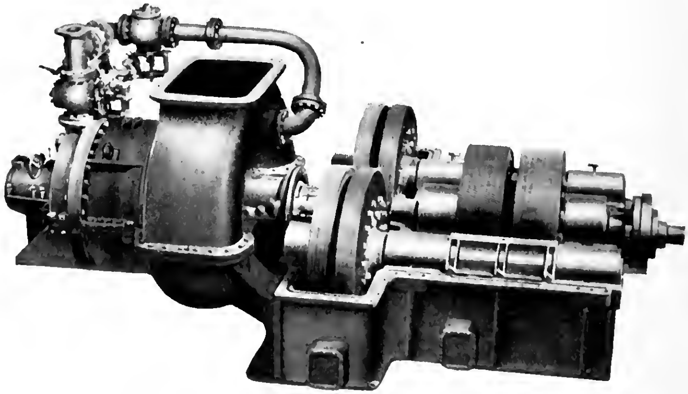


Fig. 2. Top Half of Gear Casing Removed, Showing Gears

Accurate measurements of the teeth of the Alquist reduction gears on the S. S. "Pacific" show the wear of the flexible gear teeth to be almost negligible and that the life of the gears may be expected to be at least equal to that of the ship.

An interesting commercial feature of the present abnormal demand and production of steel cargo vessels in this country is the uniformity in capacity, speed and power requirements. This has made it possible for the ship yards to standardize in the matter of hull construction and power plant requirements. Fully ninety per cent of the turbine ships completed or under construction by the Pacific Coast yards are provided with turbines of the same type and practically of the same size, namely, 2400 to 2600 h.p. A description of one may therefore be held to apply to all.

The ahead turbine is designed to run at 3380 r.p.m. It is of the Curtis type of impulse turbine as developed by the General Electric Company and consists of five stages, the first having two rows of buckets mounted on a single wheel and each of the succeeding stages a single row of buckets. The speed of the turbine is controlled by means of a lever operated balanced throttle valve in the main steam line, but in order to overcome the loss in efficiency due to throttling when running at reduced speed, two hand valves are provided which block off a number of the first stage nozzle sections. By this means it is possible to obtain 58, 75, 83 and 100 per cent of full power with full steam pressure at the nozzles, resulting in a net saving of three to five per cent in fuel when it is necessary to run the ship at reduced speed in a rough sea.

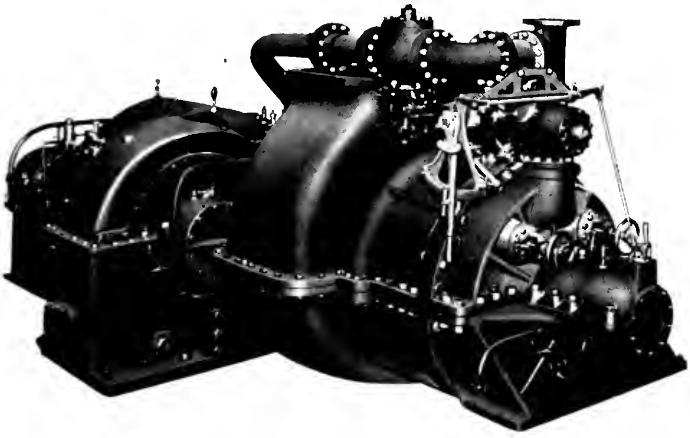


Fig. 3. End View of Set, Showing Control Mechanism

The astern turbine has two stages of similar construction but of smaller diameter, and is mounted on the same shaft and in the same casing as the ahead turbine, both having a common exhaust. Steam is admitted by a balanced valve operated by the same lever controlling the admission valve of the ahead turbine. When the ship is running forward the wheels of the astern turbine revolve in a vacuum and therefore consume but little power.

Fig. 4. Intermediate Shaft of Reduction Gear

The reversing turbine will develop two-thirds torque at two-thirds speed with a total steam flow equal to that of the forward turbine at rated capacity. The nozzle area, however, is greater than that of the ahead turbine, thus permitting the reversing power to be considerably increased if desired.

The speed of the propeller being 90 revolutions per minute and the turbine 3380, it is necessary to obtain a gear reduction of 37.5. This is accomplished by means of a double reduction, the high speed gearing having a ratio of 7.36 and the low speed 5.10.

The reduction gear is of the "one-plane" type, that is, the axes of the high and low speed pinion and gear shafts lie in the same horizontal plane. This arrangement reduces the head room, simplifies lubrication and facilitates inspection and accessibility to all parts.

Power is transmitted through the high speed or driving pinion to two gears, one on each side, and thence through the two low speed pinions to the low speed gear. Rigid bearings are used throughout for the gears and pinions. This division of power between two low speed pinions possesses several obvious advantages, such as saving in longitudinal space required, weight of parts, width of gear teeth and size of bearings.

The turbine shaft is connected to the high speed pinion shaft by means of a slip coupling which prevents any part of the propeller thrust being transmitted to the turbine. The high speed gears and pinion and low speed pinions are therefore free to adjust themselves to the position of the low speed gear which is coupled solidly to the thrust shaft. The position of the turbine wheels with respect to their nozzles is fixed by a small adjustable thrust bearing on the turbine shaft.

It is highly desirable on the score of simplicity to be able to use the same grade of oil for both the turbine bearings and the reduction gear, thus preventing duplication of oil pumps, strainers, coolers, storage tanks, settling tanks, etc. It has been possible to accomplish this by the use of a moderate tooth angle and by reason of the flexible disk construction of the gears. Several grades of oil were tried out on the S .S. "Davanger," the best results being obtained with a medium heavy oil having a viscosity of 260 (Saybolt) at 100 deg. F. This oil proved to be about

TABLE I

S. S. "LOS ANGELES"

Records of Fuel Consumption for Nine Voyages—Average Gravity of Fuel Oil 16 Deg. Baumé at 60 Deg. F. Average Steam Pressure Boilers 205 Lb. Gauge. Average Superheat 29 Deg. F.

Voyage	Date	Total Distance in Knots	Ave. Speed in Knots per Hour	Total Barrels Delivered	Name of Port	Total Fuel Used Steaming on Voyage in Bbls.	Total Bbls. per Knot Steaming	Total Bbls. Used in Port	Total Bbls. per Knot Steaming and in Port	Pumping in Port Hours	Bbls. Discharged per Hour	Cost of Fuel at 80c. per Bbl. per Knot Steaming and in Port
1	Apr. 9 to Apr. 15	423	9.4	67,074	Oleum	556	1.31	164	1.70	64½	1039	$1.36
2	Apr. 16 to Apr. 25	1845	10.13	74,739	Vancouver	1656	0.897	218	1.01	33¾	2214	0.80-8/10
3	Apr. 27 to May 25	6549	10.22	73,734	Panama	5579	0.851	169	0.877	46¾	1577	0.70-1/10
4	May 26 to May 29	220	9.1	72,592	Oleum	221	1.00	123	1.56	41	1770	1.24
5	May 30 to June 27	6348	10.60	72,538	Balboa	5462	0.860	159	0.885	35	2072	0.70-8/10
6	June 29 to Aug. 7	9151	10.24	70,959	Antofagasta, Chile	8293	0.906	186	0.926	52½	1351	0.74-1/10
7	Aug. 9 to Aug. 17	450	10.7	75,761	Oleum	375	0.833	167	1.20	42	1803	0.96-3/10
8	Aug. 19 to Sept. 27	9086.6	10.76	70,214	Tocopilla, Chile	7896	0.868	208	0.891	82	856	0.71-2/10
9	Sept. 28 to Oct. 2	450	10.9	71,149	Oleum	365	0.811	134	1.10	41¾	1704	0.88
Total		34523		648,760		30103		1528		439¼		
Ave.			10.22				0.881		0.936		1598	

right for the dual purpose for which it was used, being light enough to flow freely through the turbine bearings and heavy enough to give sufficient cushioning effect at the face of the gear teeth. The smooth and quiet running of the "Davanger" gears was remarked upon repeatedly by engineers and others present during the trial trip.

Oil for the turbine bearings and gears is circulated by means of steam-driven pumps which take the oil from the main tank and force it first through a strainer and then through a cooler before it passes through the spray nozzles supplying oil to the gears, or is delivered to the turbine bearings and the various bearings of the gears and pinions. A settling tank is also provided for removing any water which may get into the oiling system.

Economy

The engine room logs of the Union Oil Company's tank steamers "La Brea" and "Los Angeles" afford an unusual and valuable comparison in fuel consumption

TABLE II

S. S. "LA BREA"

Records of Fuel Consumption for Nine Voyages—Average Gravity of Fuel Oil 16 Deg. Baumé at 60 Deg. F. Average Steam Pressure Boilers 200 Lb. Gauge. Average Superheat 37 Deg. F.

Voyage	Date	Total Distance in Knots	Ave. Speed in Knots per Hour	Total Barrels Delivered	Name of Port	Total Fuel Used Steaming on Voyage in Bbls.	Total Bbls. per Knot Steaming	Total Bbls. Used in Port	Total Bbls per Knot Steaming and in Port	Pumping Time in Port Hours	Bbls. Discharged per Hour	Cost of Fuel at 80c. per Bbl. per Knot Steaming and in Port
1	Mar. 9 to Mar. 15	650	9.5	62,578	Oleum	574	0.883	142	1.10	36½	1714	$0.88c.
2	Mar. 15 to Mar. 26	2037	11.33	73,600	Seattle	1459	0.716	152	0.790	37½	1962	0.63-2/10
3	Mar. 28 to Apr. 6	2108	11.01	64,676 8,642	Vancouver Seattle	1584	0.751	155	0.824	26 13½	2487 640	0.65-9/10
4	Apr. 8 to May 16	9254.5	10.97	52,109 19,045	Taltal Antofagasta, Chile	6896	0.745	117	0.757	33¾ 15½	1544 1228	0.60-5/10
5	May 17 to May 23	450	11.2	77,292	Oleum	321	0.713	134	1.01	39	1980	0.80-8/10
6	May 24 to July 1	9196.5	10.65	71,824	Antofagasta, Chile	6900	0.750	109	0.762	25	2660	0.60-9/10
7	July 2 to Aug. 9	9284	10.39	71,677	Antofagasta, Chile	6875	0.740	107	0.752	31	2312	0.60-1/10
8	Aug. 10 to Aug. 19	425	10.77	73,620	Oleum	350	0.823	114	1.09	28	2629	0.87-3/10
9	Aug. 20 to Sept. 26	9021	10.68	71,160	Antofagasta, Chile	6720	0.744	83	0.754	26¼	2710	0.60-3/10
Total		42426		646,223		31,679		1113		312		
Ave.			10.72				0.747		0.773		1987	

between reciprocating engines and Curtis turbines with reduction gears. These are sister ships, both built by the Union Iron Works Company in 1916, and both operating in the same character of service and under similar conditions. The ships differ from each other only in character of the propelling machinery and the cargo pumping systems. "Los Angeles" is driven by a triple expansion engine with a propeller speed of 65 r.p.m. and has the usual type of centralized steam pumping plant for discharging her cargo of oil. The propelling machinery of "La Brea" consists of a 2600 brake horse power Curtis turbine with Alquist reduction gears giving 90 revolutions at the propeller. She is also fitted with a unique and highly efficient cargo pumping system originated by Mr. O. B. Kibele, Superintendent of Transportation of the Union Oil Company, in which a separate electric motor driven pump is provided for each compartment, power being supplied to the motors from a 300-kw. 60-cycle alternating-current Curtis turbo-generator located in the engine room.

Some of the important dimensions and data applying to the hull and propelling machinery of "La Brea" are as follows:

Hull

Length overall	442 ft.
Length between perpendiculars	435 ft.
Breadth, extreme	56 ft.
Depth, moulded	33 ft. 6 in.
Dead weight, carrying capacity	10,335 tons
On mean draught of	27 ft.
Oil tank capacity	70,000 bbls.
Speed with 10,000 tons dead weight	11 knots

Propeller

Diameter	16 ft. 6 in.
Pitch	14 ft.
Revolutions per minute	90

Power Plant

Turbine rating	2600 h.p.
Number boilers (Scotch type)	3
Heating surface, boilers	2685 sq. ft.
Working pressure	210 lb. gauge
Superheat	50 deg. F.
Fuel, oil—mechanical burners	
Condenser cooling surface	4000 sq. ft.
Circulating water, gallons per minute	4000

The data given in Tables I and II show the fuel consumption of "Los Angeles" and "La Brea" for nine typical voyages each.

It will be seen from the results shown that the increase in fuel consumption of the reciprocating engined ship "Los Angeles" over that of the steam turbined ship "La Brea" under operating conditions as found is:

While steaming	17.9 per cent
While steaming and in port	21.1 per cent

The above comparison does not take into account the fact that the average speed of "La Brea" is one-half knot better than "Los Angeles." If the speeds had been equal in each case, the advantage in favor of "La Brea" would have been not less than 20 per cent while steaming and 23 per cent total while steaming and in port.

When we consider that the engine of S. S. "Los Angeles" was specially designed for high economy, the performance of "La Brea" is seen to be such as to definitely establish the superiority of the geared turbine drive. With further improvements in the way of increased steam pressures, higher superheats and power plant design and equipment, there are still further possibilities in reduced operating costs of steamships driven by geared turbines which may be confidently expected in the future.

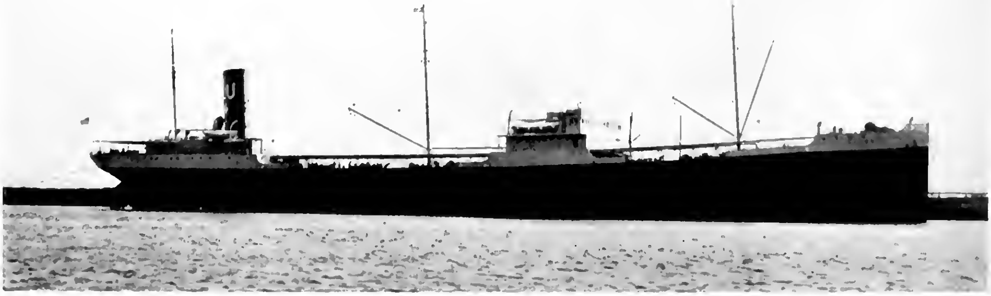


Fig. 5. Steamship "La Brea" Powered with 2600-h.p. Curtis Turbine Driving through Alquist Reduction Gear

INDUSTRIAL CONTROL

PART VI

MAGNETIC CONTROL FOR MISCELLANEOUS APPARATUS

By C. W. Gammons

Industrial Control Department, General Electric Company

This installment of the Industrial Control series is descriptive of those applications of magnetic control apparatus which have been thoroughly standardized. Many photographs and complementary wiring diagrams of the various types of apparatus are included. The descriptions of the parts of the equipments are complete and the explanations of their sometimes intricate functions are remarkably lucid. In particular, the article treats of starters for squirrel-cage, form-wound, single-phase, and direct-current motors, and equipments for master switches, valve control, arc furnace control, and arc welding control.—Editor.

General

Previous articles in this series on Industrial Control have discussed the application of magnetic control apparatus to motor drive in certain special industries. These industries, in most cases, require drives of such a nature that magnetic control is a necessity for one or more of the following reasons: first, because manual controllers would be of such size that excessive physical exertion would be required in their operation; second, because the high operating voltages used require the removal of control apparatus bearing line potential to a safe distance from the operator; third, because the complicated nature of the control requires that it be automatic, removing from the operator all care in connection with the sequence of operations; and, fourth, because the continuous operation and value of the machinery require the application of limit switches, speed controlling devices, and other safety features, which are so easily adapted to magnetic control apparatus.

An acquaintance with control conditions in connection with motor drives where the apparatus involved is usually not so large or so complicated, as that discussed in the previous articles, shows that even in connection with small motors used in comparatively simple operations, one or more of the advantages previously noted make magnetic control desirable. It is the purpose of the present article to present a few examples of the lines of control, more or less standardized, which have been developed in connection with some of the general and a few of the special applications of electrical apparatus.

Starters for Squirrel-cage Motors

The motor in most general use today is the polyphase squirrel-cage induction motor. This wide use is due not only to its operating characteristics, which make it applicable to practically all kinds of industrial drive, but also to its simplicity and ruggedness, which commend it for use where experienced electrical attendants are not available. Although mechanically strong enough to withstand the shock caused by being connected directly to the full voltage of the supply mains, where the heavy inrush current and the consequent disturbance upon the lines are detrimental, it is imperative that some starting device be used to reduce starting peaks. The most common method is to connect the motor to a supply of low voltage, from 50 to 70 per cent of normal, obtained from a transformer. To automatically start such a motor, making use of an auto-transformer for obtaining starting voltage, an automatic compensator panel has been standardized. This is shown in Fig. 1 and consists of a two-pole line contactor, a current-limit relay, a four-pole starting contactor, an autotransformer, and the necessary motor and control circuits.

The current-limit relay used on the compensator panel consists of a shunt coil and a series coil, the latter being connected in the motor line during starting. The plungers of these two coils rest one upon each end of a lever pivoted at its center. They are so proportioned that under normal conditions, with both coils de-energized, the plunger of the series coil is held up. This plunger acts upon a contact lever above the relay which normally makes contact with the upper of two studs, but which makes contact with the lower stud when the series coil plunger is allowed to drop. Below the relay is an auxiliary contact, closed when the shunt coil of the relay is energized.

The wiring of the panel is shown in Fig. 2. When the control switch is closed, a circuit is made from the line through the control switch, through the contact lever of the current-limit relay to the upper stud, through the operating coil of the starting contactor and a normally closed interlock on the line

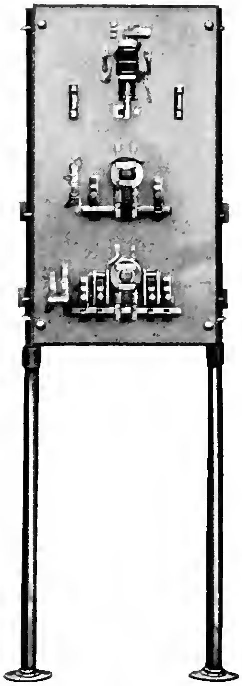


Fig. 1. Automatic Compensator Panel for Squirrel-cage Type Motors Drawing 75 Amperes or Less

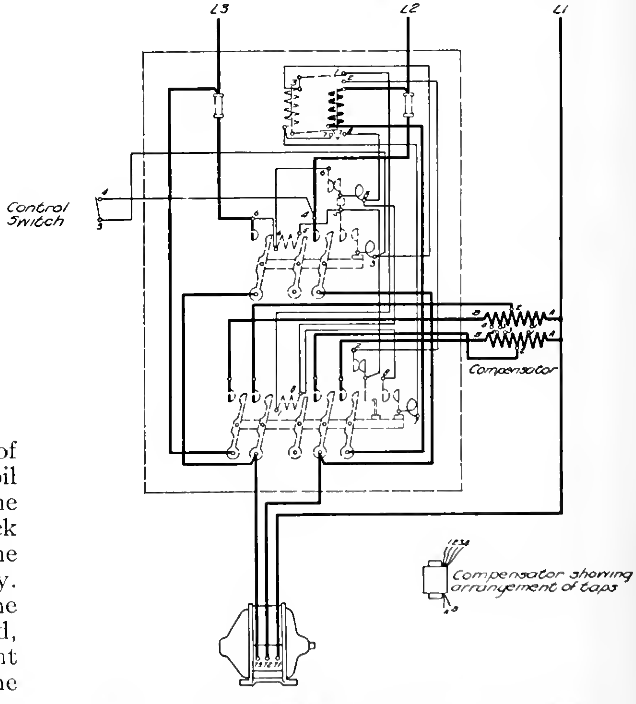


Fig. 2. Connection Diagram of the Automatic Compensator Panel shown in Fig. 1

contactor to the other side of the line, thus closing the starting contactor. This connects the supply mains to the compensator and the low-voltage taps to the motor, thus starting the motor. The starting contactor, upon closing, closes its normally open interlock, establishing a circuit from one side of the line through the control switch, shunt coil of the current-limit relay, interlock on the starting contactor, normally closed interlock on the line contactor, to the other side of the line, energizing the shunt coil of the relay. When the shunt coil plunger picks up, the auxiliary interlock below the relay is closed, establishing a holding circuit for the shunt coil that is independent of the interlock on the starting contactor but which does pass through the normally closed interlock on the line contactor. With the shunt coil of the relay energized, the plunger of the series coil is free to fall as soon as the starting current of the motor, which passes through the coil, has decreased to the predetermined value. This is usually at about twenty-five per cent above normal full-load current. When the series coil plunger drops, the contact lever at the top of the relay drops, opening the energizing circuit of the starting contactor and thus causing it to drop out. A circuit is then established from one side of the line through the control switch, through the lower contact stud of the contact lever of the current-limit relay, through the normally closed interlock on the starting contactor and the normally closed interlock on the line contactor to the other side of the line, energizing the line contactor and connecting full voltage to the motor. The line contactor on closing establishes an energizing circuit through its own normally open interlock, and at the same time opens the circuit energizing the shunt coil of the relay. It will be noted that as the energizing circuit, which causes the line contactor to pick up, passes through a normally closed interlock on the starting contactor, it is necessary for the latter to open before the line contactor can close, thus making it impossible to connect both low voltage and line voltage to the motor at the same time. As the energizing circuit for the line contactor, in the normal operating condition of the panel, is directly through the control switch, it is only necessary to open that switch to open the line contactor and thus disconnect the motor from the line.

A less efficient method of starting a squirrel-cage motor, but one which is satisfactory for motors of small size where low starting torque is permissible and high starting current with consequent line distrubance are not detrimental, makes use of resistance inserted in the lines to the motor to reduce the starting current. The panel designed to make use of this method is shown in Fig. 3, and its connections in Fig. 4. It consists of a two-pole line contactor, the necessary resistor, and a three-pole contactor for short circuiting the resistor. The closing of the line contactor connects the motor to the line through the resistor and the closing of the three-pole contactor connects the motor directly to the line voltage. Automatic acceleration is obtained by making use of a time-limit dashpot, the plunger of which carries an interlock disk. This time-limit dashpot is used in connection with the line contactor and is so arranged that when the contactor is open the plunger is held up. When the contactor closes the plunger is free to fall and after a predetermined time, depending upon the rate at which air is allowed to flow into the dashpot, the interlock disk makes contact across two studs in the energizing circuit of the three-pole contactor thus closing that contactor.

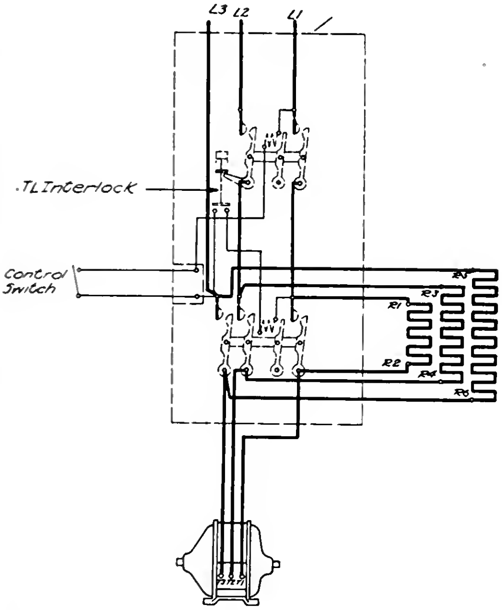


Fig. 4. Connection Diagram of the Primary Resistance Starter shown in Fig. 3

Starters for Form-wound Induction Motors

Where the wound-rotor type of induction motor is used, smooth acceleration in starting is obtained by connecting a resistor into the rotor circuit of the motor through slip-rings and then by cutting out various sections of this resistor as the motor comes up to speed. The panel designed to start a motor by this method consists of a line contactor, a resistor, a number of accelerating contactors so connected that they short circuit the sections of the resistor when closed, and one or more current-limit relays. Fig. 5 illustrates such a panel. The current-limit relay used on this type of panel differs slightly from that used on the compensator panel in that the contact lever is replaced by a contact disk held open by the series-coil plunger when that plunger is held up, and which makes contact across two studs when the plunger is allowed to fall. The auxiliary contact below the relay is removed also.

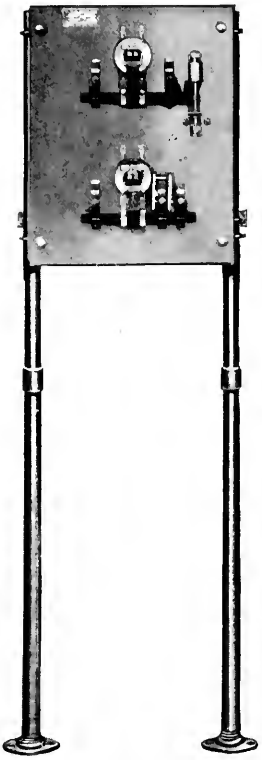


Fig. 3. Primary Resistance Starting Panel for Squirrel-cage Induction Motors

When the line contactor of this panel is closed by completing its energizing circuit through a control switch, (see Fig. 6) it closes a normally open interlock. This interlock closes the control circuit of the first accelerating contactor through the shunt coil of one of the current-limit relays. The coils of the relay and contactor are so proportioned that, when connected in series, the shunt coil of the relay will receive sufficient current to lift its plunger but the coil of the contactor will not receive sufficient current to pull in its armature. With the shunt-coil plunger lifted, the series-coil plunger is free to fall as soon as the line current, which passes through the series coil, drops to the predetermined value. The interlock carried by this plunger then short circuits the shunt coil of the relay, thus placing the coil of the contactor directly across the line and closing the contactor. A normally open disk on the contactor establishes a holding circuit for the contactor independent of the current-limit relay. The second accelerating contactor is then connected across the line through the shunt coil of the second current-limit relay and through a normally open interlock on the first accelerating contactor. When the line current again reaches the predetermined value for dropping the series coil of the relay, the second contactor is closed, forming its own holding circuit as was done by the first contactor. The third accelerating contactor is then connected across the line through a normally open disk on the second contactor, this time again making use of the first current-limit relay and closing when the line current reaches the setting value. This same closing process follows for all the following accelerating contactors, each being closed through an interlock disk on the preceding contactor and making use alternately of the two current-limit relays. As the magnetizing, current taken by the coils of such a panel reaches a considerable value, the interlocking system is usually so arranged that all but the line contactor and the last accelerating contactor, which short circuits the rotor slip rings, are de-energized when the last contactor is closed.

Panels for this type of service are usually provided with overload protection in the form of inverse-time-limit overload relays in two of the lines of a three-phase circuit or one in each phase of a two-phase circuit. These relays consist of a coil, wired in series with the motor circuit, and a plunger at the lower end of which is fitted a piston travelling in a dashpot of oil. A varying time-element is obtained

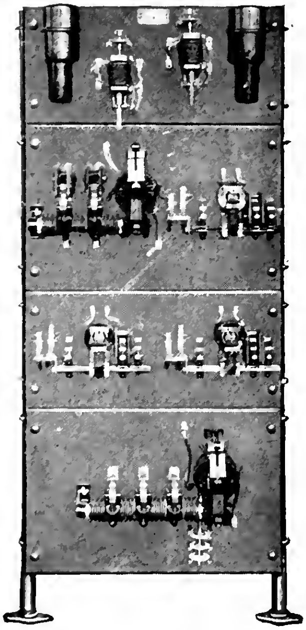
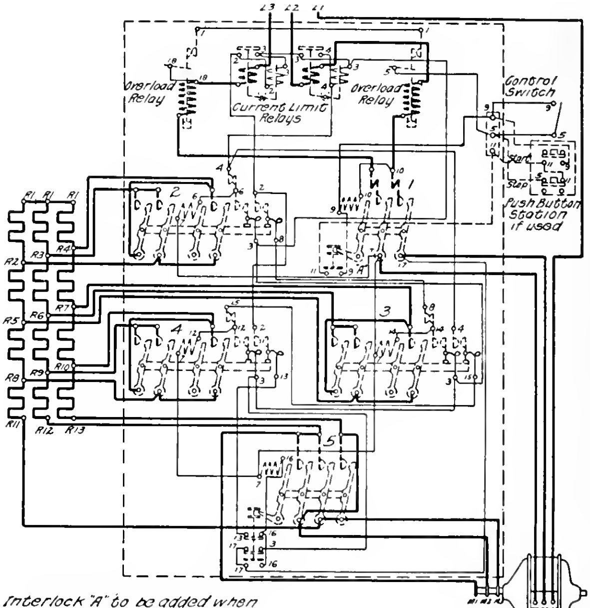


Fig. 5. Current-limit Starting Panel for an Induction Motor with Form-wound Rotor



Interlock "A" to be added when Push Button control is used

Fig. 6. Connection Diagram of the Current-limit Starting Panel shown in Fig. 5

by adjusting the size of opening in the piston through which the oil must pass. The contact element is fitted with a toggle joint which gives a snap-action break. This contact element is wired into the control circuit of the line contactor. When the magnetizing current of the line contactor control circuit is too great, a small auxiliary contactor is used. The fingers of this auxiliary contactor then operate the control circuit of the panel, the energizing coil of the contactor being wired across the line through the control switch and contact elements of the overload relays.

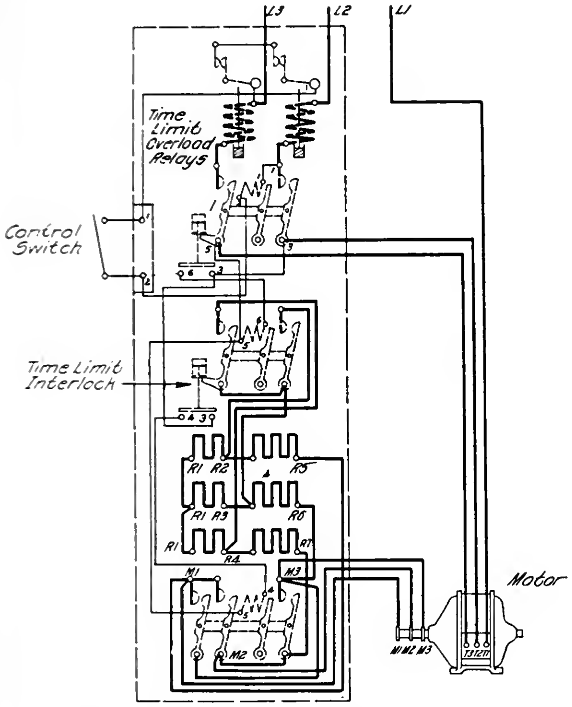


Fig. 8. Connection Diagram of the Time-limit Starting Panel shown in Fig. 7.

Under certain conditions, as on a circuit where the voltage is liable to vary considerably, or where motor starting conditions are not always the same, it is sometimes desirable to have a starting panel of more positive action, that is, one on which the contactors will close in their proper order regardless of external conditions. For this service a time-limit starter is provided, making use of a dashpot interlock as on the panels for starting the squirrel-cage motor through primary resistance. A panel of this type and its connections appear in Figs. 7 and 8. It will be seen that this type of panel is much simpler than that using current-limit relays, as it does away with the complicated interlocking system.

Starter for Single-phase Motors

The panel for starting the single-phase commutator type motor is essentially like that designed for the time-limit primary-resistance starters for squirrel-cage motors. A typical panel and its connections are shown in Figs. 9 and 10. A line contactor is provided, fitted with a dashpot, time-limit interlock, and the motor is started with resistance in the line when this contactor is closed. A second contactor, its energizing circuit being made through the disk of the time-limit interlock, short circuits the starting resistor, connecting the motor directly to line voltage. The standard control panel for this line of work is provided with an inverse-time-limit relay also.

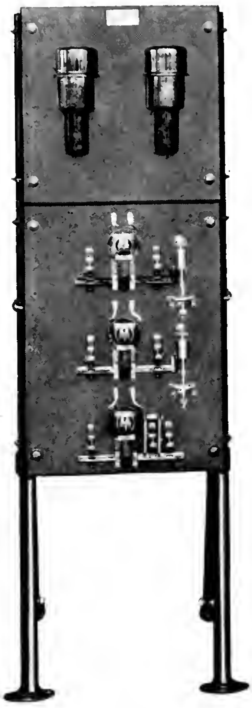


Fig. 7. Time-limit Starting Panel for a Single-phase Motor

Starters for Direct-current Motors

For starting small direct-current motors, shunt or compound wound, the simplest form of control is that which makes use of the counter-electromotive force generated by the motor for closing the accelerating contactor. Figs. 11 and 12 illustrate a panel of this type and its wiring. The coil of this contactor is connected directly across the armature of the motor, closing when the motor has reached the proper speed and cutting out the starting resistor. This type of starter is not recommended, however, for motors of large size or where the starting voltage is liable to vary to any great extent.

For the larger size direct-current motor, shunt, series, or compound wound, the simplest starter makes use of the series contactor (see Fig. 13). The energizing coil of this type of contactor is inserted directly in the starting line, receiving the full starting current of the motor. It is so designed that when it receives an inrush current its armature is locked out magnetically, but when the current is reduced to the proper value the armature is pulled in. The motor starting current with a panel using these contactors passes through the line contactor, motor resistor, and the coil of the first accelerating contactor. When the current has decreased to the proper value, the accelerating contactor closes, cutting out one step of the resistor and establishing a circuit for the motor current through the coil and tips of the first accelerating contactor and through the coil of the second accelerating contactor. This in turn closes, short circuiting the second resistor step and establishing a circuit through the coil of the third accelerating contactor. The last accelerating contactor is provided with a shunt holding coil so that

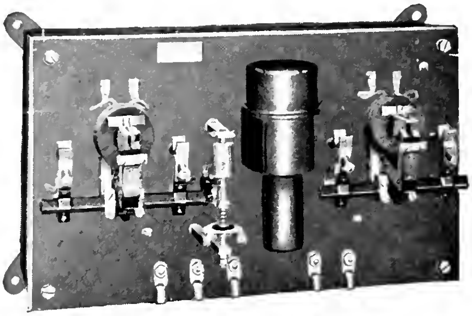


Fig. 9. Time-limit Starter for a Single-phase Motor

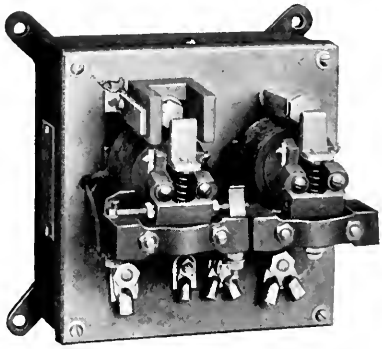


Fig. 11. Counter-electromotive-force Starter

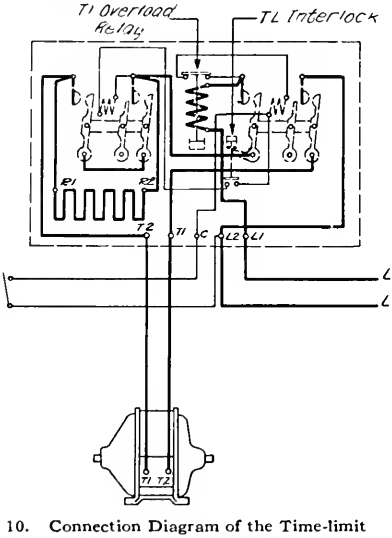


Fig. 10. Connection Diagram of the Time-limit Starter shown in Fig. 9

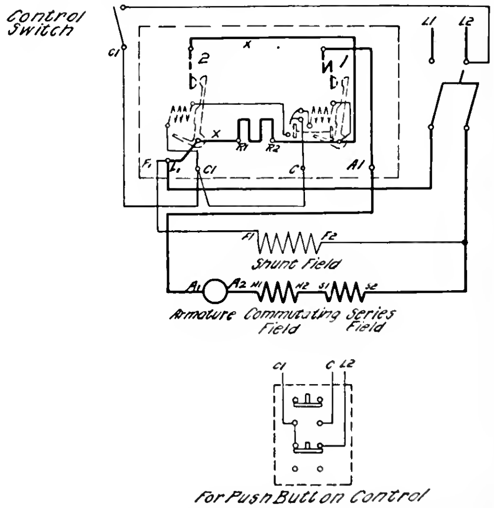


Fig. 12. Connnection Diagram of the Counter-electromotive-force Starter shown in Fig. 11

the contactor armature is held in regardless of varying line current, due to varying load conditions. The wiring is so arranged that each accelerating contactor, upon closing, short circuits not only a section of the resistor, but also the series coil of the preceding accelerating contactor. Thus all contactors, excepting the line contactors and the final accelerating contactor, are de-energized under normal operating conditions.

For direct-current motors of large size, or wherever regulating points are required, the standard starting panel makes use throughout of contactors having shunt-wound energizing coils. In order to obtain automatic acceleration with such a panel (Fig. 14), current-limit interlocks are used. This type of interlock is essentially a current-limit relay, consisting of a coil wound to be inserted in series in the motor line and an adjustable plunger carrying an interlock disk. The frame of this interlock is so attached to the frame of the contactor that the plunger is held open mechanically by the contactor armature when the latter is open, and after the contactor is closed is held up magnetically until the line current has dropped to the proper value. As each interlock drops it completes the circuit energizing the next accelerating contactor. As there is no current flowing when the line contactors close, and the accelerating interlock used in connection with them would be free to fall with the closing armature, the first accelerating interlock is fitted with a shunt-wound instead of a series-wound coil. The line contactors are then so interlocked electrically that the contactor carrying the accelerating interlock cannot close until the other line contactor has closed, and the latter completes a circuit placing the relay coil across the line. After both line contactors are closed the interlock coil receives the voltage across a portion of the motor starting resistor, and when that voltage has decreased to the proper value the plunger is free to fall, closing the first accelerating contactor.

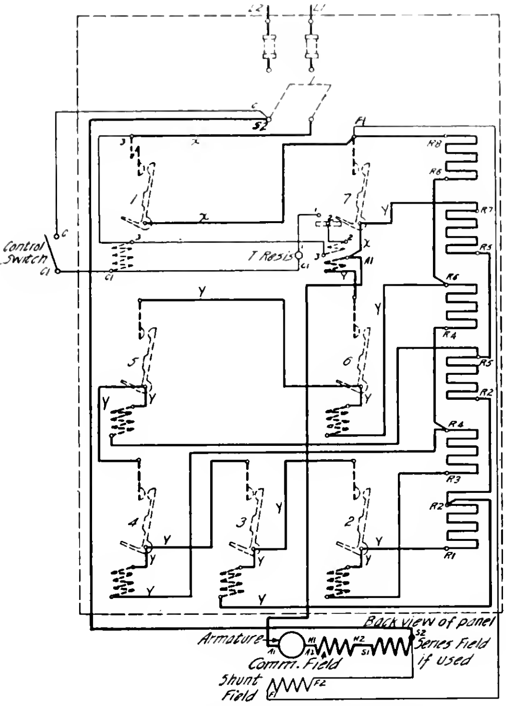


Fig. 13. Connection Diagram of a Panel Using Series Type Contactors

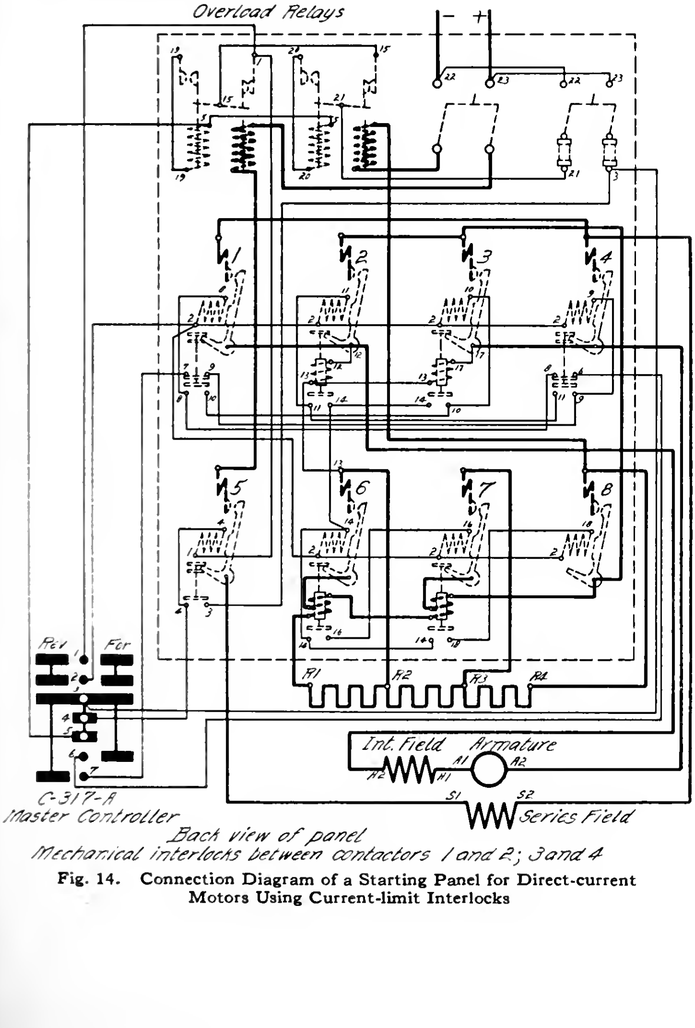


Fig. 14. Connection Diagram of a Starting Panel for Direct-current Motors Using Current-limit Interlocks

Master Switches

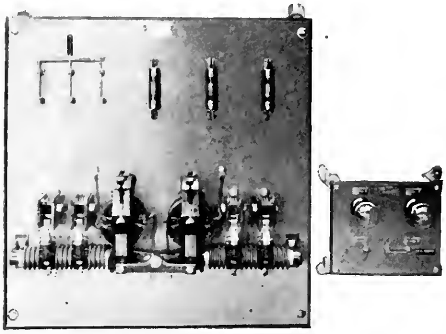


Fig. 15. Valve Control Panel

In connection with the previously described types of panels, there are several different types of master switches which may be used. The simplest form makes use of a single-pole switch inserted in the circuit energizing the contactor coils. With such control the panel is placed in operation by simply closing the switch and the contactors remain closed as long as the switch is closed. A more convenient form of hand-operated master switch, and one which provides several advantageous features, is the push-button control. The push-button station is safer than the knife switch, as all live parts are covered. The station most used contains a "start" button and a "stop" button. The "start" button closes the control circuit of the panel starting the motor. The "stop" button having normally closed contacts provides a holding circuit for the panel control, this circuit passing through a normally open interlock on the line contactors on the panel; so the motor may be stopped by pushing this button. In addition to the convenience of this method of control, there are two advantages. First, by connecting all circuits to the "start" buttons in multiple and by connecting the holding circuit through all "stop" buttons in series, several control stations may be used, advantageously placed about the machine being driven. As a second advantage, the push-button station provides a no-voltage protection since the holding circuit is broken in the normally open interlock on the line contactor if the latter opens due to failure of voltage, and the pick-up circuit placing the panel in operation again can be established, after the return of voltage, only by pressing the "start" button. Where several stations are provided in connection with one machine, an additional safety feature may be provided by using a "safe-run" button. This consists of a flush-type snap-switch with a circuit opened when the "safe" button is pressed. With such a station, the circuit being wired in series with the circuit through the "stop" buttons, any operator can stop the motor to make adjustments about the machine and may be sure that the motor cannot be started from any other station until the "run" button at his own station has been pressed.

In connection with some machines, it is desirable to have the control entirely independent of any operator. This is true in compressor systems, where it is necessary to hold air pressure between certain limits; and it is true in connection with pumps where water level is to be kept below a certain point in sumps, or above a given point in reservoirs. In connection with air compressors a pressure governor panel is used, consisting of a governor and a control relay or contactor, the latter replacing the knife switch used in hand control. In connection with pumps a float switch is used, replacing the knife switch control.

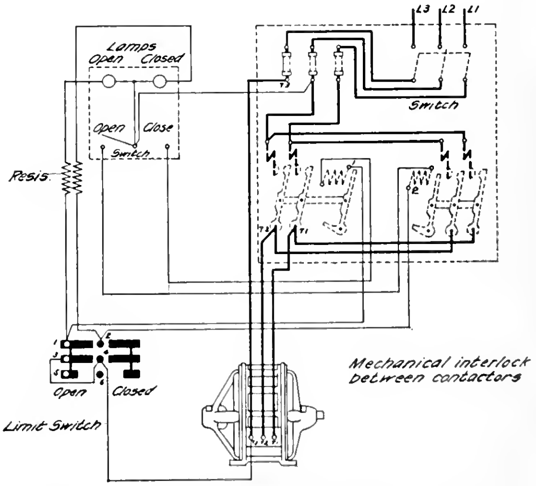


Fig. 16. Connection Diagram of the Valve Control Panel Shown in Fig. 15

The panels which have been shown are not designed for use in connection with any special industry but are for use with their respective motors wherever those motors may be used. Any variations from standard, in order to make them more especially applicable to a given service, are usually minor variations, as current-limit relay settings, contactor closing settings, or variations in values of resistor steps. There are, however, certain lines of panels designed for specific industries and so far different from the standard line of starters that they are not applicable for use with any other industry.

Valve Control

Among the special lines of panels is one developed for use with valve operating motors. A motor for this service is required to exert maximum torque at starting to unseat the valve, and must therefore be designed to be thrown directly on the line. The control requirements are, therefore, very simple, as no provision need be made for accelerating contactors. With small motors the control panel frequently used consists of a double-throw line switch only. More frequently, however, it is desired to have the control remote, and either full or semi-automatic in operation, and magnetic control is used. A combination frequently used consists of a motor control panel, a remote control master panel, and a limit switch. (Figs. 15 and 16.) The motor control panel contains a line switch with fuses and two contactors for throwing the motor onto the line either forward or reverse. These contactors are mechanically interlocked, so it is impossible to close both at once and thus short circuit the line. The remote control panel contains a double-throw switch and two indicating lamps. The limit switch, connected to the valve stem or to the driving motor, is so wired that when the valve is fully open only the contactor starting the motor in the "close" direction can be energized and vice-versa. With the valve in mid-position, however, the motor may be operated in either direction. The indicating lamps show the position of the valve.

Fig. 17. Automatic Electrode Regulating Panel for Control of Arc Furnaces

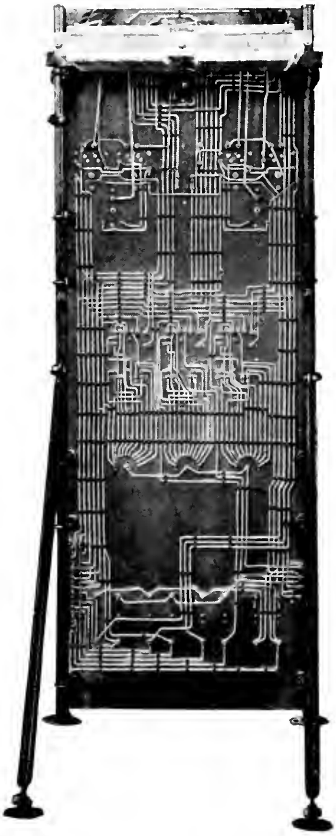
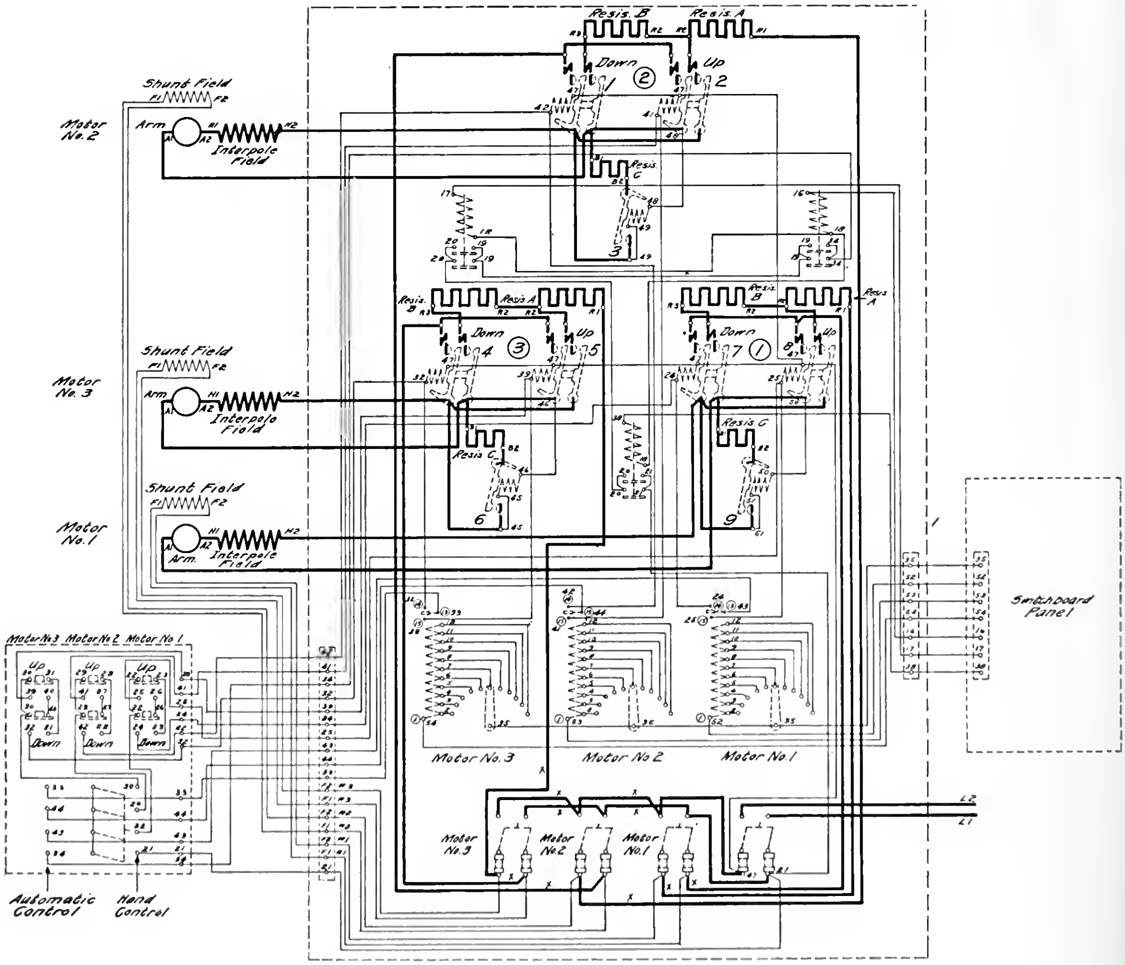


Fig. 18. Rear View of the Panel shown in Fig. 17

Arc Furnace Control

In connection with the steel industry, increasing use has been found for the arc furnace. To maintain constant arcs in such a furnace a set of small motors is used for regulating the carbon electrodes. For the control of these motors a panel of special construction has been designed. Figs. 17 and 18 illustrate a common type of these panels. Each electrode motor is connected to a set of contactors, consisting of a pair of double-pole contactors for the lowering and hoisting motion and a single-pole normally closed contactor for dynamic braking. These contactors are so interlocked mechanically that it is impossible to close any two at the same time. The regulating motors and their control apparatus are connected to a direct-current supply in accordance with Fig. 19. To raise any electrode, its motor is connected to the line through a resistor designed to give the proper motor speed. To lower the electrode, the lines to the motor armature are reversed and an additional resistor is connected in series with that used in hoisting, giving the proper lowering speed and taking into account the tendency for the weight of the electrode to overhaul the motor. When the motor is disconnected from the line the dynamic brake contactor closes, connecting a resistor across the motor armature and bringing it quickly to rest. The coil of the dynamic-brake contactor is connected directly across the motor armature and is energized by the



Contactors suitably mechanically interlocked

Fig. 19. Connection Diagram of a Three-phase, Three-electrode Arc Furnace Panel

counter-electromotive force which it generates. Until the motor armature has come nearly to rest, therefore, it is impossible to close either of the double-pole line contactors, because of the mechanical interlocks. This makes it impossible to reverse the regulating motor while running at full speed.

Automatic control of the regulating motors is maintained by a set of contact-making ammeters. The coils of these ammeters are connected to current transformers in the lines connecting the electrode to their alternating-current source of supply. The ammeter contact fingers are held in mid-position when the current through the ammeter coil is at a predetermined value, this value being made adjustable to a certain degree by connection to taps on the ammeter coil through a small dial switch. As the current through any electrode varies either above or below normal, the contact fingers of the corresponding ammeter close the energizing circuit of either the "up" or "down" contactor, thus operating the regulating motor. This lengthens or shortens the electrode arc and maintains normal current.

With this equipment a failure of voltage on the alternating-current supply to the furnace, or an opening of one of the lines, would de-energize one or more of the contact-making ammeters. This would close the circuit to the corresponding "down" contactors and would cause the motors to run in that direction continuously. To prevent this a set of low-voltage relays is provided. The coils of these relays are connected across the alternating-current supply lines, and the normally open interlock disks are wired in series in the direct-current control circuit. Failure of voltage on any one relay will then make the whole panel inoperative.

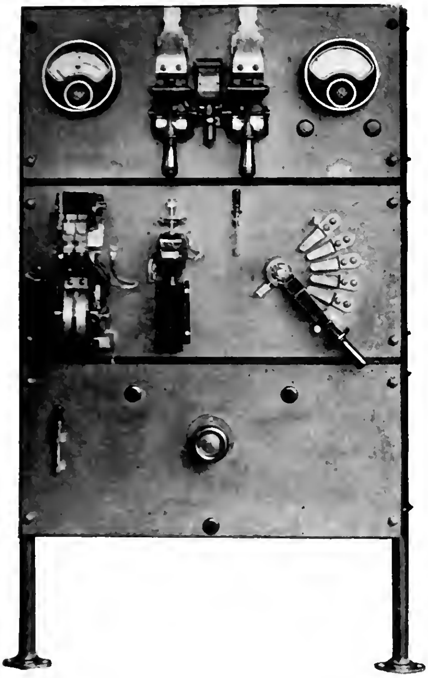
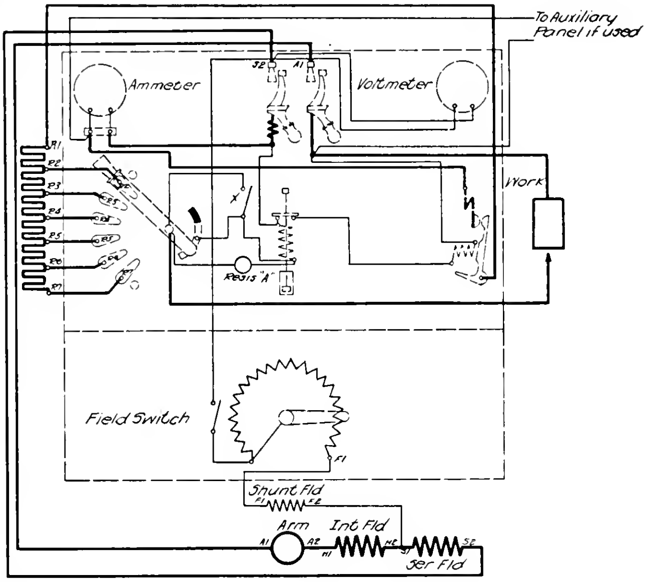


Fig. 20. Arc Welding and Generator Control Panel



Close switch "X" when using Carbon Electrode on lower points of Dial Switch.

Fig. 21. Connection Diagram of the Arc Welding and Generator Control Panel shown in Fig. 20

An auxiliary panel used in connection with the regulator panel is provided with a throw-over switch, which makes the regulator panel control either automatic or manual. For the latter, a push-button station for each electrode is mounted on the auxiliary panel. Each station contains an "up" and a "down" button, the electrode regulating motor operating continuously in either direction as long as a button is depressed. The buttons on each station are so interconnected that when either is depressed the control circuit through the other is opened. This insures a slight time interval between the release of any button and the depression of the reverse button in the same station, the time interval giving the dynamic brake contactor time to close and stop the motor.

Arc Welding Control

Another use for electric energy that is coming more and more into prominence is in connection with arc welding. For this work low-voltage direct current is the most suitable, and a motor-generator set is usually employed taking power from whatever supply lines are available and delivering current at the proper voltage. The standard control panel designed for this service includes the generator control and the welding control. The generator control consists of a field switch and rheostat, meters to indicate voltage at the generator terminals and current delivered, and a standard circuit-breaker for protection against extreme overload or short circuit.

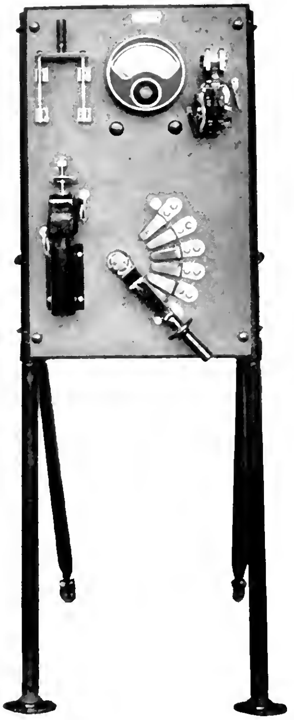


Fig. 22. Auxiliary Arc Welding Panel

For control of the welding circuit a resistor is connected in series in the line to the work. (See Fig. 20 and 21.) This resistor serves to steady the arc and also to limit the amount of current to be drawn, a dial switch being used to connect to different taps on the resistor. The welding circuit passes through a contactor, the control circuit of which is wired through the normally closed interlock of a time-limit relay. The energizing coil of this relay is so wired that it receives the voltage drop across that portion of the resistor which may be in use during any operation. With this arrangement the protective relay, having a definite setting, always opens at approximately the same percentage increase of current above normal value for any given setting of the dial switch. In case heavy current is drawn, as when the operator leaves the welding electrode lying on the work, this relay will operate, de-energizing the welding circuit contactor and thus opening the circuit. After the contactor opens, line voltage is impressed upon the relay coil, thus keeping it energized and holding the welding circuit open until the cause of the overload is removed. The time element of the relay is so set that the relay operates in from two to three seconds. This gives the operator ample time to strike the welding arc without tripping the relay.

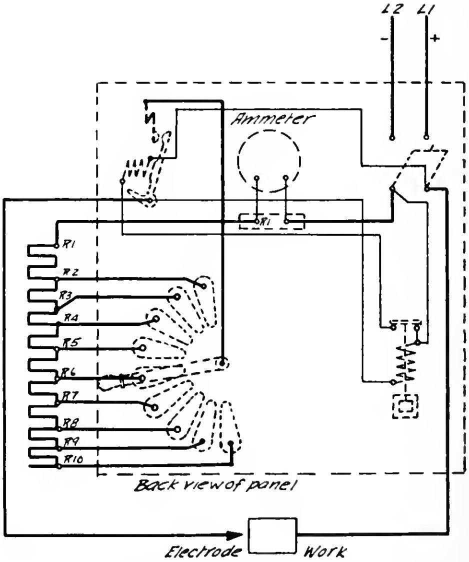


Fig. 23. Connection Diagram of the Auxiliary Arc Welding Panel shown in Fig. 22

In order to make the welding control suitable for operation with either carbon or metallic electrodes, it is necessary to so arrange the relay circuit that the relay will trip at a higher value when the metallic electrode is used. This is necessitated by the voltage drop across a metallic arc being lower than across a carbon arc, which means that the drop across the resistor is higher with the former than with the latter. Thus the relay set for the proper drop across the resistor with carbon electrodes would trip at too low a value for welding with metallic electrodes and would make it impossible to hold the contactor closed. This change from a higher to a lower voltage setting is taken care of automatically on the panel designed for use with both kinds of work. A resistor tube is inserted in the circuit energizing the coil of the time-limit relay. The resistance of this tube is of such a value that when in series with the coil the relay will trip at the proper value for metallic electrode welding, and when the tube is short circuited the relay will operate at the proper value for carbon electrode welding. As only part of the steps of the welding resistor are suitable for use with the metallic electrode, an auxiliary contact is mounted on the dial switch arm so arranged that the tube in the relay circuit is short circuited when the switch makes contact with those resistor taps where the metallic electrode cannot be used. As all taps of the resistor are suitable for use with the carbon electrode, and it is sometimes desirable to make use of those taps designed for use with the metallic electrode, a single-pole lever switch is provided to short circuit the relay resistor tube when using the carbon electrode on the metallic electrode taps.

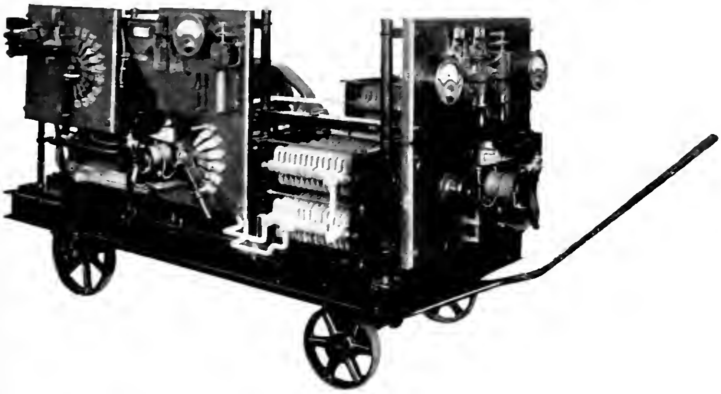


Fig. 24. Generator and Welding Panel with Auxiliary Welding Panel and Starting Panel Mounted on a Truck with Starting Rheostats and a Direct-current Driven Motor and Generator Set

Where several welding jobs are to be carried on at the same time, the generator is usually provided with a control panel containing the field switch and rheostat, the meters, and the circuit-breaker. A welding protective panel containing the dial switch, resistor, relay, and contactor is then provided for each welding station. Views of this equipment are given in Figs. 22 and 23.

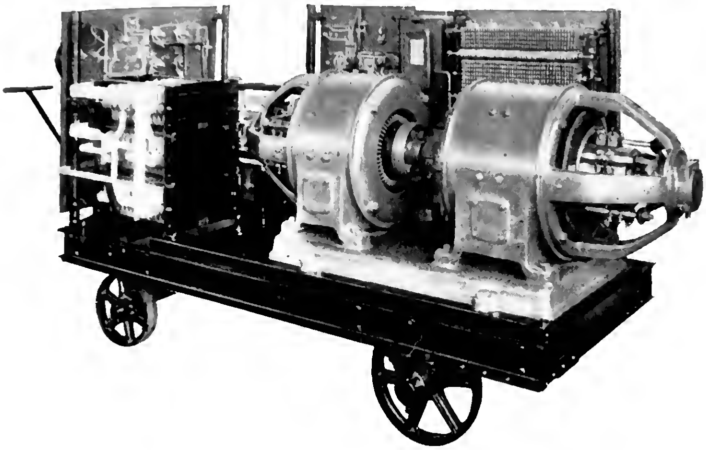


Fig. 25. Another View of the Welding Equipment shown in Fig. 24

For use in shops where a certain amount of welding is required in connection with various classes of work and where there is not a sufficient amount of welding in any one place to warrant the installation of a welding set, a portable set has been designed containing a complete welding equipment. This, as shown in Figs. 24 and 25, consists of a truck upon which is mounted a motor-generator set, a hand starting panel for the motor, a generator control panel, and a welding control panel.

No attempt has been made in this article to describe in detail the theory or practice in connection with the apparatus being operated, nor has any attempt been made to show examples of control panels containing special refinements required in connection with specific industries. It is hoped, however, that the examples of standard apparatus shown will make it evident that the magnetic controller is flexible enough to make it applicable for use in any industry and with any type of apparatus using electric energy.

LITERATURE OF THE NITROGEN INDUSTRIES, 1912–1916

By Helen R. Hosmer

Research Laboratory, General Electric Company

Nitrogen compounds are essentials to any country at peace or at war. In peace they are used extensively for agricultural purposes, for the making of dyes, and for other manufactured products, and in war nitric acid is an essential ingredient for practically every type of explosive. During peace the United States can import nitrates, but these supplies could easily be cut off in the event of war. A nation wide recognition of the importance of fixed nitrogen has stimulated the study of its production, and we feel that the present exhaustive treatise covering the literature relative to this important subject is both timely and of great value. The contents of the entire series of articles is given in this installment, as this will enable our readers to see the scope of the work.—Editor.

CONTENTS

INTRODUCTION

In the following general review of the literature of the Nitrogen Industries it is attempted to give in convenient form the essential statements of papers published during the last five years. The earlier literature is very general and often vague in nature, and is sufficiently well covered by a number of books. Moreover it is the recent material with its more specific treatment of technical and cost details which is now of particular interest in connection with the attempts being made to establish an adequate domestic supply of nitrogen compounds for the United States.

The purpose has been to present an outline giving the salient features of the subject, as stated by various authorities, together with a bibliography of such a kind that the original articles need not be consulted in order to find which contain the particular information desired. The aim has not been exhaustiveness but rather the listing of references generally available in this country. It is believed, however, that the field is fairly well covered by these and that extension of the list would but lead to duplication, or to the inclusion of trivial articles.

The arrangement is inversely chronological except where entire consistency might have separated related items. The appendix contains material not properly a part of the subject but of possible use to those interested in the present day problem. In these latter no effort is made to cover the fields at all completely.

It should be kept in mind that in all cases the statements made are those of the authors quoted. This accounts for some repetition and for contradictory data on some points. In cases where the material of different writers was obviously taken from the same authority this fact is noted and only one is quoted in detail.

In regard to the fact that the testimony given favors certain processes very markedly it must be remembered that certain industrial interests now prominent in this country have contributed disproportionately to the literature. It may well be that some of the processes not praised at all highly here, may yet prove to be cheaper and more efficient.

Very recently information of a fragmentary nature seems, for instance, to indicate that the Germans have been placing their reliance upon the Haber process, which may well have been much improved and developed during the last two years. In all cases, the data given here should be taken for what they are worth and not as authoritative.

Part I: DESCRIPTION AND CHEMISTRY OF PROCESSES

GENERAL

916 Washburn (12) discusses in some detail the factors having bearing upon the problem before the United States of establishing a domestic supply of nitrates adequate to war demands. He analyses the various proposals made.

916 Norton (15) discusses the various water powers in the United States which are available and adaptable to the nitrogen fixation industry. He favors the establishment of three plants to supply the needs of the sections of the country having the largest demands. He also mentions the possibility of getting 7,400,000 horse power during 14 hours of the day from complete harnessing of Niagara Falls. The details of this plan are given by
1915 Dunn (38). See also (13) and (124).

1916 Merrill (14) gives similar data for Western water powers.

1916 Skerrett (21) gives a very general and brief treatment of the nitrogen situation, mentioning the importance of its consideration in connection with preparedness, and outlining very briefly the arc and cyanamide processes. He quotes from Norton, and most of his other data are to be found in Washburn's articles and statements.

1916 Cushman (24) in an article entitled "Role of Chemistry in War" has discussed, among other things, the status of our nitrogen supply and the methods available for remedying this situation. His data on this point
1915 is taken from Summers (50) and Baekeland
1914 (56).

1915 Cresap (36) gives in very general terms the composition and characteristics of some 15 of the more common military explosives. It is to be noted that nitric acid is required for the preparation of all.

1914 Baekeland (56) gives a brief history of the nitrogen industries and their present status, explaining the cause of failure of the Bradley and Lovejoy process. He mentions that a French Company has taken up the application of the Serpek process.

Merrill (46) gives full statistics of the water 1915
power resources and electric power development and control in the United States. The conclusions of his report are, however, severely criticised in reference (29). 1916

Martin and Barbour (1) in their book on 1916
"Industrial Nitrogen Compounds and Explosives" present a general review of the whole subject with references. They describe the most important processes and give diagrams and photographs of the apparatus. They also discuss the more general aspects of the subject and include statistics and many patents.

Roeber (146) gives a good general review of 1910
the nature of the various processes for nitrogen fixation, and their present status.

Summers (50) discusses in detail the physical 1915
chemistry and thermodynamics of the endothermic reaction between nitrogen and oxygen, giving the results obtained by Nernst from investigation of the equilibrium at temperatures between 1500 and 3500 deg. C., by Nernst and Jellinek on rate of dissociation of *NO* at various temperatures and by Haber and Koenig working at reduced

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(12) Washburn, "The Facts in the Nitrogen Case." (1916).

(15) Norton, Statement before Senate Committee on Agriculture and Forestry, 1916. (S. 4971).

(38) Dunn, Scientific American, *113*, 492–3, 505–7 (1915)

(13) Baekeland, Statement before Senate Committee on Agriculture and Forestry, 1916. (S. 4971).

(124) Scott, "Manufacture of nitrates from the atmosphere." Smithsonian Report for 1913, pp. 359–84, (1914). (Publication 2291). Reprinted from Journal, Royal Society of Arts, (London) *60*, No. 3104, (1912).

(14) Merril, Statement before Senate Committee on Agriculture and Forestry, 1916. (S. 4971).

(21) Skerrett, Iron Age, *97*, 359–62 (1916).

(24) Cushman, Journal, Franklin Institute, *181*, 163–90, (1916).

(50) Summers, Transactions Amer. Electrochemical Society, *27*, 339–83 (1915).
Proceedings, Amer. Institute of Electrical Engineers, *34*, 337–81 (1915).
Abstract, Metallurgical and Chemical Engineering, *13*, 241–4 (1915).

(56) Baekeland, Journal, Industrial and Engineering Chemistry, *6*, 769–78 (1914).
Metallurgical and Chemical Engineering, *12*, 559–60 (1914).

(36) Cresap, Iron Age, *96*, 752–3 (1915).

(46) Merrill, Report upon Electric Power Development in the United States, etc., in response to Senate resolution of Feb. 13, 1915. Part 2, Doc. 316, 485 pp.

(29) Electrical World, *68*, 10–2, 69–70 (1916).

(1) Martin and Barbour, "Industrial Nitrogen Compounds and Explosives." (D. Appleton & Co. N. Y. 1916).

(146) Roeber, Mineral Industry, *19*, 58–67 (1910).

pressures. He computes that owing to the extreme dilution of the product there is a loss of some 95 per cent of the energy employed. He also mentions briefly the physico-chemical factors involved in the Cyanamide and Serpek processes.

The only arc processes in actual operation
1915 according to Landis (44) are the Birkeland-Eyde, the Schönherr, and the Pauling, all of which give as a product a gaseous mixture containing from 1 per cent to 2 per cent by volume of nitric oxide, from which the present well standardized condensation plants recover nearly 95 per cent in the form of 30 to 35 per cent nitric acid. This can be concentrated to 50 per cent by utilizing the waste heat of the process, but must then be further concentrated by special processes, or else converted into calcium or ammonium nitrate, before it is available for commercial purposes. The ammonia for such conversion is obtained in most cases from cyanamide.

These arc processes require enormous
1915 quantities of cheap electrical energy (44).

For a detailed discussion of the reactions involved and the thermodynamics of the case
1914 Knox (64) should be consulted. He gives a full and critical review of the literature down to 1913, devoting over 86 pp. to the chemistry of the processes with references to the original articles.

He also describes the commercial processes and furnaces, taking up the Birkeland-Eyde, Pauling, Schönherr, Haber, Serpek, Cyanamide, and some other less important ones. The book is an extremely good resumé of the subject but lacks entirely yields, cost data, and technical details.

1914 Haber (62) mentions the thermodynamical conditions limiting the yields of the arc and synthetic ammonia processes for fixing nitrogen. He believes that each process has its own field in which it may be successfully operated.

The chemistry and reactions involved in the oxidation of nitrogen and the absorption of the
1912 acid formed are discussed by Scott (124) who gives the equations. He also discusses the theories for the process of oxidation, mentioning particularly the probability that ozone is an intermediate product and very essential to the course of the reaction.

1912 Norton's (120) book like Knox's is a resumé of the nitrogen situation, including material collected from the literature, patents and personal observation. It is extremely full and comprehensive, and supplements Knox's book just where the latter is lacking, i.e., on the technical and commercial side. The development of the industry and the various plants are given special attention. Methods of producing the materials required by the various processes are considered in their bearing upon an American industry. The properties and applications of the products are taken up. The organization of the European industry is described.

The chemistry of the processes and the possibilities for improvement are mentioned. He discusses the probable future of the industry particularly with regard to the effect of the cost of power and price of Chilean nitrate.

Norton also takes up the thermodynamics of the various processes. He describes also the less well known patented processes and furnaces such as those of Guye, Von Kowalski and Moscicki, Thorsen and Tharaldsen, and Albihn. In fact he pays especial attention to patents. He includes non-electrical processes such as that of Häusser.

The uses of the various products, the syntheses of related products such as cyanides, statistics of the world's supply and consumption of nitrogen compounds, recovery of waste nitrogen products are all reviewed.

The book is, in fact, the most complete treatise on the subject that has been published. Relatively few references are given.

OXIDATION PROCESSES

Arc Processes

Summers (50) describes with diagrams the 1915
comparative operation of the three commercial types of furnace for direct combination of the oxygen and nitrogen of the air, the Häusser, and the Birkeland-Eyde, Schönherr, and Pauling. The three last, which are arc processes, take alternating-current at voltages of from 4000 to 5500 between the electrodes.

The Birkeland-Eyde furnace, which has had the most extensive application, employs

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(44) Landis, Journal Industrial and Engineering Chemistry, 7, 433-8 (1915).

Metallurgical and Chemical Engineering, *13*, 213-8 (1915).

(64) Knox, "Fixation of Atmospheric Nitrogen." (D. Van Nostrand Co. 1914. 110 pp.)

(62) Haber, Journal, Society of Chemical Industry,, *33*, 52-4 (1914).

(124) Scott, "Manufacture of nitrates from the atmosphere." Smithsonian Report for 1913, pp. 359-84, (1914). (Publication 2291). Reprinted from Journal, Royal Society of Arts, (London) *60*, No. 3104, (1912).

(120) Norton, "Utilization of atmospheric nitrogen." Dept. of Commerce and Labor. Bur. of Manufactures. Special Agents Series, 52, 1912.

(50) Summers, Transactions Amer. Electrochemical Society, *27*, 339-83 (1915).

Proceedings, Amer. Institute of Electrical Engineers, *34*, 337-81 (1915).

Abstract, Metallurgical and Chemical Engineering, *13*, 241-4 (1915).

a series of semicircular arcs rapidly expanded by means of a powerful direct-current magnet against the incoming air. The products are withdrawn at a temperature of about 1250 deg. C. and contain about 2 per cent of NO. The recent furnaces have a 3000 kw. capacity and give a yield of 580 to 600 kg. of nitric acid per kw-yr. or 65 to 70 g. per kw-hr.

1915 Scott (49) states that some furnaces take over 4000 horse power. At Notodden there are 32 furnaces using from 600 to 1000 kw. each and at Saaheim 8 of 3500 kw. each.

The Schönherr furnace uses a quietly burning arc some 23 feet long, around which the air circulates with a vortex motion. The gases pass over a water-cooler, and are withdrawn at about 850 deg. C. after having given up a further part of their heat to the incoming air. The NO concentration is about 2.25 per cent. The largest furnaces have 800 kw. capacity, and yield 550 to 575 kg. of nitric acid per kw-yr. or 65 g. per kw-hr.

1915 Scott (49) states that the Christianssand works have twelve 450 kw. furnaces of this type, and the Saaheim ninety-six 1000 kw.

The Pauling furnace makes use of a series of rapidly succeeding arcs, driven upward by the blast of incoming air, and broken by the diverging horns of the electrodes. The effect is an arc flame 30 in. high in intimate contact with rapidly moving air. The yield of NO is from 1.25 to 1.5 per cent in the 400 kw. furnace, with yields of from 525 to 540 kg. per kw-yr. or 60 g. per kw-hr.

1915 Scott (49) says that this furnace is employed in factories at Gelsenkirchen, Innsbruck, Milan, Roche-de-Rame, and in South Carolina.

1915 Scott (49) describes the Birkeland-Eyde, Schönherr-Hessberger, and Pauling furnaces and operation in considerably greater detail than Summers, and gives a comparison of their disadvantages.

1912 Scott (124) gives the temperatures of the flames and escaping gases respectively as 3500 deg. C. and 800-1000 deg. C. for the Birkeland-Eyde furnace, 3000 deg. and 1200 deg. for the Schönherr, and —— and 1000 deg. for the Pauling. The current supplies required for each furnace are as follows:

Birkeland-Eyde—Direct-current for magnetic field of 4500 lines of force per sq. cm.
—Alternating-current 5000 volts, 50 periods, 600–3000 kw.
Schönherr—Alternating-current 4200 volts, 50 periods, 600 h.p.-1000 kw.
Pauling—Single-phase Alternating-current 4000–6000 volts, 50 periods, 400 kw.

Eyde (114) gives similar values for his furnace which he states is the only type used at Notodden. Both Birkeland-Eyde and Schönherr systems are used at Rjukan. He also gives cuts, diagrams, and photographs of plants and discusses power developments. 1912

Scott's (124) article and this are very similar in context. 1912

Scott (124) gives the most detail concerning the construction of the furnaces, conditions of operation, layout of plants, yields, etc., for the arc and cyanamide process with photographs from the plants. He also describes the absorption methods. He states that the power-factor for nitrogen fixation processes is about 0.6. 1912

He also discusses the relative advantages of the three arc processes, and describes the electrical equipment with its guarantees, used by the Birkeland-Eyde plant at Rjukanfos. This last is described in considerable detail.

Scott also (49) describes the Scott-Kilburn arc furnace and process for oxidizing nitrogen. The apparatus employes a three-phase current giving, under the blast of air, an inverted cone of flame. Air enriched with oxygen is to be used cyclically, whereby it is expected to increase the yield of NO 20 per cent. Direct absorption in water is claimed to give a 50 per cent nitric acid. 1915

The process does not appear to have been applied commercially as yet. Operating factors and their effect upon yields are mentioned but no data given.

The design of a commercial furnace, similar to the experimental one, is given for which the advantages of simplicity, conservation of heat, low first and maintenance costs, etc., are claimed.

Patents of methods for the fixation of atmospheric nitrogen by arc processes issued in recent years are reviewed in reference (52). 1915

Lamy (138) gives a general review of the cyanamide and arc processes for nitrogen fixation. His description of the Birkeland- 1911

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(49) Scott, Journal, Society of Chemical Industry *34*, 113–26 (1915).

(124) Scott, "Manufacture of nitrates from the atmosphere." Smithsonian Report for 1913, pp. 359–84, (1914). (Publication 2291). Reprinted from Journal, Royal Society of Arts, (London) *60*, No. 3104, (1912).

(114) Eyde, Transactions, 8th International Congress of Applied Chemistry (New York, 1912) *28*, 169–81 (1912).
Abstracts, Chemical Engineer, *16*, 188–91 (1912).
Journal of Industrial and Engineering Chem., *4*, 771–4 (1912).

(52) Elektrochemische Zeitschrift, *21*, 211–21 (1915)

(138) Lamy, Metallurgical and Chemical Engineering, *9*, 99–104 (1911).

Eyde, Schönherr, and Pauling processes, illustrated with diagrams, is very good.

1912 Auzies (108) discusses the theory of nitrogen oxidation and gives tables showing the relation between temperature and yield. The catalysis of the reaction by oxides of cobalt, magnesium, chromium, nickel, platinum, palladium, barium, lead, cerium, and thorium has been effected. Cerium works best. Work has also been done on the catalysis of the reaction between nitrogen and hydrogen.

1912 Tausent (128) shows the advantage of vertical arcs over horizontal, both in stability and yield of nitric acid.

1911 Ehrlich and Russ (136) conclude from experiments on mixtures of nitrogen and oxygen that ozone is an important factor in the oxidation of nitrogen. They give the variation of per cent of nitric oxide formed, with the oxygen in the original mixture.

1911 Vanderpol (142) gives a detailed description with diagrams for the Pauling process and absorption towers at La-Roche-de Rame, Hautes-Alpes, France.

1910 Haber, Köenig, Platou and Holwech (144) have studied the effect of high voltage, high frequency alternating-current, cooled direct-current arcs, and pressure upon the oxidation of nitrogen and give their experimental data in considerable detail.

1910 Holwech (145) has studied the formation of nitric oxide in the short direct-current arc at various temperatures with a cooled anode. He obtained the best results with the shortest arc and the highest field strengths compatible with the proper temperature, getting yields as high as 80 g. of nitric acid per kw-hr. at a maximum concentration of 9 per cent of NO.

1910 Wolokitin (148) has studied the formation of nitrogen oxides in the flame of hydrogen and discusses the thermodynamics of the reaction.

1910 Zenneck (149) gives a general discussion of the various methods for oxidizing nitrogen in the arc.

1915 Köenig (42) discusses rather fully the subject of active nitrogen and its relation to nitrogen fixation. He reviews the literature and gives the results of work of his own upon the activation of nitrogen, oxygen, and hydrogen.

1914 Hene (63) got a higher yield from sparking oxygen before mixing it with nitrogen than from sparking the nitrogen. He concludes that ozone is formed.

The reaction of active hydrogen and oxygen
1914 has been studied by Köenig and Elöd (65) and
the conclusion reached that the electric discharge must also produce an active form of oxygen.

Lowry (67) finds spectroscopically that when 1914
active nitrogen and ozonized air are mixed, nitric oxide is produced, and suggests that the fact may throw light upon the molecular condition necessary for the oxidation of nitrogen.

Köenig (88) criticizes the conclusion of 1913
Fischer and Hene (115) that the electrical 1912
discharge activates the oxygen and not the nitrogen.

Fischer and Hene (115) conclude from a study of the effect of subjecting nitrogen and air separately to the action of electric discharges, that the oxidation of nitrogen in the arc flame is dependent upon the dissociation or activation
of the oxygen and not of the nitrogen. In 1913
reference (84) they reply to Köenig (88) and 1913
give their experimental data in detail.

Lowry (118) got increased yields of nitrogen 1912
peroxide from mixing air which had been subjected to the action of a series of spark gaps, with ozone.

Russ (123) discusses the evidence of various 1912
investigators that the reaction is not purely thermic but may involve electronic factors and points out that the formation of active nitrogen might be harmful.

Strutt (126) states that active nitrogen is not 1912
oxidized by oxygen but that the latter probably acts as a catalyser to destroy the active modification.

Strutt (140) has studied the flame arising 1911
from the nitrogen-burning arc and concluded that it, like the after-glow phenomena in vacuum tubes containing air, is due to the oxidation of oxides of nitrogen by ozone.

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(108) Auzies, Revue generale de Chimie pure et **applique**, *15*, 233-41 (1912).
Abstract, Journal, Society of Chemical **Industry**, *31*, 919, (1912).

(128) Tausent, Zeitschrift für Elektrochemie, *18*, 314-9 (1912).

(136) Ehrlich, Russ, Monatshefte fur Chemie, *32*, 917-6 (1911).
Abstract, Journal, Society of Chemical Industry, *30*, 1393-4 (1911).

(142) Vanderpol, Metallurgical and Chemical Engineering, *9*, 196-8, (1911).

(144) Haber, Köenig, Platou; and Holwech, Zeitschrift für Elektrochemie, *16*, 789-813 (1910).

(145) Holwech, Zeitschrift für Elektrochemie, *16*, 369-90 (1910).

(148) Wolokitin, Zeitschrift fur Elektrochemie, *16*, 814-26 (1910).

(149) Zenneck, Physikalische Zeitschrift, *11*, 1228-33 (1910).
Abstract, Metallurgical and Chemical Engineering *9*, 73-5 (1911).

(42) Köenig, Zeitschrift für Elektrochemie, *21*, 267-86 (1915).

(63) Hene, Disertation der Berliner Technischen, Hochschule, 1912, p.48.
Abstract, Elektrotechnische Zeitschrift, *35*, 745 (1914).

(65) Köenig, Elöd, Berichte, Deutschen Chemischen Gesellschaft, *47*, 516-29 (1914).

(67) Lowry, Transactions, Faraday Society, *9*, 189-92, (1914).

(88) Koenig, Berichte, Deutschen Chemischen Gesellschaft, *46*, 132-4 (1913).

(115) Fischer, Hene, Berichte, Deutschen Chemischen Gesellschaft, *45*, 3652-8 (1912).

(84) Fischer, Hene, Berichte, Deutschen Chemischen Gesellschaft, *46*, 603-17 (1913).

(118) Lowry, Journal, Chemical Society, *101*, 1152-8 (1912).

(123) Russ, Zeitschrift fur angewandte Chemie, *25*, 586 (1912).
Journal, Society Chemical Industry, *31*, 383 (1912).

(126) Strutt, Proceedings, Royal Society, *86*, (A) 56-63 (1911).
Abstract, Journal, Society of Chemical Industry, *31*, 70-1 (1912).

(140) Strutt, Proceedings, Royal Society, *85*, 533-6 (1911).

1915 Dary (37) states that Nodon has been able to obtain nitric acid very economically by electrolyzing peat under 10 volts. Peat contains 2 per cent by weight of nitrogen, which is converted into nitric acid by the combined action of nitrogen bacteria, the oxygen of the air, water, and heat from the electric current. The yield of nitric acid per ampere hour is 1 g., or 432 kg. in 24 hours per ha consumes 180 kw-hr. The yield per year on 150 ha is 100,000 tons of nitrate.

Häusser Process

1915 The Häusser process (50) of which a single commercial installation has been made in Germany, employs coke oven gases mixed with air under pressure in an explosion bomb, fired by a high tension spark. The products are cooled at once by a high pressure spray of water. The temperature attained is 2100 deg. A. and the concentration of NO, 0.5 per cent. The maximum yield is 99 g. of nitric acid per cu. m. of gas equal to 6.2 lb. per 1000 ft.

1912 Dobbelstein (113) has experimented with the Häusser process using coke oven gas in a bomb of 100 litres capacity. Diagrams of the plant are given as well as curves showing the relation of yield to pressure, temperature of gas, and per cent of oxygen. The advantages and costs are compared with other processes.

1912 Häusser (116) gives a detailed account of investigations upon nitrogen fixation by the explosion of gas mixtures and the influence of the various factors of pressure, etc. Increase in size of bomb gave larger yields.

Absorption

1915 The NO mixtures (50) produced by all these processes are cooled, passed into a gas holder, where time is allowed for the reaction:

$$2\,NO + O_2 = 2\,NO_2$$

and are then sent to counter absorption towers, where they react with water, according to the equation

$$2\,NO_2 + H_2O = HNO_3 + HNO_2$$

The nitrous acid is oxidized by the excess oxygen. An acid of 30 to 50 per cent concentration is thus obtained. The residual gases are circulated through towers containing weak alkaline solutions yielding nitrite-nitrate salts. About 2 or 3 per cent of the original NO gas is discharged with the waste gases.

1915 Scott (49) discusses his absorption system and compares its operation and the concentration and nature of the products with those of the ordinary systems.

1912 Briner and Durand (112) have studied the equilibrium of nitrous and nitric acids formed when oxides of nitrogen are absorbed in water and conclude that increase in the pressure of NO and lowering the pressure favor the formation of nitric acid.

1911 Lewis and Edgar (139) have also studied the equilibrium between nitrous and nitric acids in aqueous solution and get as the value for the dissociation constant for

$$\frac{(HNO_2)^3}{(H)\,(NO_3)} = K = 0.0267 \text{ at 25 deg. C.}$$

REDUCTION PROCESSES

Haber Process (Synthetic Ammonia)

The Haber process depends upon the direct combination of nitrogen and hydrogen at temperatures of about 500 deg. C. under the influence of uranium as a catalyser, and is carried out under pressures of 200 atmospheres. The 8 per cent of ammonia formed is condensed out by cooling the mixture. The power expenditure is about 1.5 kw-hr. per kg. of nitrogen, the lowest of any of the fixation processes. The preparation of the nitrogen and hydrogen, and the compression required, increase the costs very considerably (50). 1915

1915 Haber (40) and his co-workers have made extended investigations of the heat of formation of ammonia at temperatures from 659 deg. C. to 466, and at ordinary temperatures, and have determined its specific heat.

1915 They (39) (41) have also determined the equilibrium at various temperatures, at ordinary pressures, and at 30 atmospheres.

1915 Landis (44) doubts whether even the Badische Company, with its supply of waste

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(37) Dary, Revue d'Electrochimie et d'Electrometallurgie, *8*, 70–2 (1914).
Abstract, Elektrochemische Zeitschrift, *21*, 226 (1915).

(50) Summers, Transactions Amer. Electrochemical Society, *27*, 339–83 (1915).
Proceedings Amer. Institute of Electrical Engineers, *34*, 337–81 (1915).
Abstract, Metallurgical and Chemical Engineering, *13*, 241–4 (1915).

(113) Dobbelstein, Stahl und Eisen, *32*, 1571–7 (1912).
Abstract, Journal, Society of Chemical Industry *31*, 982 (1912).

(116) Häusser, Zeitschrift, Vereines Deutschen Ingenieure, *56*, 1157–64 (1912).

(49) Scott, Journal, Society of Chemical Industry, *34*, 113–26 (1915).

(112) Briner, Durand, Comptes Rendus, *155*, 1495–7 (1912).

(139) Lewis, Edgar, Journal, Amer. Chemical Society, *33*, 292–9 (1911).

(40) Haber, Tamaru, Oeholm, Zeitschrift für Elektrochemie, *21*, 191–245 (1915).

(39) Haber, Maschke, Zeitschrift für Elektrochemie, *21*, 128–30 (1915).

(41) Haber, Tamaru, Ponnaz, Zeitschrift für Electrochemie, *21*, 89–106 (1915).

(44) Landis, Journal Industrial and Engineering Chemistry, *7*, 433–8 (1915).
Metallurgical and Chemical Engineering, *13*, 213–8 (1915).

sulphuric acid and hydrogen, is able to supply ammonium sulphate at a profit in normal times. The process, while not requiring very much electric power, does demand a great deal of skilled labor, and so probably has no future in the United States, in competition with the cyanamide process, which provides the same end product, ammonia.

1914 Crossley (59) gives a brief outline of Haber's synthetic ammonia process.

1914 Haber (61) discusses in detail the history of the development and thermodynamics of the process for the production of synthetic ammonia.

1913 Reference (86) gives the report of Haber and Le Rossignol, presented to the Badische Anilin-und Soda-fabrik in 1909, which led that company to take up the large scale development of the process for synthetic ammonia. The thermodynamics of the reversible reaction between hydrogen and nitrogen are discussed and the reasons for working the process between 500 and 700 deg. C. and under 200 atmospheres pressure are explained.

1912 Bernthsen (109) gives a detailed but general review of the history of the development of process for making synthetic ammonia. He mentions the various catalysers tried and their adaptability and the effect of poisons and "promoters."

1912 Billiter (110) finds that the rapid exhaustion of cerium hydride and intride, which are quite active catalysts at 200–300 deg. C. is due to gradual oxidation.

1914 Serpek (70) discusses the general problem of inorganic ammonia synthesis taking up the chemistry of each of the several processes known. He quotes his material mainly from patents.

Cyanamide Process

The fixation of nitrogen by the cyanamide process depends upon reactions that are generally expressed by the equation

$$CaC_2+N_2=CaCN_2+C$$

which is not only reversible, but so complicated that its equilibrium constants have
1915 not yet been established. Landis (44) points out a few of the difficulties and special problems to be met and solved in preparing satisfactory grades of carbide and nitrogen, and then combining them on a commercial scale.

1915 Summers (50) discusses the thermodynamics of the reactions involved in making calcium cyanamide from the elements, giving figures to show that the yield per unit of electrical energy is 4 to 5 times that of the direct oxidation methods, but this advantage is partly offset in practice by other costs, such as that of the preparation of nitrogen.

A history of the development of the cyanamide industry in America, with descriptions of operations, and illustrations of the apparatus and buildings of the American Cyanamide Company is given in the Engineer-
ing News (53). The output of the various 1915
factories of the world is given. (See Production, Cyanamide.)

Landis (45) also describes the various sub- 1915
sidiary installations, such as the calcium carbide, lime, and coal gas plants, necessary to the operation of a cyanamide plant. Photographs are given, and capacities stated.

Reference (77) describes in great detail the 1914
electrical equipment and water power development employed in making calcium carbide and cyanamide in Norway and Sweden, under the control of the Nitrogen Products and Carbide Co., Ltd. which also owns plants in Belgium for making ammonium nitrate by the Ostwald process. The history of the development of the business is also outlined.

Reference (79) is a short general article 1914
describing with photographs the coal-gas and lime plants of the American Cyanamide Company's works at Niagara Falls.

Pranke (95) gives a brief history of the 1913
development of the process and its chemistry, and mentions the uses of the material.

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(59) Crossley, Journal, Society of Chemical Industry, *33*, 1140 (1914).

(61) Haber, Zeitschrift für angewandte Chemie, *27*, (1) 473–7 (1914).

(86) Haber, Le Rossignal, Zeitschrift für Elektrochemie, *19*, 53–72 (1913).
Abstracts, Metallurgical and Chemical Engineering, *11*, 211–4 (1913).
Journal, Society Chemical Industry, *32*, 134–8 (1913).
Journal, Industrial and Engineering Chemistry, *5*, 328–31 (1913).

(109) Bernthsen, Transactions, 8th International Congress of Applied Chemistry, *28*, 182–210 (1912).
Journal, Industrial and Engineering Chemistry, *4*, 760–7 (1912).

(110) Billiter, Nernst Festschrift, 86–9 (1912).
Abstract, Journal, Society of Chemical Industry, *31*, 919 (1912).

(70) Serpek, Zeitschrift für angewandte Chemie, *27*, (1) 41–8 (1914).

(44) Landis, Journal Industrial and Engineering Chemistry, *7*, 433–8 (1915).
Metallurgical and Chemical Engineering, *13*, 213–8 (1915).

(50) Summers, Transactions, Amer. Electrochemical Society, *27*, 339–83 (1915).
Proceedings, Amer. Institute of Electrical Engineers, *34*, 337–81 (1915).
Abstract, Metallurgical and Chemical Engineering, *13*, 241–4 (1915).

(53) Washburn, Engineering News, *73*, 16–21 (1915).

(45) Landis, Metallurgical and Chemical Engineering, *13*, 218-20 (1915).

(77) Wagner, Engineering (London) *98*, 267-72, 294-6, 351–3, 465-8 (1914).

(79) Metallurgical and Chemical Engineering, *12*, 265-8 (1914).

(95) Pranke, Chemical Engineer, *12*, 113-5, (1913).

1913 Pranke's book (96) discusses very fully the history and chemistry of cyanamide, its preparation, conversion products and uses, and their reactions, and its action in the soil. Reports of tests and analyses are also given. Over two-thirds of the book is devoted to its agricultural value and properties. Extremely little manufacturing or cost data is given.

1907 Foerster and Jacoby (143) have studied the reaction between calcium carbide and nitrogen with especial attention to the lowering of the temperature required, produced by the admixture of calcium chloride or fluoride.

Ammonia from Cyanamide

1906 Calcium cyanamide (23) is readily and almost quantitatively (98–99 per cent) converted into ammonia by treatment with steam, in accordance with the reaction

$$CaCN_2+H_2O=CaCO_3+2\ NH_3$$

This reaction is exothermic, evolving from 200 to 300 lb. cals. of heat per pound of ammonia, and to realize the advantage of this fact the commercial process (U. S. Patent 1,149,633, Aug. 10, 1915) is carried out in autoclaves. Lime nitrogen is fed slowly and with constant agitation into water, or mother liquor from a previous run, with ventilation to carry off the acetylene evolved from unconverted carbide, soda and lime added, the autoclave closed, and steam admitted up to a pressure of 3 or 4 atmospheres, at which temperature the reaction starts at a fair rate, generating ammonia and steam so rapidly as to necessitate relief of pressure by special valves. Even then the pressure generally reaches 12–15 atm. in 20 minutes, then falling off again. The steaming operation is repeated once or twice more to expel the ammonia from the solution, which is then filtered from the mud, the latter going to the dump.

The course of the reaction is illustrated by curves, showing the variation of pressure, rate of discharge, and percentage of ammonia in the ammonia-steam mixture, with time for quantities of from 7000–8000 lb. of lime nitrogen. Less than 0.2 per cent of ammonia remains in the sludge.

The mixture of ammonia and steam may either be absorbed directly, producing a high grade ammonium sulphate, or passed through a simple rectifying column, giving an ammonia gas which is stated to be so pure that it can even be oxidized directly with no trouble from poisoning of the catalysers.

1913 Reference (103) gives a brief description of the method for obtaining ammonia by treating cyanamide with steam and states that ammonia of 99.8 per cent purity is thus obtained. Figures are given showing the completeness of decomposition.

Landis (23) considers it certain that the process for the preparation of ammonia by treating cyanamide with steam is already in successful operation in Norway, France, Switzerland, Italy, and Japan, and was installed in Belgium, before the war. The bulk of the product is used, in the form of ammonium sulphate, by the chemical and fertilizer industries. Norway produces large quantities for absorption of nitric acid from its Birkeland-Eyde plants. Germany is making enormous quantities for oxidation to nitric acid. 1916

The American Cyanamide Company has had a small plant in successful operation, in the United States, for six months, and is producing several tons per day of pure ammonia gas.

Serpek Process

The Serpek process is typical of the methods depending upon the formation of a nitride from which ammonia may be obtained by treatment with steam. The reaction which it involves is represented by the equation

$$Al_2O_3+3C+N_2=2\ Al\ N+3CO$$

and is carried out at a temperature of from 1800 deg. to 1900 deg. C. in a revolving barrel type of electric resistance furnace which affords the constant agitation necessary. Bauxite and coal from a producer type of furnace are fed into this and the product is discharged as aluminum nitride containing from 26 to 34 per cent of nitrogen.

Summers (50) calculates that under the most favorable conditions 9 to 10 kw-hrs. of electrical energy will be required per kg. of nitrogen, besides the heat from the coal and producer gas. The cyanamide process requires about 16.2 kw-hr. per kg. of nitrogen, or if all energy be supplied by the electrical current, the two processes will have practically the same power consumption. The Serpek process is hampered by the necessity for disposing of the by-product alumina. 1915

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(96) Pranke, "Cyanamide," (Chemical Publishing Co., Easton, Pa. 1913 106 pp.)

(143) Foerster, Jacoby, Zeitschrift für Elektrochemie, *13*, 101–7 (1907).

(23) Landis, Journal Industrial and Engineering Chemistry, *8*, 156–60 (1916).

(103) Tucker, Coal Trades Review (L) May 23, 1913.
Coal Trades Review (L), *11*, 476 (1913).

(50) Summers, Transactions, Amer. Electrochemical Society, *27*, 339–83 (1915).
Proceedings, Amer. Institute of Electrical Engineers, *34*, 337–81 (1915).
Abstract, Metallurgical and Chemical Engineering, *13*, 241–4 (1915).

1914 Reference (69) discusses the nitride reactions and the chemistry of the Serpek process mentioning the catalytic effect of hydrogen and iron.

1914 Reference (81) gives briefly the history of the reactions fixing nitrogen by the formation of metallic nitrides. Of these, the only one to find commercial application is that involving the production of by-product alumina which has been developed by Serpek.

The starting point is impure oxide, or bauxite, which is mixed with carbon and heated in the presence of nitrogen. Combination occurs at about 1550 deg. C. without any carbide formation, and is hastened by the presence of certain catalyzing reagents such as iron, silica, titanium oxide, nickel, and manganese, of which the first is most effective. The reaction temperature is further lowered by the presence of hydrogen, and aluminum nitride may thus be prepared at from 1250 to 1300 deg. C. provided a large excess of nitrogen be used. At higher temperatures this is unnecessary, and the rate of the reaction is much increased. At 1900 deg. the alumina is completely converted into nitride in 5 minutes, and recently Serpek has reduced the time to a fraction of a second by suitable control of the reaction mixture and of the nitrogen supply.

The nitride is easily decomposed into aluminum hydrate and ammonia by heating under several atmospheres pressure for 3 or 4 hours. Pure alumina may be produced as a by-product. The yield is 2 tons of alumina and 500 kg. of fixed nitrogen per kw-yr.

The process is in operation only in an experimental installation at Saint Jean de Manrieme in Savoy, though other plants are under construction at Arendal, in Norway, and in the United States.

1913 Fraenkel (85) has investigated the progress of the reaction for the formation of aluminium nitride from alumina, carbon, and nitrogen, which he finds begins under suitable conditions at 1400 deg. C. He has determined the effect of various factors upon the velocity.

1913 Richards (97) gives the history of the reactions involved in the Serpek process, and outlines the process as patented.

1913 Ross (98) has carried out some preliminary experiments upon the fixation of nitrogen by the alumina in feldspar, as a by-product in the preparation of potash. Larger percentages of nitrogen were fixed than corresponded to the aluminum present.

1913 Russ (99) has been able to demonstrate the exothermic formation of aluminum nitride from the elements.

Tucker (102) has studied the chemistry of this process and concludes that it is of commercial interest only where the by-product of pure alumina may find use in the aluminum industry. He compares the advantages and disadvantages of this and the cyanamide process for amonia. 1913

Reference (104) gives an abstract of the patent (U. S. 1,040,439) discussing the chemistry of the Serpek method for decomposing aluminum nitride by means of alkaline aluminates. 1913

Tucker and Read (129) have studied the reaction between nitrogen, alumina, and carbon, and state the necessary conditions for a good yield. 1912

Stähler and Elbert (100) have studied the reaction for the formation of boron nitride by heating boron oxide or boro-calcite with carbon in the presence of nitrogen at various pressures. From the mixture containing oxide a yield of more than 85 per cent of $B\,N$ was obtained under increased pressure at temperatures between 1500 and 1700 deg. C. Using instead of oxide, borocalcite (CaB_4O_7) a nearly theoretical yield was obtained between 1400 and 1800 deg. C. without effect from pressure. 1913

OXIDATION OF AMMONIA (OSTWALD PROCESS)

Zeisberg (4) reviews the history of the process and development of the industry for the catalytic oxidation of ammonia to nitric acid with estimates of costs for American conditions. (See Costs). He reviews recent patents and other literature. He states that a successful plant in Westphalia built in 1909 had an annual production of 2400 tons of 53 per cent nitric acid. From Jan. 1911 to Aug. 1912 the efficiency was 89.6 per cent on a monthly production of 130 tons of ammonium nitrate. The efficiency of conversion was 83 per cent and of absorption 97 per cent. This plant operates on coal-tar ammonia. It is stated 1916

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(69) Matignon, Chemiker Zeitung, *38*, 894–5 (1914).
Abstract, Journal, Society of Chemical Industry, *33*, 829 (1914).

(81) Wagner, Zeitschrift, Vereines Deutschen Ingenieure, *58*, 66–7 (1914).

(85) Fraenkel, Zeitschrift für Elektrochemie, *19*, 362–73 (1913).

(97) Richards, Chemical Engineer, *17*, 196–9 (1913).

(98) Ross, Journal, Industrial and Engineering Chemistry, *5*, 725–9 (1913).

(99) Russ, Zeitschrift für Elektrochemie, *19*, 923–5 (1913).

(102) Tucker, Journal, Society of Chemical Industry, *32*, 1143–4 (1913).
Journal, Industrial and Engineering Chemistry, *5*, 191–2 (1913).

(104) Engineering and Mining Journal, *95*, 602 (1913).

(129) Tucker, Read, Transactions, Amer. Electrochemical Society, *22*, 57–66, (1912).

(100) Stähler, Elbert, Berichte, Deutschen Chemischen Gesellschaft, *46*, 2060–77 (1913).

(4) Zeisberg, Metallurgical and Chemical Eng'g. *15*, 299–304 (1916).

that this product has never appeared in the market. In 1912 and 1913, 8 per cent dividends were paid to stockholders. In 1910 the process was purchased by a London company capitalized at £2,000,000 and a new plant was erected in Belgium.

1916 It is stated that the diagrams of the converter given by Schüphaus (27) are the only ones ever published. It is not possible to ascertain actual dimensions used. A few other details of the probable methods of operation of the process are mentioned.

1916 According to Schüphaus (27) the nitric acid needed for the manufacture of sulphuric acid by the chamber process was supplied in Germany, after cutting off of other sources at the beginning of the war, by oxidation of ammonia from ammonia water. He describes the process and the apparatus which is manufactured and sold by the Berlin-Anhaltischen Maschinenbau-Aktiengesellschaft in Berlin.

The ammonia gas is liberated by treating a spray of its 3 per cent solution, mixed with milk of lime, with steam. The gas is passed through coolers to condense the water-vapor and then through caustic soda scrubbers to a gas holder.

The ammonia gas is thoroughly mixed with air and passed over very fine meshed platinum gauze heated by electric current (24 to 26 v. 120–125 amp.) to about 700 deg., where almost quantitative reaction forming nitrogen oxides and water occurs. The oxides then go to the lead chambers.

The apparatus is illustrated by cuts and a photograph, showing the arrangement of the parts of the system. Details of construction are given, but no exact dimensions nor capacities.

1916 Reference (103) mentions that this process has been in successful commercial operation for some time in Belgium and probably has a great future.

1913 The process for the oxidation of ammonia gas to nitric acid (generally known as the Ostwald process) is described in detail in reference (106) with the history of its development. Cuts show the arrangement of a plant capable of converting 25 tons of ammonia per month into about 150 tons of 36 deg. Bé commercial nitric acid. The reaction

$$NH_3+4O=HNO_3+H_2O$$

is brought about by passing the mixture of gases over spongy platinum, or platinum, or platinum black as a catalyser at a temperature of about 300 deg. C. at a velocity of 1 to 5 meters per second. The time of contact between gas and catalyser should not exceed $\frac{1}{100}$ of a second, or decomposition of the product into nitrogen and water will cut down the yield very seriously. Under properly adjusted conditions the yield is very nearly the theoretical.

The condensation plant is also described in detail, and costs are estimated. See Costs (106). 1913

The successful development (107) of the process using platinum for a catalyst is mentioned with outline of its development at Odda and other places in Norway, Iceland and England. 1913

Meneghini (91) has investigated the oxidation of ammonia by various oxides as catalysts. His efficiency was highest with increased rate of gas flow and with those oxides that were effective only at the higher temperatures, exceeding 95 per cent for burnt pyrites, chromic oxide, and oxides of rare earths. Values are given for various temperatures. 1913

Kochman (117) mentions the oxidation of ammonia by metallic contact agents at relatively low temperatures as a practical problem and gives a description and drawing of a furnace. 1912

Meneghini (119) had previously studied the catalytic action of electrically heated platinum and found that no reaction occurred below 350 deg. C. Rapid action occurs between 400 and 450 deg. The principal product was nitrous acid. 1912

Reinders and Cats (122) also studied the conditions for this catalysis using platinum, ferric oxide, platinized copper, thoria. With the first two 80–90 per cent of the ammonia was oxidized to nitric acid and nitrogen trioxide. The velocity of the gas current is very important, there being an optimum for each catalyser. The best temperature found for platinum was 500 deg. C. and for ferric oxide 650–700 deg. C. 1912

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(27) Schüphaus, Metall und Erz, *13*, 21–8 (1916)
Abstract, Metallurgical and Chemical Engineering, *14*, 425–6 (1916).

(103) Tucker, Coal Trades Review (L) May 23, 1913.
Coal Trades Review (L), *11*, 476 (1913).

(106) Metallurgical and Chemical Engineering, *11*, 438–42 (1913).

(107) Times Engineering Supplement, Oct. 15, 1913.
Abstract, Journal, Society of Chemical Industry, *32*, 1008 (1913).

(91) Meneghini, Gazzetta chimica italiana, *43*, (1) 81–90 (1913).
Abstract, Journal, Society Chemical Industry, *32*, 230 (1913).

(117) Kochmann, Arbeit. Pharm. Institut. Berlin, *8*, 81
Abstracts Chemiker Zemtralblatt, 1912 (1) 169.
Chemical Abstracts, 6, 2295 (1912).

(119) Meneghini, Gazzetta chimica italina, *42*, (1) 126–34 (1912).
Abstract, Journal, Society of Chemical Ind., *31*, 383 (1912).

(122) Reinders, Cats, Chemisch Weekblad, *9*, 47–58 (1912).
Abstracts, Chemisches Zentralblatt, *83*, (1) 708 (1912).
Journal, Society of Chemical Industry, *31*, 280, (1912).

THEORY OF THE SINGLE-PHASE ALTERNATING-CURRENT MOTOR

PART II

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In the first part of this article a description is given of the combination of the repulsion motor and the single-phase induction motor to form the shunt compensated repulsion motor, in which the high starting torque of the repulsion motor and the limited no-load speed and flat torque-speed characteristics of the induction motor are retained. The theory of the individual component motors is also discussed. In this installment the theory of the shunt compensated single-phase induction motor, shunt compensated repulsion motor, series compensated repulsion motor, and the compensated induction motor is given.—Editor.

THE SHUNT COMPENSATED SINGLE-PHASE INDUCTION MOTOR

If we impress upon the brushes 7 and 5 a small voltage E_c derived from the line by means of an additional winding on the stator, as shown in Fig. 20, we obtain the shunt compensated induction motor. This voltage can be just large enough to balance the resistance drop $I_c r_c$, as is shown in the diagram of Fig. 21. Assuming sine wave distribution, the motor will run light at synchronous speed, E_{r2} being equal and opposite to E_{w2} at this speed. The secondary current I_2 will be zero, and $I_1 = I_m$. Hence we see that by means of the voltage E_c we have reduced the current drawn from the line at no-load to the magnetizing current which would flow with open armature. The torque exerted by both armature circuits is zero, the current I_2 being zero and I_c being perpendicular to E_{rc}. If, again, we take into account the actual distribution of the flux, the theoretical no-load speed will be equal to $S = 1.045$, which in this case is reduced by the hysteresis, friction and windage only and not by any generator torque in the circuit 5-7. If we increase the voltage E_c beyond the value covered by Fig. 21, we can still further reduce the running light current. In Fig. 22 is shown diagrammatically the operation at synchronous speed, with an impressed voltage E_c of such a time phase and value that the current I_2 is equal to I_m, so that $I_1 = I_m - I_2 = 0$. Under these conditions the stator circuit will not draw any current from the line at synchronous speed.

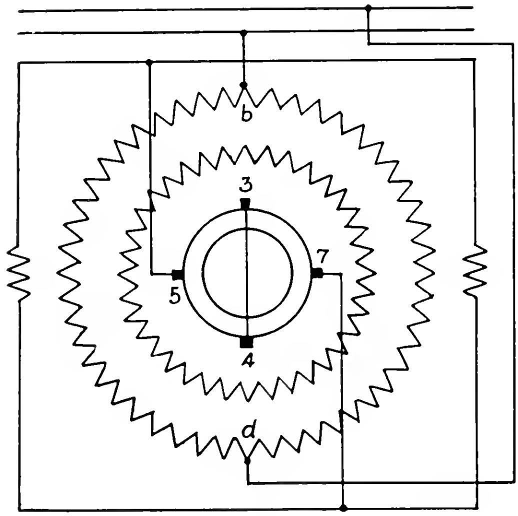

Fig. 20

The current I_2 yields with the flux excited by I_c a generator torque, the angle between E_{r2} and I_2 being smaller than 90 degrees.

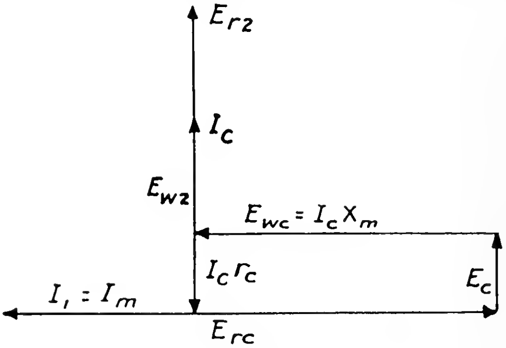

Fig. 21

The current I_c yields with the flux of transformation a motor torque. the angle between I_c and E_{rc} being larger than 90 deg. When loaded the shunt compensated induction motor will operate in a manner similar to the induction motor, and the speed will decrease with increasing load so as to enable the current I_2, which is usually called the "energy current," to increase and change its time phase to exert the torque required by the load, by reacting on the motor field flux yielded by the current I_c, usually called the "compensating current." The principle difference between the shunt compensated and the plain induction motor is that the former will operate in the neighborhood of synchronous speed with a higher power-factor than the latter, depending on the voltage E_c which excites the motor field flux by means of a watt current, as will be noted from Fig. 21 and Fig. 22, in which I_c is practically in time phase with E_c.

At standstill $E_{rc}=0$, so that I_c is very small and lags considerably behind E_c. The starting torque of the shunt compensated induction motor is therefore very small and in general will not suffice for overcoming the static friction.

The Effect of External Reactance in the Compensating Circuit

The circuit 5-7 of Fig. 20, which carries the compensating current I_c, is usually called the compensating circuit. If we insert in this circuit an external reactance x_e and make the compensating voltage E_c equal to the resistance drop $I_c r_c$, we shall obtain at no-load the diagram of Fig. 23. At no-load the rotation voltage E_{r2} will be equal and opposite to the voltage E_{w2} induced by alternation between the brushes 3 and 4. We can calculate the speed S in percentage of the synchronous speed, at which this condition will be fulfilled:

$$E_{rc}=S\ I_m\ X_m.$$

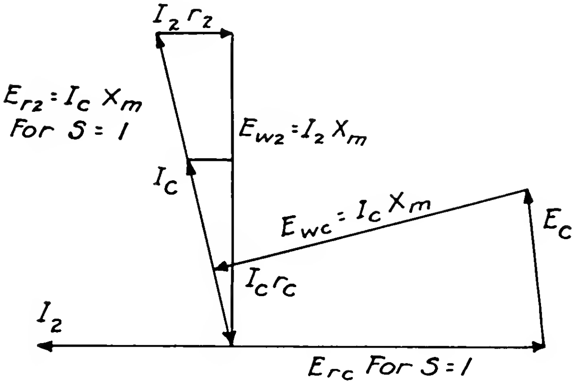

Fig. 22

It further follows from Fig. 23 that:

$$I_c\ X_m+I_c\ x_e=S\ I_m\ X_m \text{ or}$$

$$I_c=\frac{S\ X_m}{X_m+x_e} I_m$$

$$E_{r2}=S\ I_c\ X_m \text{ or } E_{r2}=S^2\frac{X_m}{X_m+x_e}\ X_m\ I_m$$

As $E_{w2}=I_m\ X_m$, we find that E_{w2} will be equal and opposite to E_{r2} for $S^2\frac{X_m}{X_m+x_e}=1$ or

$$S=\sqrt{\frac{X_m+x_e}{X_m}}$$

We thus find a simple equation for determing the no-load speed of the shunt compensated induction motor with external reactance in the compensating circuit. It can be proved easily that this equation applies also in case E_c is larger or smaller than the resistance drop $I_c r_c$.

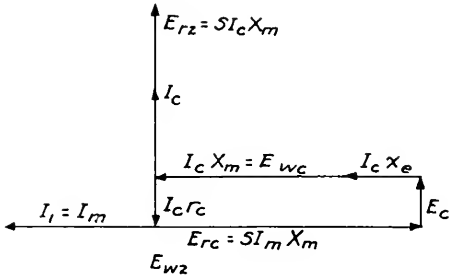

Fig. 23

So far we have neglected the leakage reactance of the armature itself. As long as we have one set of brushes only, as on the plain repulsion motor, this leakage reactance is independent of the speed. If, however, we have two sets of brushes, the reactance voltage induced by the commutation of the current flowing in one of the armature circuits will induce a voltage in the other armature circuit so that the leakage reactance is approximately zero at no-load and complete compensation; i.e., such a value for E_c that $I_2=I_c$ and $I_1=0$. In that case the two quadrature armature circuits carry approximately equal currents differing approximately 90 deg. in time phase, as follows, from Fig. 22, and we have conditions similar to those existing in the quarter-phase series motor, for which we have found the armature reactance to be approximately zero at synchronous speed.

If we compensate, as shown in Fig. 21, then the current in the energy circuit is zero and the leakage reactance of the armature compensating circuit will not disappear at synchronous speed, but will have the same effect as an external reactance, i.e., it will raise the no-load speed.

If we have no compensation at all, as shown in Fig. 19, the current in the energy circuit is reversed, which has the same effect approximately as doubling the leakage reactance of the armature compensating circuit and results in a corresponding increase in the no-load speed.

The above considerations lead to the conclusion that a high compensating voltage E_c tends to decrease the no-load speed, provided we do not introduce an additional external reactance by securing this increased compensating voltage from a source with high internal leakage reactance. The increased losses which are incidental to an increased compensation further decrease the no-load speed.

The compensating voltage required for obtaining complete compensation is approximately equal to

$$E_c \cong I_m\,(r_c+r_2+r_e+2\,r_b)$$

in which r_e is the internal resistance of the source which supplies the voltage E_c, I_m the magnetizing current reduced to the armature circuit, and $r_b=\frac{\text{brush drop}}{I_m}$.

As the shunt compensated induction motor has little practical value on account of its lack of starting torque we will not go further into its theory, but will explain how some of the phenomena which we have analyzed for both the repulsion motor and the shunt compensated induction motor reappear in the shunt compensated repulsion motor, which is a combination of the repulsion and shunt compensated induction motors. (1)

THE SHUNT COMPENSATED REPULSION MOTOR

A comparison of Fig. 3 representing the shunt compensated repulsion motor, and Fig. 20 representing the shunt compensated induction motor, immediately shows the difference between the two motors which, if we neglect the external reactance shown in Fig. 3 and not in Fig. 20, merely results from the brush shift A that divides the stator winding of Fig. 3 into two components, one of which (the stator transformation turns) is in inductive relation to the armature circuit 3-4 and the other (the motor field turns) is in inductive relation to the armature circuit 5-7. If the compensating voltage E_c has such a value that both the motor field flux and the flux of transformation are excited by it, in which case the diagram at no-load is covered by Fig. 22, a small brush shift will not materially alter the conditions; the stator turns of transformation, which are equal to *cos* A times the total number of turns, being reduced by only a slight amount, so that the flux of transformation is changed only slightly while the motor field turns do not carry any current and therefore cannot change the conditions. As soon as the motor is loaded the primary load current flowing through the motor field turns will help to excite the motor field flux and the voltage diagram of the circuit 5-7 will be changed. The compensating current I_c will be reduced and the vector diagram which results can be covered by Fig. 24. Assuming that both stator and rotor have the same number of effective turns $W_2=W_1$, then with a brush shift A the resultant ampere turns OL exciting the motor field flux are the vector sum of I_1W_1 *sin* A and I_cW_1. The motor field flux F yielded by these ampere turns induces by alternation in the compensating circuit the voltage E_{wc} lagging 90 deg. in time phase behind the flux and induces by rotation in the energy circuit the voltage $E_{r2}=$ S E_{wc} in time phase with the flux. The motor field turns W_1 *sin* A and the armature compensating circuit 5-7, are in the same relation to each other as the primary and secondary winding of a series transformer with air gap, the secondary winding being connected to a source in which the voltages E_c and $E_{rc}=SI_m\,X_m$ are induced and having a leakage reactance x_e and resistance r_c+r_e. The secondary induced voltage of the transformer is E_{wc}. As long as the vector sum of E_c and E_{rc} is larger than E_{wc}, as is the case in Fig. 24, the compensating current I_c (which by the reactance drop $I_c\,x_e$ and the resistance drop $I_c\,(r_c+r_e)$ built up by it in the compensating circuit balances the vector difference between E_{wc}, E_{rc} and E_c), will have such a time phase that the sum of the ampere turns of I_cW_1 and $I_1\,W_1$ sin A is larger than either of the components. The motor field flux in this case is excited partly by the primary ampere-turns $I_1\,W_1$ *sin* A and partly by the compensating ampere-turns $I_c\,W_1$.

When the speed of the motor decreases, $E_{rc}=SI_m\,X_m$ will also decrease and a condition will soon be reached where E_{wc} is larger than the sum of E_c and E_{rc}. At standstill $E_{rc}=0$ and the diagram for this condition is represented in Fig. 25. In this case, moreover, we have to take into account the leakage reactance x_c of the armature circuit, which is only negligibly small at synchronous speed and under the conditions described above. OL again represents the ampere-turns exciting the motor field flux.

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(1) For a complete theory of the shunt compensated induction motor see "E. Arnold, Die Wechselstromtechnik BdV2."

A comparison of Fig. 24 and Fig. 25 shows how the compensating current changes its time phase with decreasing speed, so that at standstill $I_1 W_1$ *sin* A and $I_c W_1$ are nearly opposite to each other. The flux of transformation induces between the brushes 3-4 a voltage E_{w2} that is balanced by the reactance and resistance drop $I_2 x_2$ and $I_2 r_2$ of the circuit 3-4. In the circuit 5-7 at standstill the voltage E_{wc} induced by the motor field flux is balanced by the applied compensating voltage E_c and the impedance drop $I_c \sqrt{(x_c+x_e)^2+(r_c+r_e)^2}$. The stator field turns are equal to W_1 sin A. We can assume that they are equal to W_1 and that the current is equal to I_1 *sin* A. In that case the mutual inductive reactance will be constant and equal to X_m. The equivalent circuit for the stator field turns in inductive relation to the armature circuit 5-7 has been represented in Fig. 25. If $E_c=0$ we have simply a reactance in multiple with an impedance, which gives as resultant impedance:

$$\frac{X_m\sqrt{(x_c+x_e)^2+(r_c+r_e)^2}}{\sqrt{(X_m+x_c+x_e)^2+(r_c+r_e)^2}}$$

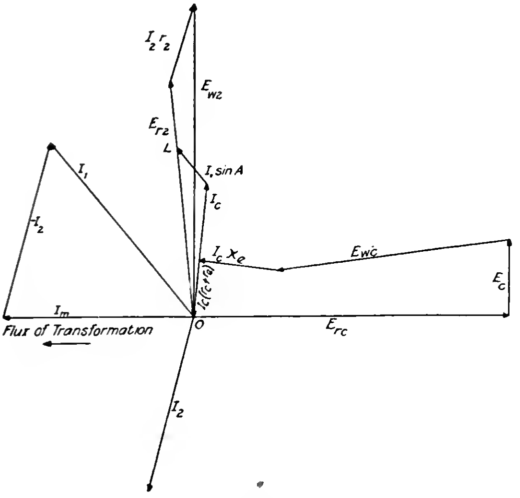

Fig. 24

so that

$$E_{wc}=I_1 \sin A\,\frac{X_m\sqrt{(x_c+x_e)^2+(r_c+r_e)^2}}{\sqrt{(X_m+x_c+x_e)^2+(r_c+r_e)^2}}$$

$$I_c=\frac{E_{wc}}{\sqrt{(x_c+x_e)^2+(r_c+r_e)^2}}$$

$$=I_1 \sin A\,\frac{X_m}{\sqrt{(X_m+x_c+x_e)^2\ (r_c+r_e)^2}}$$

and the magnetizing current required for exciting the flux which induces E_{wc} is equal to

$$I_{m2}=\frac{E_{wc}}{X_m}=I_1 \sin A\,\frac{\sqrt{(x_c+x_e)^2+(r_c+r_e)^2}}{\sqrt{(X_m+x_c+x_e)^2+(r_c+r_e)^2}}$$

If the circuit has been opened and E_c is directly applied to X_m, a current I_{mc} would flow so that $E_c=X_m\ I_{mc}$. Hence, for the circuit of Fig. 26 we can calculate the currents I_{m2} and I_c by first resolving (as has been shown in Fig. 27) I_1 *sin* A$=OK$ in two currents, viz., $OH=I_{mc}$ which furnishes the ampere-turns required by E_c, and I_1 *sin* A$-I_{mc}=HK$. We then find that

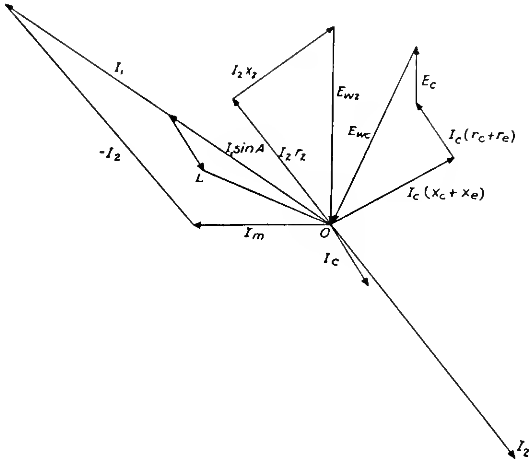

Fig. 25

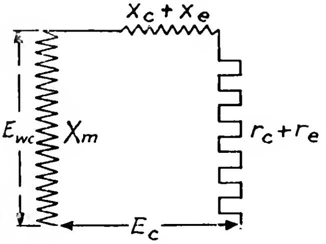

Fig. 26

$$HL=I_{m2}=HK\frac{\sqrt{(x_c+x_e)^2+(r_c+r_e)^2}}{\sqrt{(X_m+x_c+x_e)^2+(r_c+r_e)^2}}$$

$$LK=I_c=HK\frac{X_m}{\sqrt{(X_m+x_c+x_e)^2+(r_c+r_e)^2}}$$

With the aid of the above equations we are able to predetermine the starting torque of the shunt compensated repulsion motor. We reduce all quantities to the armature circuit. Assuming a certain brush shift A and secondary current I_2 we make (see Fig. 28) $OA = I_2r_2$ $AB = I_2x_2$ and find $OB = E_{w2}$. E_{w2} is induced by the flux of transformation which requires a magnetizing current $I_m = \frac{E_{w2},}{X_m}$ which we set off at right angles to E_{w2} and which we can obtain from the saturation curve. The combination of I_m and I_2 gives the primary current I_1 reduced to the secondary, and as the primary turns of transformation are equal to W_1 *cos.* A, the primary current will be equal to $\frac{I_1}{\cos A}$. The ampere turns exciting the motor field flux are therefore equal to $I_1 W_1 \frac{\sin A}{\cos A}$ and not $I_1 W_1 \sin A$, as shown in Figs. 24, 25 and 27. As long as the angle of brush shift A is small, *cos* A can be omitted without altering the results. The voltage induced by the flux of transformation in the stator transformation turns is equal to $OP = OB \cos A$.

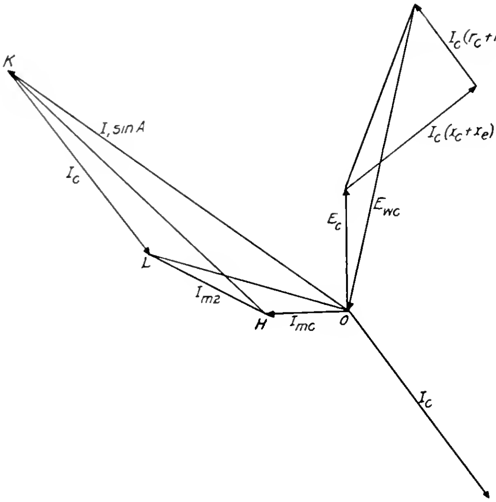

Fig. 27

We find $\frac{I_1}{\cos A} r_1 = PC$ and $\frac{I_1}{\cos A} x_1 = CD$, the primary resistance and reactance drop.

If E_c is equal to the compensating voltage induced in the stator compensating winding at standstill with open armature and full line voltage E_1 applied to the stator, at starting the compensating voltage will be equal to $OF = \frac{E_{w2}}{E_1} E_c$, which is set off in Fig. 28 in time phase with OB. We find the magnetizing current $I_{mc} = \frac{OF}{X_m}$ and set this current off as OH at right angles to OP. We further make $OK = I_1 \frac{\sin A}{\cos A}$ and find HK. Then

$$HL = I_{m2} = HK \frac{\sqrt{(x_c + x_e)^2 + (r_c + r_e)^2}}{\sqrt{(X_m + x_c + x_e)^2 + (r_c + r_e)^2}}$$

and

$$LK = I_c = HK \frac{X_m}{\sqrt{(X_m + x_c + x_e)^2 + (r_c + r_e)^2}}$$

so that the triangle KHL can be constructed, in which $HL = I_{m2}$ and $LK = I_c$. Hence, the resultant ampere turns which excite the motor field flux are equal to $W_1 \times OL$. The motor field flux induces in the stator field turns a voltage $DM = OL.\ X_m \sin A$ at right angles to OL, so that the applied line voltage should be equal to $OM = E_l$. The torque in synchronous watts exerted by the energy current I_2 through its reaction on the motor field flux is equal to $OL.I_2\ X_m \cos AOL$, and the torque exerted by the compensating current $I_c = LK$ by its reaction on the flux of transformation is equal to $I_m L.K.\ X_m \cos KNO$. In order to find the actual

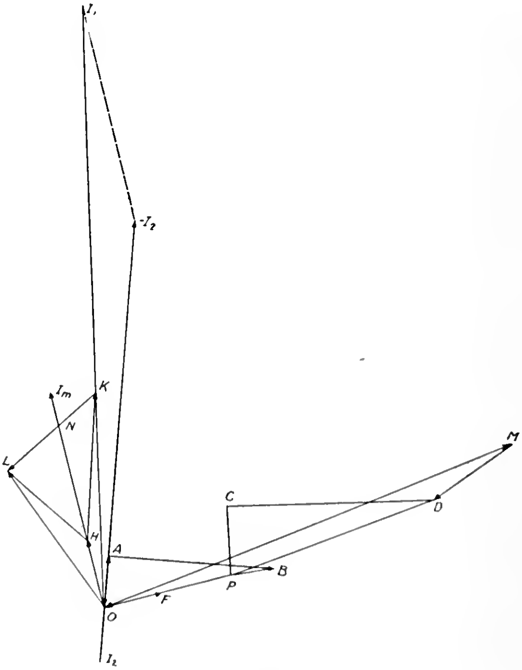

Fig. 28

primary line current, we have to reduce the current and voltage to the primary turns. If we find that the voltage thus obtained does not correspond to the line voltage to be applied to the motor, we can repeat the calculation or recalculate both current and torque by assuming that the former changes proportionally to the line voltage and the latter proportionally to the square of the line voltage. We should also add to I_1, under the proper angle, I_c reduced in the ratio of the turns of the compensating coil to the primary turns.

The construction of the diagram for the running condition is still more complicated. If we assume the angle of brush shift A, the speed S, the flux of transformation inducing between the brushes 3-4 the voltage E_{w2}, and the secondary current I_2 both in magnitude and time phase, we can construct a diagram which will show how large the reactance x_e and the voltage E_c of the compensating circuit should be in order to have the motor operate under these conditions. Finally the torque, output, primary current, efficiency and the power-factor can be determined for the operating conditions covered by the diagram. In Fig. 29 we have made OB equal to the assumed voltage E_{w2} and I_2 equal to the assumed current. We set off $BA = I_2 x_2$ and $AC = I_2 r_2$ and find $OC = E_{r2}$. The voltage OB is induced by the flux of transformation, requiring the magnetizing current I_m to be determined with the aid of the excitation curve. By subtracting I_2 vectorially from I_m we find I_1. With the aid of an excitation curve we further find that it takes OL amperes to excite with $W_2 = W_1$ turns $\frac{OC}{S}$ volts. Hence, the equivalent magnetizing current for the motor field flux is OL. We make $OK = I_1 \frac{\sin \mathrm{A}}{\cos \mathrm{A}}$ and find that the compensating current I_c must be equal to KL. For the compensating circuit we make $OS = S.OB$, $OH = \frac{OC}{S}$ at right angles to OC, and $HG = I_c\ (r_e + r_c)$ parallel to KL. In G we draw a line at right angles to HG and in S a line at right angles to OS. These two lines meet in F and we should make $E_c = FS$ and the value of x_e such that $GF = I_c\ x_e$. We further make $OP = OB \cos \mathrm{A}$, $PQ = I_1 \frac{r_1}{\cos \mathrm{A}}$, $QR = I_1 \frac{x_1}{\cos \mathrm{A}}$, $RM = OH \sin \mathrm{A}$, and find the line voltage $OM = E_l$ to be applied to the motor. If the stator turns differ from the rotor turns we can reduce this voltage in the proper ratio. The torque in synchronous watts exerted by the current I_2 is equal to $I_2 \frac{OC}{S} \cos\ (180° - COI_2)$, and the torque exerted by the current $I_c = LK \times OB \cos ONL$, if the prolongation of LK meets OS in N. The output can be calculated from the torque and the speed. The input is equal to $I_1 \times OM \cos I_1\ OM$. By dividing the output minus the friction windage and core loss by the input, we find the efficiency. The power-factor is equal to $\cos I_1\ OM$. In order to obtain the real primary current, we should have added to I_1 under the proper angle the compensating current $\frac{FS}{OB} LK$.

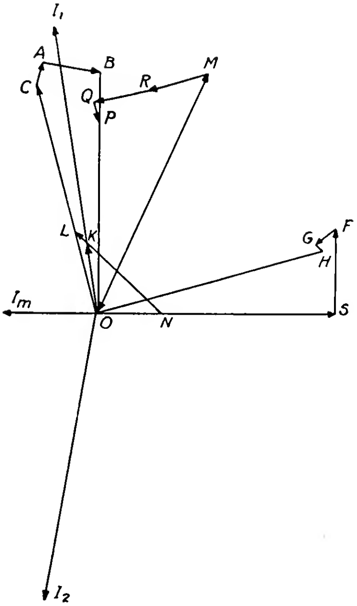

Fig. 29

The calculation can be repeated for different values of the secondary current, brush shift, speed, and voltage E_{w2} until the desired load point has been obtained in a brush position in which the motor exerts sufficient starting torque and does not run at too high a no-load speed. Instead of taking into account the full rotor reactance x_c at standstill and no rotor reactance at full speed for the compensating circuit, we can always figure with the full rotor reactance for both compensating and energy circuit and introduce in the energy circuit the voltage $I_c\, x_n$ and in the compensating circuit $I_2\, x_n$ for the voltage induced by the commutation of both the energy and the compensating current.

Commutation

The commutation conditions of the energy brushes when the motor is running are essentially the same as for the brushes of the repulsion motor. At starting they are considerably better due to the reduction of the motor field flux. Hence the armature of the shunt compensated repulsion motor can be wound for a considerably higher voltage than that of the repulsion motor without exceeding the safe commutation limits at starting, which results in a material reduction in the size of the commutator and the brush service.

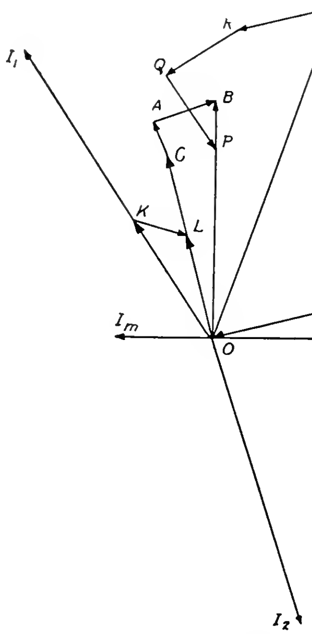

Fig. 30

An examination of Fig. 3 shows that the axis of the coil short circuited by the compensating brush 7 follows the axis of the stator turns of transformation. Hence, a voltage lagging 90 deg. behind the flux of transformation will be induced in this coil. The axis of the coil short circuited by brush 7 is displaced 90 deg. in the direction of rotation with respect to the axis of the motor field turns hence by rotation a voltage will be induced in it which is in time phase with the motor field flux, i.e., opposite to the voltage induced by the alternation of the flux of transformation. The flux of transformation increases approximately proportionally to the speed and the motor field flux and the voltage induced by rotation through the motor field flux increases proportionally to the speed and the motor field flux so that the resultant voltage induced in the coils short circuited by the compensating brushes is approximately zero for all speeds. The commutation of the compensating brushes does for this reason not offer any difficulties.

If we take into account the secondary impedance drop for determining the flux of transformation, then at standstill both the flux of transformation and the voltage induced in the coils short circuited by the brush are not zero.

Reversed Compensation

If we reverse the connections between the stator compensating coil and the compensating brushes, then the motor will operate with an extremely low power-factor. Fig. 30 covers the diagram for this condition, and has been drawn in the same way as Fig. 29, with the compensating voltage $E_c = SF$ in the opposite direction. Unless the reactance and resistance drop of the compensating circuit is very large, the compensating current which flows in the opposite direction will have to be

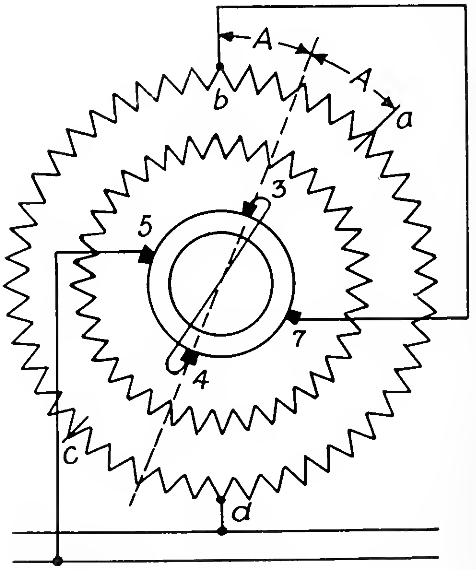

Fig. 31

very large in order to balance the vector difference between F and H. If the reactance and resistance of the compensating circuit is small, then the rotation voltage OC will have to lead OB in order that OH, which is at right angles to OC, may move to the other side of OS and thus bring H and F together. This means that the secondary current has to lag still more and still further lowers the power-factor of the primary current. The reduction of the power-factor further affects the output of the motor, and the condition of reversed compensation is therefore always easily recognized.

For the performance curves of the shunt compensated repulsion motor we refer to Fig. 4 and Fig. 7 on page 582 and 583 of the GENERAL ELECTRIC REVIEW of July, 1916.

SERIES COMPENSATED REPULSION MOTOR

If we connect the compensating brushes 5 and 7 of Fig. 3 in series with the line, we obtain the series compensated repulsion motor shown in Fig. 31. Instead of connecting these brushes directly in series with the stator winding, we can do this over a series transformer. If the ratio of the primary to the secondary turns of the series transformer equals c, the number of armature turns between two diametrical brushes W_2, the number of turns thus connected in series with the stator winding reduced to the primary circuit will equal $W_3 = W_2$ *eff* c. We have found that with the motor represented by Fig. 1, the number of field turns exciting the motor field flux equals W_1 *eff. sin* A. Hence if $W_1 = W_2$ the total number of field turns of the motor covered by Fig. 31 will be equal to W_1 *eff.* $(\sin \mathrm{A} + c)$. The leakage reactance and the resistance of this additional field circuit, which we will call the armature compensating circuit reduced to the primary circuit, equals $x_2\, c^2$ and $r_2\, c^2$. The characteristics of this motor can be derived in the same manner as explained for the repulsion motor, bearing in mind that the field turns are equal to W_1 *eff.* $(\sin \mathrm{A} + c)$ instead of W_1 *eff. sin* A. The motor operates like the repulsion motor, with the difference that the field flux is excited by ampere turns which are partly located on the armature and partly on the primary.

In Fig. 32 we show the vector diagram for the motor covered by Fig. 31, with the aid of which we can determine the speed, the power-factor, efficiency, torque and output for a given brush shift A, transformer ratio c, and line voltage E_l. We make:

$OA = I_1\ (r_1 + r_2 \cos^2 \mathrm{A} + r^2\, c^2)$

$AC = e_b\ (c + \cos.\ \mathrm{A})$ if e_b is the reduced brush drop of one circuit for $A = O$.

$CD = I_1\ (x_1 + x_2 \cos.^2 \mathrm{A} + x_2\, c^2)$

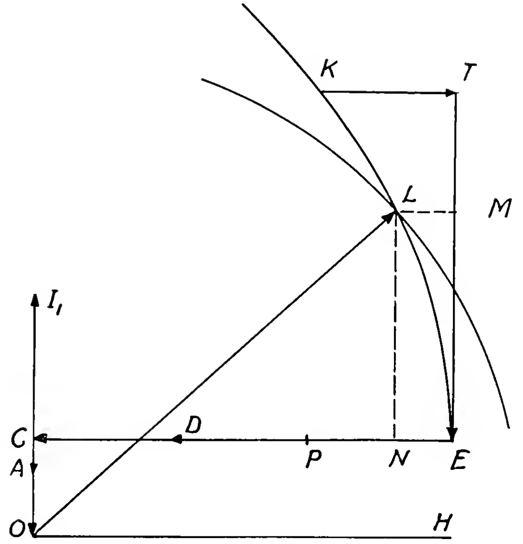

Fig. 32

DE = field drop determined with the aid of Fig. 15 for the abscissa $OX = I_1\ (\sin \mathrm{A} + c)$ for which $XA = E$ so that $DE = E\ (\sin \mathrm{A} + c)$

$ET = E \cos.\ \mathrm{A}$.

Furthermore, due to the rotation through the flux of transformation, a voltage will be induced between the brushes of the compensating circuit proportional to the speed and proportional and opposite to the flux of transformation; the axis of the compensating circuit being displaced 90 deg. opposite to the direction of rotation with respect to the axis of the flux of transformation. For $S = 1$, this voltage reduced to the primary circuit will be equal to cE and has been drawn in Fig. 32 as $KT = cE$. For any speed differing from synchronous speed this voltage will be equal to $S^2\, cE$, as it is proportional to both the speed and the flux of transformation, the latter also being proportional to the speed. The locus KE of the vector sum of the voltage of transformation and the voltage induced by rotation in the armature compensatng circuit can easily be determined, and has been shown in Fig. 32. With the line voltage E_l as radius, we can draw a circle which intersects KE in L. The speed S in percentage of synchronous speed will be equal to $S=\frac{ME}{TE}$.

The efficiency, power-factor, torque and output can be determined in a way similar to that for the repulsion motor. The diagram is substantially the same as that of the polyphase series motor (2) with the exception that KE is no longer a straight line. The voltage induced between the compensating brushes improves the power-factor. For $A=O$, we will have $KT=DE$, and the power-factor will be unity when the motor is running slightly above synchronous speed. We can even operate this motor with unity power-factor at synchronous speed if we shift the brushes beyond the neutral so that $KT=CE$. The commutation, however, is inferior in that case, so that in general the brushes should not be shifted back further than to the line neutral position.

So far we have neglected the influence of the magnetizing current required for exciting the flux in the series transformer. This flux leads the voltage appearing at the armature compensating brushes by 90 deg. The voltage induced by transformation between these brushes is equal to $PE=\frac{c}{sin\ \Lambda+c}\ DE$. The voltage induced by rotation through the flux of transformation is equal to NE, N being the projection of L on CE (see Fig. 32). Hence, the voltage appearing at the compensating brushes is equal to NP and the flux in the series transformer will be in time phase with the line current I_1. As this flux has to be excited by the vector difference between the primary and secondary ampere-turns of the transformer, it follows that the secondary ampere-turns will have to be lower than the primary. As long as we neglected the magnetizing current required for exciting the flux in the transformer, the compensating current was equal to cI_1. If we have a saturation curve taken on the primary of the transformer, we know that for the speed under consideration, at which the compensating voltage is equal to NP, a magnetizing current I_t is required. Hence, in that case, the compensating current will be equal to $c\ (I_1-I_t)$ and the total number of ampere turns exciting the motor field flux $I_1\ W_1\ eff.\ sin\ A+c\ I_1\ W_1\ eff.-c\ I_t\ W_1\ eff.$ With the aid of Fig. 15, we can find the voltage E for $OX=$

$$\frac{I_1\ W_1\ eff.\ sin\ \Lambda+c\ I_1\ W_1\ eff.-c\ I_t\ W_1\ eff.}{W_1\ eff.}$$

and we can make:

$$DE=E\ (sin\ \Lambda+c).$$

The voltage across the transformer is $NP=cE\ (1-S^2)$.

If this voltage differs from the transformer voltage which we have assumed for the speed under consideration, the calculation has to be repeated.

The transformer has the same effect as an increase of the magnetic reluctance of the path of the motor field flux at the low speed; which means that, due to the reduction in the field drop with a certain brush-shift and line voltage, the motor can draw more current from the line and the torque will be increased as long as the reduction of the motor field flux is not carried on too far. The reduction of the motor field flux will further result in improved commutation at low speed. As soon as the motor runs above synchronous speed, the voltage NP appearing at the compensating brushes reverses its direction and is opposite to ED. Hence, the flux in the transformer will be opposite to the line current I_1 and the secondary ampere turns of the transformer will have to be larger than the primary ampere turns. If I_t is again the magnetizing current required by the transformer, the motor field flux will be excited by $I_1\ W_1\ eff.\ sin\ \mathrm{A}+c\ I_1\ eff.+I_t\ E_1\ eff.$ ampere-turns. Hence, the larger the magnetizing current I_t of the transformer, the sooner the motor field flux will increase with increasing speed, in spite of the reduction of line current I_1, and thus the speed can be limited. The increase of the secondary current flowing in the circuit 3-4 with increasing speed, which has been analysed for the repulsion motor, helps in limiting the speed.

The transformers of standard motors are designed in such a manner that the no-load speed is no more than 150 per cent of the synchronous speed.

I_t required for exciting the flux of the transformer can be larger than the line current I_1. In that case, when running below synchronous speed, part of the excitation will be furnished by the secondary turns of the transformer and the current in the armature compensating circuit will be reversed so that the ampere-turns yielded by it are opposite to the ampere-turns of the stator field turns. Part of the excitation required by the flux of the transformer is transmitted by transformation from the stator field-turns to the armature compensating circuit and

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[2] (See G.E. Review, February, 1916.)

flows from there to the secondary of the transformer.

In case it is desired to run the motor of Fig. 31 counter-clockwise in a brush position in which the motor has the same characteristics as in the brush position *A* in which the motor runs clockwise, we should shift the brushes clockwise over 180-2*A* degrees. On the plain repulsion motor we could have shifted the brushes just as well over 2*A* degrees counter-clockwise to obtain the same result; but on the compensated repulsion motor this cannot be done, as the armature compensating circuit and stator field winding buck one another. Nevertheless, it is possible to obtain counter-clockwise operation by shifting the brushes far enough counter-clockwise; however, the power-factor and commutation will be inferior. As with the polyphase brush-shifting motor, the voltage *KT* of the diagram of Fig. 32 has in that case to be put into the right of *TE* which explains diagrammatically the reduction of the power-factor.

The torque, speed, efficiency, and power-factor characteristics of the series compensated repulsion motor have been shown on page 582 of the GENERAL ELECTRIC REVIEW of July, 1916, in an article which also deals with its practical application, as varying speed brush-shifting motor.

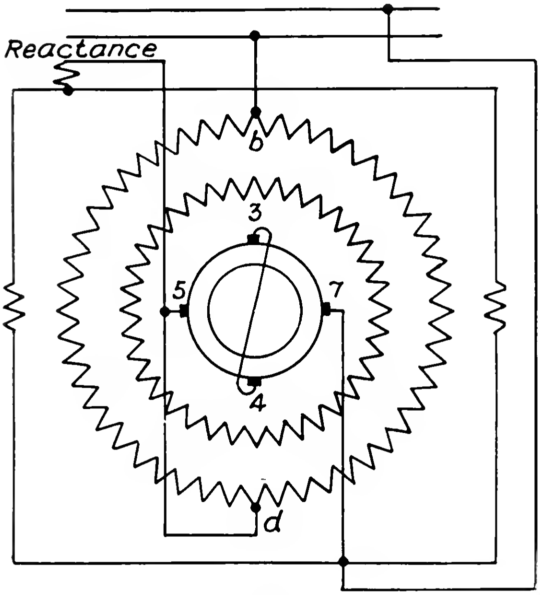

Fig. 33

By shifting the brushes the motor field turns can be varied, which results in a variation of the speed. The motor is designed in such a manner that the brushes are in the live neutral when it is carrying its full load at full speed. In this brush position the motor really operates as what might be called a series compensated induction motor, the motor field flux being yielded by the armature compensating turns only, which are connected in series with the line.

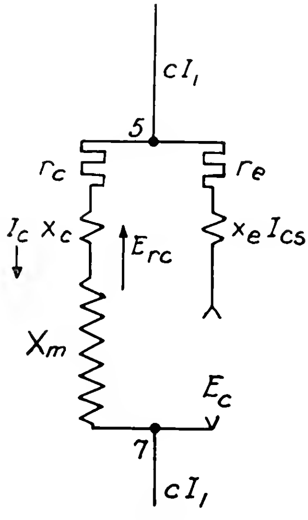

Fig. 34

Commutation

The commutation conditions are essentially the same as for the shunt compensated repulsion motor, only at starting and slow speed the series compensated motor will usually operate with a higher motor field flux than the shunt compensated motor. This depends on the design of the series transformer.

THE COMPOUND COMPENSATED INDUCTION MOTOR

If we connect the end *d* of the stator winding of the shunt compensated induction motor to the compensating brush 5 instead of to the line, and connect the compensating brush 7 to the line, we obtain the compound compensated induction motor of Fig. 33. This motor has characteristics similar to those of the shunt compensated repulsion motor represented by Fig. 3, the principal difference being that the field turns through which the line current flows are no longer located on the stator but on the rotor, while the compensating current is the combination

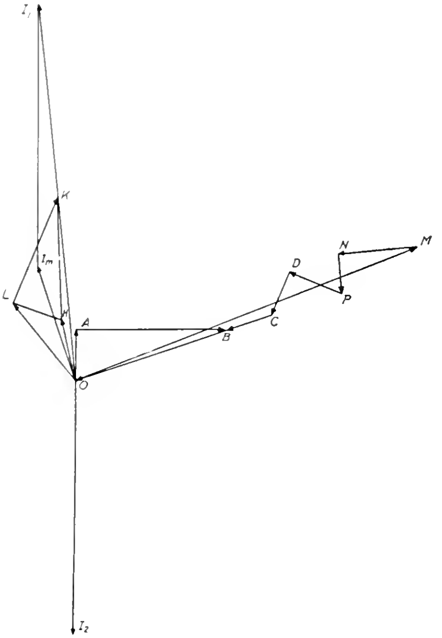

Fig. 35

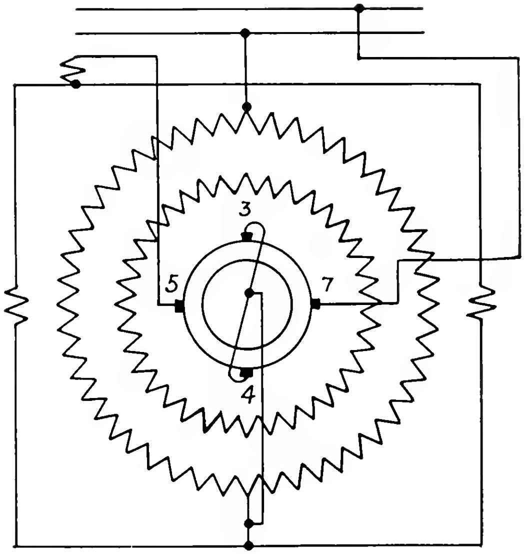

Fig. 37

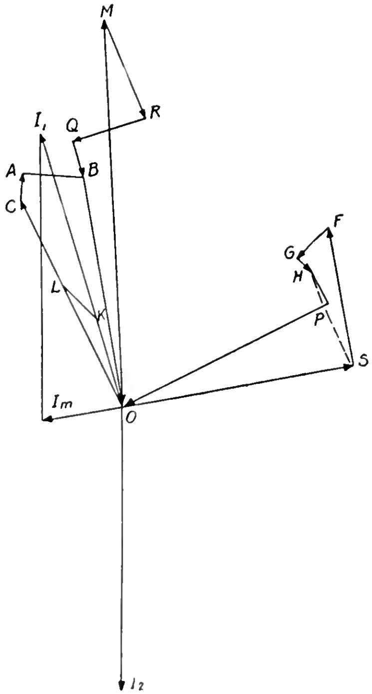

Fig. 36

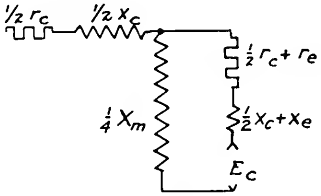

Fig. 38

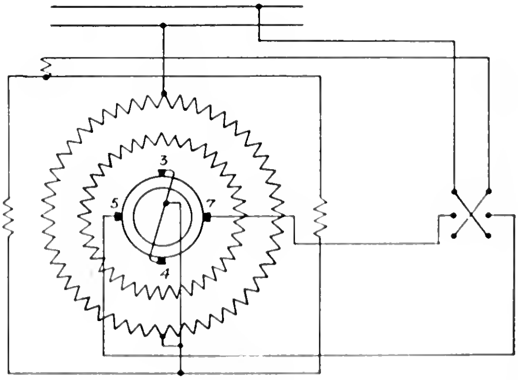

Fig. 39

of the line current and the current resulting from the voltage E_c induced in the stator compensating coil. The equivalent circuit for the armature and stator compensating circuit has been represented in Fig. 34. The current flowing from brush 5 to 7 we will call I_c, and the current flowing through the stator compensating coil I_{cs}. I_1 is the primary current reduced to the secondary, and c is equal to the ratio of the secondary to the primary turns of the motor. In accordance with Kirchhofs law the vector sum of I_c, I_{cs} and I_1 must be zero.

With the aid of the equivalent circuit we can calculate the starting torque and current in a way similar to that for the shunt compensated repulsion motor in Fig. 28. We assume the secondary current I_2 and make (see Fig. 35) $OA=I_2\ r_2$, $AB=I_2x_2$, and find $E_{u2}=OB$. If with a line voltage E_l the compensating voltage is equal to E_c, at starting the compensating voltage will be equal to $\frac{OB}{E_l}E_c$. The line current cI_1 has to be resolved into two components in such a manner that the vector sum of the voltages in both circuits is equal. Therefore, we subtract from cI_1 the current OH, so that

$$OH=\frac{OB}{E_l}E_c\frac{1}{\sqrt{(X_m+x_c)^2+r_c^2}}$$

If $OK=cI_1$, then we have to resolve HK into two currents, i.e.,

$$HL=\frac{\sqrt{x_e^2+r_e^2}}{\sqrt{(X_m+x_e+x_c)^2+(r_e+r_c)^2}}HK$$

and

$$LK=\frac{\sqrt{(X_m+x_c)^2+r_c^2}}{\sqrt{(X_m+x_e+x_c)^2+(r_e+r_c)^2}}HK$$

The compensating current $I_c=OL$, and the current flowing through the stator compensating coil $I_{cs}=LK$. For the calculation of the torque we refer to Fig. 28.

To OB we add $BC=\frac{OB}{E_l}\ E_c$; $CD=I_{cs}\ r_e$; $DP=I_{cs}\ x_e$; $PN=I_1\ r_1$ and $NM=I_1\ x_1$ and find the line voltage OM.

The diagram for the operation at full speed can also be drawn and has been shown in Fig. 36. We can derive it like the diagram of Fig. 29. We assume a secondary current I_2 and voltage OB. We make $CA=I_2\ r_2$ $AB=I_2\ x_2$. Then the voltage to be induced by rotation is equal to CO. After assuming the speed S, we find with the aid of a saturation curve the current OL. The primary current I_1 is found by adding the magnetizing current I_m to I_2; $OK=c\ I_1$, and we thus find the current $LK=I_{cs}$ which flows through the stator compensating coil. We further make $OS=\ S.OB$ perpendicular to OB and $OP=\frac{OC}{S}$ perpendicular to OC. To P we add $PH=OLr_e$ parallel to OL and $HG=LKr_c$ parallel to LK. We then draw SF perpendicular to OS and GF perpendicular to HG. The latter lines meet in F, so that the compensating voltage should be equal to SF, and we have to select the value of x_e in such a manner that $x_e=\frac{GF}{LK}$. To B we add $BQ=I_1\,r_1$; $QR=I_1\ x_1$ and $RM=HS$, i.e., the drop across the brushes 5 and 7. The rest of the calculation is similar to that of Fig. 29.

As to the relative value of the shunt compensated repulsion motor and compound compensated induction motor, the diagrammatic analysis shows that if with a certain starting torque we want to obtain as low a no-load speed as possible and the smallest possible variation between no-load and full load speed, the shunt compensated repulsion motor will be the more suitable one. A comparison of Fig. 26 and Fig. 34, representing the equivalent circuits for the field circuits of both types of motors, shows that in the case of the shunt compensated repulsion motor the mutual inductive reactance X_m (see Fig. 26) is connected in multiple to x_e+x_c and r_e+r_c, while in the case of the compound compensated induction motor (see Fig. 34) X_m is connected in series with x_c and r_c and in multiple to x_e and r_e. This means that if we want to obtain the same field flux at starting, x_e will have to be larger for the compound compensated induction motor than with the shunt compensated repulsion motor. An increase of x_e results in a higher no-load speed, as has been explained before. This condition can be improved by connecting the shunt compensation across half the armature from 5 to 3 and the series compensation from 3 to 7 as has been shown in Fig. 37. In this case we get for the equivalent field circuit Fig. 38, which is essentially the same as Fig. 26. Hence, the diagram of Fig. 28 can be used for determining the starting torque and the diagram of Fig. 29 for the operation at full speed. We have only to add $cI_1\frac{1}{2}\ r_c$ and $c\ I_1\frac{1}{2}\ x_c$ to RM, and when the motor is running the rotation voltage induced between the brushes 5 and 7.

As the brushes are standing in the neutral position the motor can be readily reversed by a change in connections by means of a double throw switch, as shown in Fig. 30. It is possible to take a standard Type RI, shunt compensated repulsion motor and operate it with the brushes in the neutral position as a reversible compound compensated induction motor connected as in Fig. 39. This applies to the 110-volt connection in which the two circuits of the stator winding are connected in multiple. In the 220-volt connection, in which the two stator circuits are connected in series, the whole armature is used for the series excitation, as shown in Fig. 40. The equivalent current for this connection has been shown in Fig. 41. In some cases, to secure higher starting torque, it is necessary to connect a small reactance in series with the stator compensating coil. The characteristics of this motor are represented by Fig. 15, page 584, General Electric Review, July, 1916.

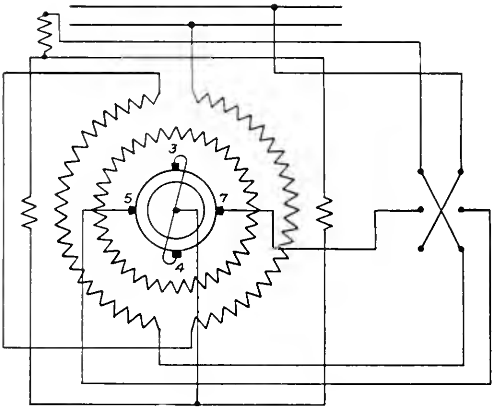

Fig. 40

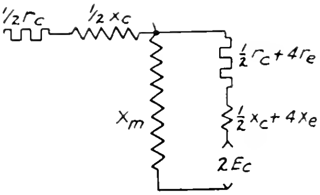

Fig. 41

QUESTION AND ANSWER SECTION

The purpose of this department of the REVIEW is two-fold.

First, it enables all subscribers to avail themselves of the consulting service of a highly specialized corps of engineering experts, or of such other authority as the problem may require. This service provides for answers by mail with as little delay as possible of such questions as come within the scope of the REVIEW.

Second, it publishes for the benefit of all REVIEW readers questions and answers of general interest and of educational value. When the original question deals with only one phase of an interesting subject, the editor may feel warranted in discussing allied questions so as to provide a more complete treatment of the whole subject.

To avoid the possibility of an incorrect or incomplete answer, the querist should be particularly careful to include sufficient data to permit of an intelligent understanding of the situation. Address letters of inquiry to the Editor, Question and Answer Section, General Electric Review, Schenectady, N. Y.

INDUCTION MOTOR: STARTING TORQUE

(202) What is the ratio existing between the low-speed and high-speed starting torques of a two-speed induction motor?

Two-speed induction motors do not possess a common ratio between their low-speed and high-speed starting torques. The value of the ratio is a property of the particular design of a two-speed motor, not of two-speed motors as a class. Therefore, a specific design of two-speed motor must be considered and its characteristics must be known. The factors upon which the value of the ratio depends are: (1) the pitch of the stator windings, i.e., whether the high-speed winding is over half-pitch and the low-speed winding is above full-pitch; (2) the end-ring resistance as compared with the bar resistance of the squirrel cage; and (3) whether the motor is designed for constant torque or torque in proportion to speed.

While it is a fact that the torque per ampere at starting is ordinarily about twice as great on the low-speed as on the high-speed, the actual delivered torque is usually somewhat greater on the high speed than on the low. However, this condition is sometimes reversed by a change in the type of winding used. A.E.A.

SYNCHRONISM INDICATOR: PHASE ROTATION

(203) If a synchronism indicator is properly connected to indicate synchronism between two three-phase generators that are both running in the same direction will not the instrument incorrectly indicate that synchronous conditions also exist when the generators are running in opposite directions and are 180 degrees out of phase?

Since the standard synchronism indicator is a single-phase device,* it will not detect the fact that one machine is running reversed; consequently, it might incorrectly indicate that synchronism occurs under these conditions. However, it is fundamentally impossible to operate two machines together while one is running reversed—unless two armature leads of one machine are interchanged. When this interchange has been made, the synchronism indicator will correctly designate the proper time for paralleling the two machines.

In case it is desired to detect reversed rotation in one machine, it would only be necessary to use two synchronism indicators, one connected to each of two phases of the machines. J.A.H.

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* For a detailed description of the construction and operation of the synchronism indicator see Question and Answer No. 174, GENERAL ELECTRIC REVIEW, August, 1916, page 731.

TRANSFORMER: VARIATION OF VOLTAGE WITH LOAD FOR OPEN AND CLOSED-DELTA

(204) Given a closed-delta secondary made up of three single-phase transformers and also an open-delta secondary made up of two single-phase transformers, all five units being identical.

Are the changes in voltage that are produced by changes in load greater for the open-delta connection than for the closed-delta connection?

For the same change in load, greater changes are to be expected in the voltage of the open-delta bank than in the closed-delta bank. Considered broadly, this is due to the fact that the members of the open-delta connection are not as symmetrically linked together as are those of the closed-delta connection, and as a natural consequence the effects of load conditions are likely to be more pronounced in the former.

Balanced Load

Consider the closed-delta connection. When connected to a unity power-factor load the separate windings of the delta operate at unity power-factor regardless of the load.

Consider now the open-delta connection. (The load may be drawn from two phases or from three phases without causing any difference in operation of the transformers provided the currents in the windings are the same in each case.) When connected to a unity power-factor load the currents in the windings are 30 degrees out of phase with their respective voltages, leading in one winding and lagging in the other. (This is caused by the V-connection.) Thus, one winding operates at 87 per cent power-factor leading and the other at 87 per cent power-factor lagging. Consequently, with additional load the voltage delivered by the first winding will increase and that by the second winding will decrease. Therefore, for unity power-factor load the difference in voltages is greater in a V-connected secondary than in a delta-connected secondary; in fact, the difference is greater than in a delta-connected secondary for 87 per cent power-factor load.

For loads of less than unity power-factor the regulation (or change in voltage) of the V-connection would be further increased over that of the delta-connection.

Unbalanced Load

The difference in voltages for unbalanced load would increase in various degrees, depending upon just where the greater and lesser loads were connected, but in any case it would likely be greater for the V-connection than for the delta connection.

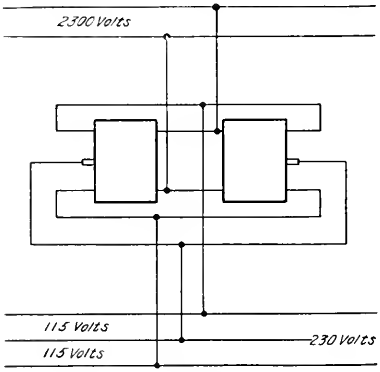
W.P.W.

TRANSFORMER: ONE OF TWO IN PARALLEL BURNED OUT

(205) In an instance in which two identical three-wire transformers were mounted on a pole and connected in parallel, according to Fig. 1, one of them burned out. That the two combined were not overloaded was later demonstrated by the remaining transformer carrying the entire load satisfactorily. What was the probable cause of the burnout?

With identical transformers having properly balanced windings successful parallel operation should be obtained with the connections shown in Fig. 1, unless there was some defect in one or both machines.

If the machine was not defective a possible cause of the burnout may have been an imperfectly balanced design, resulting in an unbalanced heating on three-wire load. The wiring diagram of a transformer having balanced windings is shown in Fig. 2. This transformer will maintain a uniform heating on either balanced or unbalanced three-wire load.



(205) **Fig. 1.**

In it both halves of the secondary winding are distributed equally on each side of the primary coil; in other words, the entire length of each half of the secondary winding is directly adjacent to the whole primary winding. The diagram shows that the inside secondary coil is in series with the outside secondary coil. Such an interconnection insures that the resistances of the two secondary halves are equal and also that the reactances are equal; thus perfect regulation of the two halves is obtained and the voltage drop in either secondary circuit will not exceed the listed regulation drop under ordinary unbalanced load conditions. E.S.

GROUND DETECTOR: ELECTROSTATIC

(206) What is the principle of operation of the electrostatic ground detector?

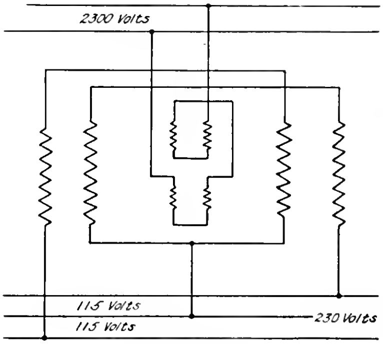
The electrostatic ground detector, being in effect a differential voltmeter, measures the difference in insulation resistance between a line conductor and ground. For its operation, it is dependent upon the electrostatic attraction and repulsion between a stationary set and moving set of vanes. Instruments of the single-phase type indicate a ground by the pointer deflecting toward the terminal of the line on which the ground occurs. Instruments of the three-phase type indicate a ground of one line by the two pointers of the ungrounded lines deflecting toward the terminal of the grounded line. E.C.S.

REGULATOR: WIRING

(207) Why are switches not permitted in the primary circuit of a feeder regulator?

The omission of switches is necessary to insure the proper co-operation of the primary and secondary windings of the regulator. Specifically, the primary and secondary windings must be so electrically interlocked that neither can be open-circuited while current is flowing in the other. The need for such a system of connections results from the fact that a current in the secondary would induce an excessive potential in the primary winding if the primary were open-circuited. An induced potential of this magnitude may permanently modify the magnetic characteristics of the iron core, may break down the primary insulation, and may endanger the life of a person who for any reason comes in contact with an exposed part of the primary winding.

E.C.S.



(205) **Fig. 2.**

INDUCTION MOTOR: DRYING OUT

(208) Describe the methods recommended for drying out an induction motor.

There are several methods for drying out an induction motor that has become damp or water soaked. Perhaps the best is to run the motor without load at reduced voltage to cause it to draw a heavy current for heating without dangerous voltage stress. The current should be from one to two times full load value, which will require from ⅙ to ⅓ full voltage for the average motor (slightly less for 25-cycle motors and perhaps slightly more for 60-cycle low-speed motors). If the rotor is of the wound type, the collector rings should be short-circuited as for normal running. This method will apply heat from the interior of the conductors of both stator and rotor.

Another method is to apply direct current in a manner similar to that described for synchronous motors in Q. and A. No. 197, December, p. 1139. The temperature limits specified therein for synchronous machines will also apply to induction motors when dried by the direct-current process.

A third method involves the application of external heat in a manner identical to that also described in Q. and A. No. 197 for synchronous motors.

A. E. A.

GENERAL ELECTRIC REVIEW

A MONTHLY MAGAZINE FOR ENGINEERS

Manager, M. P. RICE
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Subscription Rates: United States and Mexico, $2.00 per year; Canada, $2.25 per year; Foreign, $2.50 per year; payable in advance. Remit by post-office or express money orders, bank checks or drafts, made payable to the *General Electric Review*, Schenectady, N. Y.

Entered as second-class matter, March 26, 1912, at the postoffice at Schenectady, N. Y., under the Act of March, 1879.

VOL. XX., No. 2
FEBRUARY, 1917

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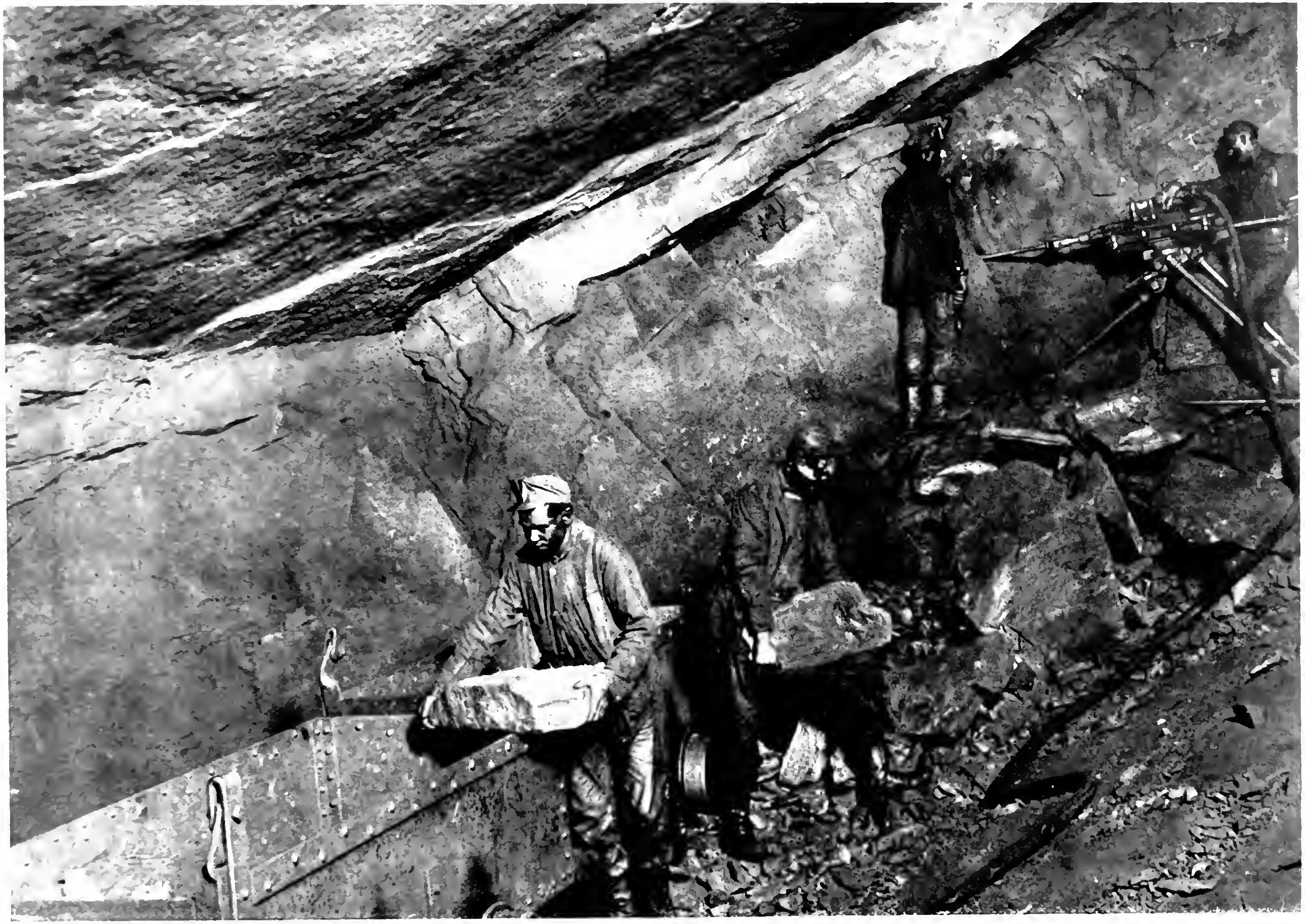

MINING OPERATIONS IN THE BIRMINGHAM, ALA., DISTRICT OF THE TENNESSE COAL, IRON & RAILROAD COMPANY

(See page 167)

GENERAL ELECTRIC REVIEW

THE PATHS OF PROGRESS

We believe that there are few things more necessary for the sound economic development of the industrial world than organized industrial research. For this reason, we are particularly pleased to publish in this issue two articles devoted to the need of fostering research work. One of these articles is written by Dr. W. R. Whitney, Director of the Research Laboratory of the General Electric Company, the other by Dr. Charles P. Steinmetz.

We feel that there is an imperative need for the extension and better recognition of research work. The laboratory of which Dr. Whitney is Director, is one of the most encouraging factors in industrial research activities, as the existence of such an institution as part of a manufacturing establishment speaks well for the future of the industry, denoting as it does the recognition of the value that is likely to be derived by instituting sound organized methods of learning the secrets of nature, rather than by trusting to haphazard methods.

One of the most important results that will be obtained from industrial research laboratories is the training of men as scientific investigators. Dr. Whitney shows in a most striking manner that results are not obtained by casual workers, or by those who are only interested in scientific investigation. It is specially worthy of note that important results have only been obtained by those who have been specially trained and who have devoted a large part of their lives to investigations. The whole business of research work is finding out the laws of nature and simplifying our understanding of the law, and this is a work that nothing but patience and perseverance can accomplish. It is a work that those undertaking it must pay undivided attention to, and it is for this reason that a man must be an investigator first, and if possible a teacher second, not a teacher first, and if possible an investigator.

The list of names that Dr. Whitney recites, with the mention of the work that some of these great men have accomplished is an inspiration and serves to show the limitless worth to the world of research in scientific subjects. Who could attempt to calculate the value to mankind of the discovery of electro-magnetic induction? Practically speaking the electrical industry of the day is based on this discovery. We believe that there are still to be discovered secrets from nature of equal or of greater importance. If this is the case we can well afford to stimulate research work both industrially and nationally, even if the cost is very great.

Our men of science should receive better recognition for the service they are rendering, and this is specially true in connection with our educational institutions. As it is more than likely that the future of every country will depend to a vital degree on scientific research, and whether any individual nation is to become a leader or follower will in a large measure depend upon the facilities they give their investigators to work with. It is easy to copy the work of others, but the nation that originates and has men of inventive genius will always lead.

It is highly probable that the next few decades will see competitions in getting results from research. If this is to be so, the nations which are to lead must discard the old methods and bring modern methods of organization to bear upon the work of scientific investigation as actively as they are willing to do in the case of manufacture.

The final object of research work is to enable us to use the resources of nature to better advantage tomorrow than we can today. This is a commercial question as well as a scientific question. The industrial supremacy of the future will certainly belong to those who conduct organized research work, improve their product by the knowledge thus gained and keep ahead of others by constantly improving the quality and increasing the efficiency of their product by new developments.

SPEED CONTROL OF INDUCTION MOTORS FOR STEEL MILL DRIVE

By J. D. Wright

Power and Mining Engineering Department, General Electric Company

An all-round satisfactory method of speed control for induction motors had long been a desideratum. The late modification of the Scherbius system, as described in the following article, has met actual operating requirements with remarkable success. The construction of the component units is described below, the function of each unit and the operation of the system as a whole is explained, and special attention is given to the valuable double-range regulation feature. This article was read as a paper before the November, 1916, meeting of the Association of Iron and Steel Electrical Engineers.—Editor.

The ordinary induction motor with phase wound rotor is essentially a constant speed machine, but on account of its many desirable characteristics, such as its ability to exert very high starting and running torques and to carry heavy overloads, its high efficiency and its extreme simplicity of construction, considerable time has been devoted to the study of means of obtaining speed control.

Many methods have been used, among which are the following:

Rheostat control
Multispeed windings
Concatenated control
Scherbius system
Kraemer system
Heyland system

It is the object of this paper to describe a modification of the Scherbius system as applied to induction motors for steel mill main roll drives which permits the operation of the roll motor at speeds above and below synchronism.

An attempt is made here to present a clear view of the actions of the machines, avoiding all unnecessary discussion of the somewhat complex theories involved.

Main Motor

The main roll motor is, of course, the usual type of three-phase machine with phase wound rotor, the stator winding being the primary and the rotor winding the secondary.

It is well known that when voltage is applied to the primary windings, the alternating currents in the various coils produce a magnetic field which revolves at a speed depending directly upon the frequency and inversely upon the number of poles.

In the secondary windings, which are cut by the rotating magnetic field, there is generated a voltage which is a maximum when the rotor is at standstill. The secondary frequency is then exactly the same as the primary frequency.

The currents which flow in the secondary windings will exert a torque, causing the rotor to turn in the direction of the rotating field. The rotor speed will continue to increase, and at the same time the secondary voltage and frequency will decrease, until the secondary voltage is just sufficient to send through the impedance of the windings sufficient current to develop the required torque. At exact synchronism the secondary voltage and frequency are zero. If the load remains constant (normal conditions being assumed) and the speed is reduced by the well-known method of inserting resistance in the secondary circuit, then at any other speed the voltage and frequency are practically proportional to the slip in per cent of synchronous speed. These relations are shown by the curve in Fig. 1.

If, instead of the external resistance, a constant voltage at rotor frequency is used to oppose the secondary voltage, the speed of the rotor will adjust itself to such a value that the secondary voltage exceeds the opposing voltage by an amount equal to that necessary to send through the impedance of the circuits sufficient current to develop the required torque. If the opposing voltage is adjustable, the speed of the main motor may be changed simply by varying the opposing voltage.

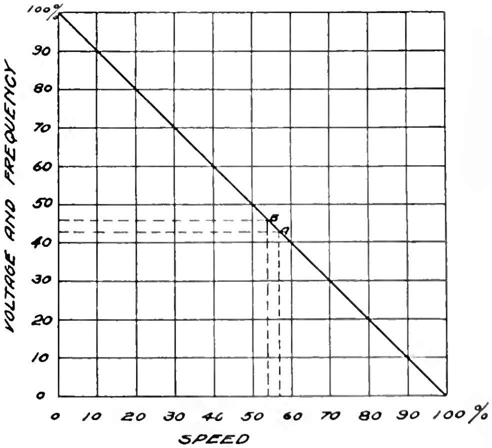

Fig. 1. Curve Showing Relation Between Secondary Voltage, Frequency and Speed of Phase Wound Induction Motor

If the opposing voltage has a value represented by A in Fig. 1, the motor at no load will run at a corresponding speed. If a load should come on, the motor would slow down to B, for example, so that the increased secondary voltage would be just sufficient to cause enough current to flow to enable the motor to develop the required torque.

It is the function of the regulating set to provide a source of adjustable voltage which may be impressed on the secondary windings of the main motor.

Regulating Set

Fig. 2 shows a typical regulating set. It consists of an induction generator, regulating motor, and exciter. The induction generator is an ordinary squirrel-cage machine which may operate either below or above synchronism. When the speed is less than synchronism the machine acts as a motor taking power from the line. When the rotor is driven above synchronism the machine acts as an induction generator and delivers power to the line.

The regulating motor is a polyphase commutator motor with an armature similar to that of an ordinary direct-current machine. Its stator is usually wound with three distinct windings; viz., a compensating field winding, an interpole field winding, and a main exciting field winding.

The exciter is similar to the regulating motor, but is somewhat simplified because of its smaller size and lighter service.

Ohmic Drop Exciter

In addition to the regulating set there is required a small auxiliary exciter which has been called an ohmic drop exciter.

The armature is mounted on the shaft of the main motor, so that its speed is always the same as that of the main motor. This exciter has the property of giving a constant voltage with a varying frequency, the frequency always being exactly the same as that of the secondary circuit of the main motor. This necessitates that the machine be wound with the same number of poles as the main motor.

The machine consists of an armature like that of a rotary converter, having both commutator and slip rings. The field punchings which surround the armature are without slots or windings. Since it is usually designed to handle three-phase current, its commutator is usually supplied with a multiple of three sets of brushes.

As shown in the diagram of connections, Fig. 3, the slip rings are connected through a transformer to the main power lines. If voltage is applied to the slip rings with the armature at rest the alternating currents in the various coils produce a magnetic field which revolves around the rotor at a speed depending directly upon the frequency and inversely upon the number of poles, the same as in an ordinary induction motor.

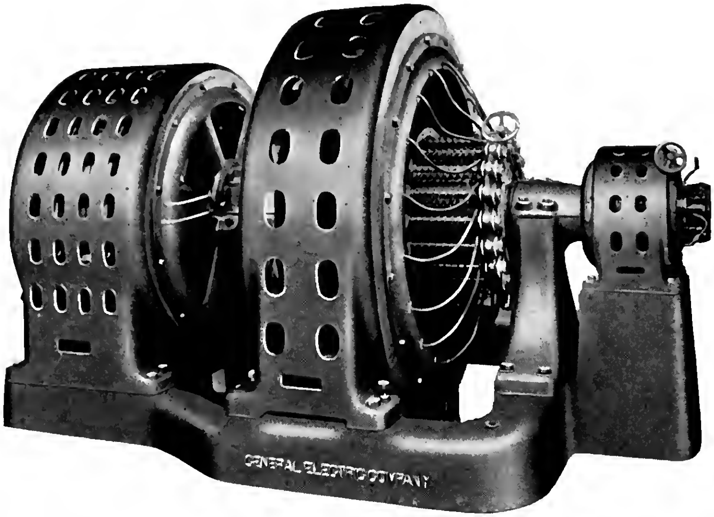

Fig. 2. Regulating Set Consisting of an Induction Generator, a Regulating Motor, and Exciter

If the armature of the main motor be rotated at synchronous speed, and if the phase rotation of the ohmic drop exciter be such that the direction of rotation of its magnetic field is opposite to the mechanical rotation, the magnetic field would no longer rotate but would stand still in space. The armature conductors revolving at synchronous speed would thus cut this stationary flux and a voltage would be generated which would deliver direct current from the brushes on the commutator just as in a direct-current generator. At one half synchronous speed, for example, the magnetic field would be rotating at half speed and the armature at half speed, with the result that the armature conductors would still cut the flux at the same rate, and the voltage generated would therefore be the same as at synchronous speed and at standstill. The frequency, instead of being zero as at synchronous speed, would be one half of the normal frequency applied to the slip rings of the ohmic drop exciter, or exactly the same as the frequency of the secondary of the main motor, since, as stated above, the magnetic field of the ohmic drop exciter is rotating in space at one half of its synchronous speed. At any other speed the voltage generated is constant and the machine delivers from its brushes alternating-current at a frequency equal to the slip frequency of the main motor. It may be noted that alternating current at zero frequency is direct current.

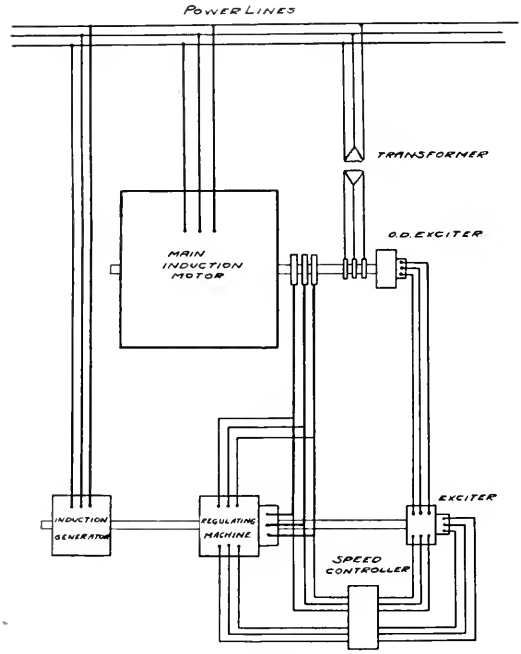

Fig. 3. Diagram of Connections for Induction Motor with Double Range Speed Regulating Equipment

If the armature is driven above synchronism the magnetic field will of course rotate in an opposite direction and the machine will deliver from the brushes alternating current having a phase rotation reversed from that when operating below synchronism.

The use of this form of exciter has made possible the development of a method of operation of the main motor that retains all the desirable characteristics of the normal induction motor operating with short circuited slip rings, not only at speeds considerably below synchronism but equally well at speeds near synchronism, in synchronism, or above synchronism.

Operation of the System

In the regulating motor the exciting winding is a shunt winding connected directly across the main induction motor slip rings. The shunt field therefore has practically a fixed flux regardless of variation in load on the main motor; for as the speed of the main motor varies due to a changing load the secondary voltage and frequency also vary proportionally, and therefore the flux remains constant.

The exciter armature is connected in series with the exciting winding of the regulating motor so that it can buck or boost the slip-ring voltage and leave any desired percentage to be applied to the field of the regulating motor. If it is desired, for example, to operate at a speed where one half of the slip-ring voltage is applied to the regulating motor field the exciter must buck away the other half. It must therefore have the property of generating a voltage always proportional to the slip-ring voltage, instead of a constant voltage like the regulating motor. Since it is an unsaturated shunt machine its voltage is proportional to its field current. One of the fields is excited from the main motor slip rings over a resistance that is large compared to the reactance of the circuit, so that the field current is practically proportional to the slip-ring voltage.

Thus, since for any particular adjustment of the field resistance of the exciter the exciter terminal voltage is proportional to the slip-ring voltage, the difference between the two is, of course, proportional to the slip-ring voltage, and is therefore of the right nature to apply to the field of the regulating motor to produce constant flux. A change in the exciter field resistance makes the exciter consume a different proportion of the slip-ring voltage, thus altering the regulating motor field and voltage, and as a consequence the speed of the main motor.

Reference to Fig. 4 will show that the exciter has, in addition to the field excited from the slip rings, another field which is excited from the brushes of the ohmic drop exciter. It might be mentioned here that this exciter is called an ohmic drop exciter because it excites the regulating motor exciter in such a manner as to cause the latter to generate a voltage which actually balances the ohmic drop in the field circuit of the regulating motor. The effect of this second field upon the speed variation compared to that of the first is small when operating remote from synchronism, but large when operating near synchronism. When operating exactly at synchronism it must of course provide all the required excitation.

To illustrate the actions of the different machines, let it be assumed that the main motor is running below synchronism and that it is desired that the speed be raised above synchronism. Fig. 5 may help to illustrate the various points. Curve 1 shows the variations of speed and secondary voltage. It is assumed that the load is such that a voltage represented by *B* is necessary to send through the impedance of the secondary circuits sufficient current to enable the motor to develop the required torque. At any speed below synchronism the slip-ring or rotor voltage *A* must be greater than *C*, which is the opposing voltage, by an amount equal to *B*. Thus *A*, in addition to overcoming the opposing voltage *C*, also supplies the voltage *B*.

Curve 2 is an enlarged view of the same quantities close to synchronism. Condition 1, Curve 2, has been reached by decreasing the voltage of the regulating motor. This regulation toward synchronism was accomplished by increasing the resistance in the ohmic drop rheostat and decreasing the resistance in the exciter field rheostat. (When regulating toward synchronism the resistance in the exciter field rheostat is decreased in order that the exciter may be made to consume a greater and greater percentage of the slip-ring voltage, as the voltage consumed in the field windings of the regulating motor decreases when the flux and frequency decrease in approaching synchronism.) Condition 2, Curve 2, Fig. 5, is where the regulating set offers no opposing voltage and the voltage *A* is equal to *B*. At this point the conditions are practically the same as when operating the main motor with the slip rings short-circuited. The circuits to the main fields of the regulating motor are completely opened so that no voltage is generated.

Fig. 4. Connections of Double Range Speed Regulating Equipment

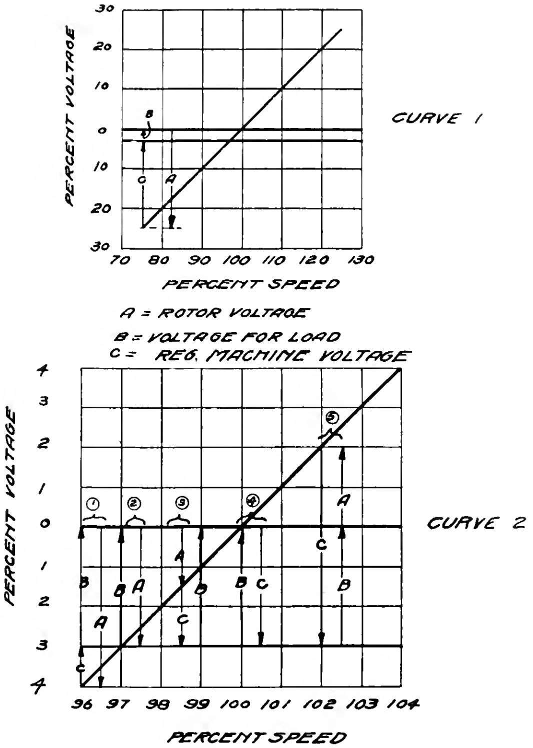

Fig. 5. Curves of Speed *vs.* Secondary Voltage Through Synchronism Resolved into Their Component Voltages

Up to this point it is evident that, since the rotor voltage exceeds the voltage of the regulating set, the regulating machine has been acting as a motor and the induction generator, being driven above synchronism, has been delivering power to the line. It should be noted that the regulating motor has the characteristics of a shunt wound direct-current motor. That is, its speed with a given field is proportional to the voltage applied to the armature. When operating the main motor below synchronism it is evident that the induction generator must be driven above synchronism in order that the power delivered to the regulating motor may be absorbed. It is also evident that if the regulating motor were connected to the main motor slip rings without the induction generator the speed of the main motor would continually decrease and the speed of the regulating motor increase; because, since there would be no torque to resist the torque of the regulating motor, the latter would speed up. Its voltage, opposing the rotor voltage, would therefore increase, with the result that the secondary voltage of the main motor would no longer be sufficient to send through the impedance of the circuits sufficient current to enable the motor to develop the torque required by the load, and the main motor speed would decrease. The rotor voltage would then become higher, causing the speed of the regulating motor to still further increase. This action would tend to continue as long as the rotor voltage could continue to increase.

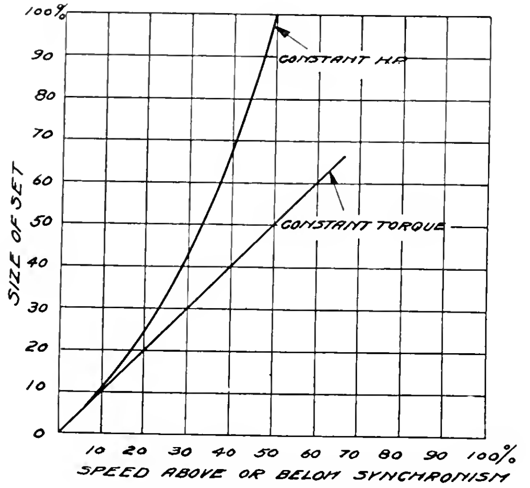

Fig. 6. Curve Showing Size of Regulating Set in Per Cent of Capacity of Main Motor

Referring further to Curve 2, it is seen that, in order to regulate toward synchronism from condition 2, it is necessary that the voltage of the regulating machine be reversed. To arrive at condition 3, the regulating machine must act as a generator and assist the rotor voltage *A* by a voltage equal to *C* to supply *B*. At exact synchronism, condition 4, the rotor voltage is zero and the voltage of the regulating machine must be large enough to send through the secondary circuits sufficient current to enable the motor to develop the torque required by the load. If voltage *C* is still further increased the main motor torque increases above that required by the load, with the result that the rotor speed must increase. The rotor voltage therefore begins to develop in the reversed direction, so that at condition 5 the voltage *C* of the regulating machine must be equal to *A* plus *B*.

Size of Regulating Set

The size of the regulating equipment is determined by the amount of speed adjustment required above and below synchronism. The secondary energy from the main motor is equal to the following: $\frac{\text{Slip}}{1-\text{Slip}}\times$shaft horse power. Fig. 6 shows the size of the regulating equipment for any speed adjustment above or below synchronism where the main motor is called upon to deliver either constant torque or constant horse power. From an inspection of this curve it is evident that it is desirable to have the synchronous speed of the main motor midway between the maximum and minimum speed at which it is required to operate, as under this condition the size of the regulating equipment is a minimum.

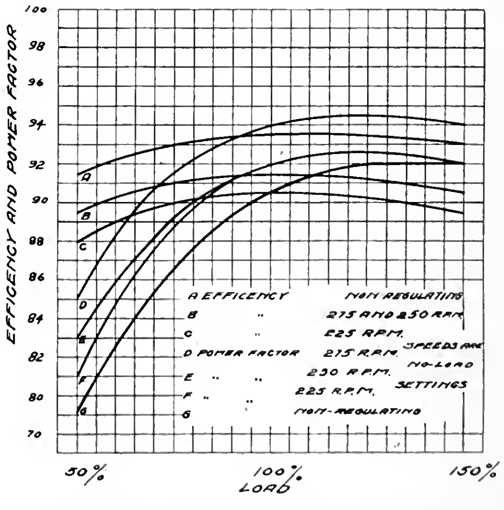

Fig. 7. Efficiency and Power-factor Curves for 12-pole 2200/2000/1800-h.p. 275/250/225-r.p.m. Motor with Regulating Set

Efficiency and Power-factor

Fig. 7 shows typical overall efficiency and power-factor curves for an induction motor with regulating equipment. The illustration also shows the efficiency and power-factor curves for the main motor when operating without the regulating set, that is, with short-circuited slip rings. The efficiency values under this condition are of course higher because of there being no regulating set losses. The power-factor values are lower because the power-factor correction obtained from the regulating set is no longer available. Fig. 8 shows a diagrammatic arrangement of connections with approximate distribution of losses and calculations of overall efficiency for various assumed conditions. The speed of the main motor is assumed to be regulated from 20 per cent below synchronism to 20 per cent above synchronism with constant load torque. The power transmitted by the regulating set, which is determined by the percentage regulation below or above synchronism, is approximately equal to $\frac{\text{Slip}}{1-\text{Slip}} \times$ shaft horse power or $\frac{20}{80} \times 1600 = 400$ horse power, or, above synchronism, $\frac{20}{120} \times 2400 = 400$ horse power.

When operating at the intermediate speed it has been assumed that the losses in the set would be approximately ⅔ of the losses at maximum or minimum speed, as the set is then not handling as much power as at other speeds.

Control

Magnetic control is usually provided for induction motors with speed regulating sets, and is especially desirable on account of the ease with which the proper interlocking of the various circuits may be accomplished.

The control is so designed that the following sequence of operations must be observed when starting the main motor from rest, assuming that it is desired to operate with the regulating set:

1. The master controller which governs the operation of the contactors controlling the main motor must be in the off position.
2. The speed regulating rheostat must be placed in the starting position. (The position corresponds to the setting at which the regulating machine generates no voltage.)
3. The regulating set must be started from an ordinary starting compensator by the squirrel cage machine acting as a motor.
4. The main motor may then be started by the operation of the master controller.

A contactor is provided for opening the armature of the regulating motor and another for opening its field circuit when the main motor is being started from rest. Provision is made for closing these contactors after the motor has been accelerated and all the starting resistance cut out of the secondary circuit.

It is evident that to prevent an excessive flow of current the regulating set must be connected to the main motor slip rings at a motor speed corresponding approximately to the setting of the speed regulating rheostat. This has been chosen as the normal speed of the motor without the regulating set.

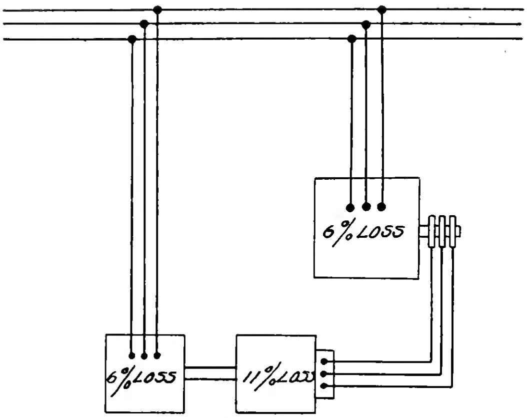

Fig. 8. Main Motor 1600/2000/2400-h.p. 20 Per Cent Regulation Above and Below Synchronism

Size of Regulating Set		400 h.p.
Losses Main Motor	120 h.p.	
Losses Main Regulating Motor	44 h.p.	
Losses Induction Motor generator	24 h.p.	
Total Loss	188 h.p.	

Shaft H.P. at Max. Speed 2400

$$\text{Efficiency} = \frac{2400}{2400+188} = 92.5 \text{ per cent}$$

Shaft H.P. at Min. Speed 1600

$$\text{Efficiency} = \frac{1600}{1600+188} = 89.5 \text{ per cent}$$

Shaft H.P. at Average Speed 2000

$$\text{Efficiency} = \frac{2000}{2000+120+\text{Approx. } \frac{2}{3} \times 68} = 92.5 \text{ per cent}$$

Provision is, of course, made for operation of the main motor without the regulating set, and a double throw control switch is arranged to make the proper change in connections.

In case it is desired to "plug" the main motor to stop it quickly, additional secondary resistance is provided to limit the current.

The regulating set is automatically disconnected from the main motor when the master controller is thrown to the reverse position.

Advantages of Double Range Regulation

Double range speed regulating equipments (that is, those that permit operation of the main motor above and below synchronism) evidently possess several important advantages from an operating point of view. The following may be noted:

Flexibility: The double range system permits the operation of the main motor non-regulating at an average speed with maximum efficiency. (With single range systems providing speed reduction only, the main motor, without the regulating equipment, operates at maximum speed.)

Maintenance: The double range auxiliary set may be idle while rolling at the non-regulating speed, thus minimizing wear and upkeep.

Production: In event of trouble with the regulating set, the main motor operating at an average speed will permit rolling a wider variety of sections than will a single range system operating under similar conditions. Sections for which higher speeds are desirable can nearly always be rolled in emergency at the average speed with reduced tonnage, while if trouble develops with a single range set, many low speed sections cannot be rolled at synchronous speed.

Running Points: A great number of running points up to 100 or more can easily be obtained.

Power-factor: Improvement of the power-factor of the main motor is easily obtained.

Asynchronous Apparatus: Since no synchronous machines are used there is no tendency for the regulating equipment to fall out of step under sudden loads.

SCIENTIFIC RESEARCH IN ITS RELATION TO THE INDUSTRIES*

By Charles P. Steinmetz

Chief Consulting Engineer, General Electric Company

In the introduction of his article, Dr. Steinmetz states that in the latter decades industries have established and maintained their own research laboratories because educational institutions, as operated, proved incapable of increasing scientific knowledge fast enough to permit of rapid industrial progress. Continuing, the author recommends that educational institutions and industrial research laboratories supplement one another for the limitations of the one, as a class, are not those of the other. He allots to each class the type of research that can best be prosecuted by it and then compares the methods of procedure that are followed by each. The remainder of the article is devoted to a strong appeal to scientists and abstractors for a broadminded recognition of the work of the industrial research laboratory and the engineering profession in general.—Editor.

Industry, and with it all our modern civilization, depends on engineering. Engineering, however, is nothing but applied science, and science thus is the foundation, scientific research the ultimate means, which have created our civilization. For ages the chief homes of scientific research have been the universities and other educational institutions. During the last generation, however, the industrial development has been so rapid, and the demand for the results of scientific research so great and urgent, that the universities have not been able to supply it, and the industries, especially the more powerfully organized modern industries, as electrical engineering, chemistry, etc., had to enter the field of scientific research. The country's educational institutions did not advance in fostering scientific research to the same degree as the industries advanced and many universities and educational institutions rather retrograded in scientific research—became submerged in a false commercialism which figured the output of the college in student hours per professor, judged efficiency by the percentage of students graduated, and altogether too often wasted the university's best assets, its professors. Thus we find in our colleges men who had shown themselves capable as investigators to do scientific research work of the highest order, overloaded with educational or administrative routine, and deprived of the time for research work. Private industries rarely commit such crimes of wasting men on work inferior to that which they can do: industrial efficiency forbids it.

Thus, when the advance of industry demanded a more rapid extension of our scientific knowledge than that given by the educational research institutions, scientific research laboratories were established in the industries. Some of them very soon showed their ability to produce scientific work of high character. As illustration, I may mention how an entire new branch of chemistry, the chemistry of the free atom, has resulted from the work of Langmuir in the Electrochemical Research Laboratory of the General Electric Company, and has been communicated to the literature by numerous papers.

However, these scientific research laboratories of the industry represent only a part, often the minor part, of the research work done within the industry, and in many places throughout the industrial organization opportunity is afforded for the right men to carry

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* Presented at a joint meeting of the Franklin Institute and the Philadelphia Section, American Institute of Electrical Engineers, held Wednesday, October 18, 1916.

out scientific research. Thus in the materials testing laboratories of our industrial corporations, in their standardizing laboratories, their apparatus testing departments, development sections, etc., research work is being carried out, and as a rule is encouraged by the corporations.

Referring only to the field of electrophysics, most of our knowledge of the phenomena of electric waves and impulses in circuits, of magnetism, of dielectric phenomena, etc., has come from this source.

When speaking of industrial research laboratories, we must not forget the commercial testing laboratories, development laboratories etc., which have been established and which serve the same purpose to the smaller industrial organization as do the private laboratories to the great industrial corporations.

Theoretically, there is a limitation imposed on scientific research work in industrial establishments: It should be of such character that it may lead to results which are industrially useful. In reality, however, this is no limitation at all; for there is no scientific investigation, however remote from industrial requirements, which might not possibly lead to industrially useful developments, although obviously no immediate or direct usefulness is expected. Any investigation offering a definite prospect of industrial utility is not scientific research, but is industrial development or design. Indeed experience has shown that it is rare that some industrially valuable results do not follow sooner or later, no matter how abstruse and remote from apparent utility a scientific investigation may appear, and any scientific research whatsoever is thus industrially justified.

To illustrate, when the Consulting Engineering Laboratory of the General Electric Company undertook research work on the electrostatic corona and in general on dielectric phenomena in the air, no immediate or direct benefit could be seen for the industrial company which financed the work; but it was justified by the consideration that a greater knowledge of these phenomena might extend the economic limits of long distance power transmission and thereby increase the industrial demand for transmission apparatus. Nevertheless, before the research was completed—if research can ever be considered completed—it had led to a redesign of practically all high-voltage transmission apparatus, and has thus proven valuable in industrial design.

Some research work can be carried out more efficiently by educational institutions, and other by the industry. In general, better facilities in materials and in power are available for industrial research, but the high class skilled labor of investigators and research men, such as is available in university research through graduate students, is expensive in the industry. Thus research requiring little in facilities, but a large amount of time and attention from research men, is especially adapted to educational laboratories; while investigations requiring large amounts of material or of power rather than time of the investigators are specifically adapted to the industry, and often beyond the facilities of the educational institution. Efficiency should thus require a division of research between educational and industrial laboratories in accordance with their facilities, and where this is done the results are splendid. Thus, for instance, the phenomena of the dielectric field beyond the elastic limit, or in other words those of the disruptive effects in air and other dielectrics under high electric stress, were almost entirely unknown a very few years ago, and it was even unknown whether there is a definite dielectric strength of materials, analogous to the mechanical strength. This field has been very completely cleared up, and a comprehensive knowledge of the phenomena of the dielectric field gained, not only under steady stress, but also under oscillating stress, and under the transient stress of sudden electric blows or impulses, ranging down to time measured by microseconds, as the result largely of the work of an industrial research laboratory, the Consulting Engineering Laboratory of the General Electric Company under Mr. F. W. Peek, and an educational laboratory, John Hopkins University under Professor Whitehead—both laboratories working independently and devoting their attention to those subjects for which they are specifically fitted, though naturally often overlapping and checking each other.

Unfortunately, this limitation of research work in accordance with available facilities is not always realized, and educational institutions especially not infrequently attempt research work for which industrial laboratories are far better fitted, while research work for which the educational institution is well fitted and which the industry needs but can not economically undertake, is left undone. It is usually the desire to "do something of industrial value" which leads universities to undertake investigations on railroading and similar subjects, in which the probability of adding something material to our knowledge is extremely remote, or to undertake investigations on industrial iron alloys in competition with the vastly greater and more efficient research of industrial laboratories in this field of magnetism, while all other magnetic research is largely neglected. Our knowledge of the phenomena of magnetism is therefore still very unsatisfactory, and it is obvious that a material advance can be expected only from a comprehensive study of the entire field of magnetism, and the little investigated non-ferrous magnetic materials thus would be the ones most requiring study.

The closer relation of industrial research laboratories to engineering practice leads to a tendency which in general may be expressed by saying that in the results of industrial research the probable error is greater, but the possibility of a constant error less, than in educational research. In any investigation typical conditions are selected. As these conditions naturally never can be perfect, two ways of procedure are feasible: either to investigate the errors and disturbing factors and correct for them, or to select the condition of experiment so that the disturbing factors are negligible; for instance, experiment on a large scale. The latter method can not give as high accuracy as the former; but the former method, while theoretically more accurate, may give a constant error, possibly of hundreds of per cent, if some of the assumptions on which the corrections are based are not completely justified. Industrial research leans towards the first method as giving results which are safer in reliability, even if somewhat less accurate, while educational research leans towards the method of applying corrections. As an illustration, in magnetic investigations the effect of joints in the magnetic circuit, yoke, etc., may be determined and corrections for it applied, or such a magnetic circuit may be chosen that the effect of joints, etc., is negligible and can be neglected, or taken care of by a correction which is so small that its accuracy is not material.

In industrial research the liability exists of limiting the work to such a narrow field that it has little general scientific value: for instance, to determine the hysteresis loss in a magnetic material without determining the magnetization curve. Inversely, in educational research there is sometimes the tendency to generalize beyond the limits justified and so draw wrong conclusions. For instance, numerous investigations have been made and conclusions drawn therefrom in treatises on "the arc," while in reality the investigation was made with the carbon arc only, and the conclusion applies only to this kind of arc, and as the carbon arc is not typical but rather exceptional, the conclusions are wrong for most other arcs.

As regards the quality of the scientific research work done in industrial organizations compared with that in educational establishments, there is no material difference; but the work done in the industry, just as that done in universities, varies from scientific research of the highest quality down to investigations which are of little if any value—investigations crude and inaccurate or directly erroneous in premises, in method, and in results and interpretation, or investigations which while correctly conceived and correctly made are useless because essential conditions have not been controlled or recorded. Still worse are those pseudo-scientific investigations occasionally made, which owe their inception to the desire of self-advertisement or which are made for commercial or legal purposes; for instance, to give the appearance of a scientific standing to some theory which some inventor has recorded in his patents. Such work, met occasionally though less and less frequently, in industrial as well as in educational institutions, tends to discredit scientific research in the eyes of the layman, who can not discriminate between science and pseudo-science.

The essential difference between industrial and educational research, however, is found in their method of publication: the publication mediums of scientific research carried on in educational institutions are the scientific publications published more or less under the direction or supervision of universities, while the publication mediums of the scientific research carried on in the industry are the technical or engineering papers, and only occasionally an abstract reaches the scientific publications. Unfortunately a large number of scientists still look on publications in the technical press as unscientific, take no cognizance of it, do not recognize it in scientific abstracts, reviews, etc., and as a result a large and steadily increasing part of the scientific research of the country is practically lost to the scientists, is not available or easily accessible, through not being recorded, abstracted or indexed in the records of scientific progress. For instance, in the tables of physical constants published only a few years ago, under "hysteresis" are published the losses in a Siemens cable transformer (a type which had ceased to exist a quarter of a century ago), and practically all that mass of data on magnetism that has been recorded in the engineering proceedings is neglected, apparently as not "scientific," which shows that there is something wrong with the attitude of those responsible for the records of science. Among the worst offenders in this unjustified exclusiveness are the physicists, while the chemists make a recommendable exception. In the chemical abstracts published by the American Chemical Society, the results of industrial research as well as those of the chemical university laboratories are recognized, and these abstracts are therefore comprehensive and valuable, which cannot be said of the abstracts of some other sciences. Possibly the reason for this is that applied chemistry is chemistry just as much so as is theoretical chemistry, while applied physics goes under the name of engineering, and the average theoretical physicist is rather inclined not to recognize engineering as being scientific.

Some excuse may be found in the nature of the two classes of publications, the physical science publications and the engineering publications. The former accept for publication only scientific papers, exert a critical judgment, and the appearance in the scientific publication medium thus implies that the article, at least in the opinion of the editors, is of scientific value. This is not the case, and can not be the case with the engineering or technical publications: the technical press is the medium of all the publications of those engaged in the industry, from scientific research of the highest value to mere commercial statements, and the appearance of an article in an engineering paper or transaction does not imply, nor intend to imply, that it is of scientific value; but the discrimination between scientific worth or otherwise, which in the scientific publications is attempted by the editors, has in the engineering press to be left to the reader or abstractor. If, however, the purpose of the engineering publication is to bring together all classes of industrial records and it thus includes commercial and other articles this is no justification to refuse recognition to scientific papers contained in these publications, but rather makes it desirable, and indeed necessary in the interest of our nation's scientific efficiency, to find some means or organization to carry out this discriminaton and make available to the scientific world at large the scientific work contained in the annals of applied science, that is, engineering.

To conclude then: scientific research of the highest class is carried out today in our nation in educational institutions as well as in industrial organizations and commercial testing laboratories, and the scientific research work in the latter is increasing at a far greater rate than that in the former. The publication mediums for the scientific research of industrial organizations are the engineering publications and transactions, and the failure, in many branches of science, of recognizing the engineering publications in the records of science makes the records of science incomplete and increasingly so, and therefore seriously retards the progress of science, and with it that of applied science, that is, engineering; and as engineering is the foundation of our civilization this practice constitutes a serious menace to our nation's progress.

It is therefore important that those scientists who are engaged in keeping the records of science and making the results of scientific research available and easily accessible should recognize all sources and records of scientific research, including those of applied science, that is, the engineering publications, and should undertake the work of reviewing the technical press as well as the purely scientific publications, judging and selecting from the former those publications which are of scientific value and recognizing them. Only then will our records of science be complete and correspondingly valuable.

The question then immediately arises, is not the keeping of records of science one of the most important and most valuable activities, which in the interest of our national progress should be undertaken by our national government, by the National Bureau of Standards, as the only body which is unpartisan and unprejudiced, and by its nature is in close contact with and intensely interested in engineering and at the same time has proved its scientific standing and ability to do scientific work of the highest class, and therefore of judging scientific work?

RESEARCH

By W. R. Whitney

Director, Research Laboratory, General Electric Company

In this address, which was delivered at the Alumni Dinner of the Massachusetts Institute of Technology, January 6th, Dr. Whitney makes an urgent plea for the better recognition of the value of scientific research work and a more liberal treatment of those engaged in this pursuit. He recites the accomplishments of many great men and shows how each of these had spent long years of faithful work on investigations, emphasizing the point that the results are not obtained by haphazard methods, but only by highly trained men through persistent and consistent effort.—Editor.

I want to talk about pure research because we Americans seem to know so little about it. Nothing in the world is so important to engineers. Although the Massachusetts Institute of Technology is the greatest engineering school, it is the home of few research men.

Since the war began we have all taken inventories. We see that there is need on every side for national planning which shall extend beyond the four years for which our political parties are separately responsible. Our nation will not mature under a single administration. National policies should be planned for long periods. The part which I want to talk about to-night is the advancement of science, and the improvement of Americans by our Institute.

Because of the inherited conservatism of systematized teaching, radical steps are slow. William Barton Rogers, in establishing this Institute, did something radical. Men were to be taught by contact with things, instead of being merely told about them by teachers—the custom of a thousand years. A great technical school resulted. It prepares men for useful work in trade and industry, but neither this nor any other American school is doing much to read the countless uncut pages of science or to lay the foundations of the future engineering structures.

Even if research had no greater value than its application to engineering, much more of it ought to be done at this Institution. If working into new levels of Nature's infinite mines merely made students brighter, or teachers more interesting, there would be ample warrant for research. But there are better reasons. Some are instinctive and as difficult of analysis as are our reasons for developing at all.

Man seems to be the supreme, mentally elastic organism. He develops by trying novelties and by taking new paths. No one knows to what extent he may develop, but everyone knows that through acquisition of knowledge, or, let me say, production of it, he may transcend any physical limits. This will not come about by continuous repetition of what we have already learned. Monkeys and parrots do as much. It will come through the continual and active appreciation of new knowledge. In national mental development we might be wise to learn to do as well as Germany has done until we can do better. In most every little town of the Empire there is a university. In almost every university there are several high-brow professors, and in almost every professor there is a research man of high order. Such has been the condition for two score years. During that time a large part of the basic knowledge of our engineering has come from these people, whether it be the engineering of the physician, the chemist, or the electrician, or the engineering of music, economics, or religion. Every one of these professors delved patiently in his university laboratory, using his own and students' hands, and his lectures were far the lesser part of his work. Such men teach by example, and produce others like themselves by contagion. When the student has in turn contributed to new knowledge, and only then, he may become a doctor, and in Germany this means something real. When this doctor has later shown great originality and productivity, he may become a professor, and that means "wie ein Gott"—only a little lower than a Kaiser. Do not make a mistake here, of laughing at the funny foreign facts. Maybe we are funny, and slow to see it. When I "made my doctor" in Germany, a laurel wreath was put at my place at table. In America, I should have had to buy a box of cigars for the boys.

A professor with us is a conscientious alumnus a little older than his assistants. He is stunting his mental growth on a salary that no chauffeur would accept. He is not expected to be a scientist, nor a worker in science. He is not asked to show boys how new things may be done by doing them. He must confine himself to talking about accomplishments of others, usually foreigners. We rail at him, but do not help him at all. The fault is not his. He was raised as a part of the system which we, in our poverty, have had to employ.

In the advance of civilization it is new knowledge which paves the way, and the pavement is eternal. While the physical structures of man are decaying, the facts he has learned are ever doing new service. Antitoxic devices will be increasing when locomotives are forgotten. Magnetic induction will work after the pyramids have blown away. We ought to see that everything distinguishing our lives from those of Indians has come from studying something new.

As we grow in years and wealth, we ought to grow in new wisdom and knowledge. H. G. Wells, who wrote "Mr. Britling Sees it Through," once made some notes on Boston which have enough of fair criticism of our immobility to warrant repeating. He says: "There broods over Boston an immense effect of finality. One feels in Boston as one feels in no other part of the states, that the intellectual movement has ceased. * * * It makes little in the mind of the world whether anyone is concentrated upon medieval poetry, Florentine pictures, or the propagation of pills. The common significant fact in all these cases is this: a blindness to the crude splendor of the possibilities of America now, and to the tragic greatness of unheeded issues that blunder towards solution, etc.," and finally, "Over against unthinking ignorance is scholarly refinement (the spirt of Boston); between that Scylla and this Charybdis the creative mind of man steers its precarious way."

The creative mind of man steers its precarious way, and there is little reason for it but habit. We are not too old to grow the creative mind. England, France, and Germany do it. We are not too young, because western universities are doing it in some lines.

In many countries there exist today classes of men who devote their lives to public welfare and are kept from starvation by long established customs of community support. This grouping may extend from government officers on the one hand, to monks on the other. As a matter of fact, much of our accumulated knowledge has been disclosed by these two extreme classes. If one recalls the ways by which much of our scientific knowledge has been obtained, he realizes that it has been through simple, individual inquisitiveness. At irregular times and places men have appeared who seemed to be perpetual interrogation signs. They were never satisfied with what was already known, but they themselves wanted to extend the known with an ardour which was perpetual. They were usually professors.

There are a few very marked peculiarities surrounding these cases which we Americans have thus far failed to realize. And this is the more surprising because these peculiarities deal with the very practical matter of bread and butter. Most of the foundations of the world's great advances in experimental knowledge have been laid by men who were set apart and supported by the government, or some more or less public institution, where, for very long periods (usually for life), they were encouraged to delve into the unknown. Think of Davy and Faraday in the Royal Institution; of Graham, Ramsay, Rayleigh, J. J. Thomson, and Kelvin, in English institutions; of Pasteur in the Sorbonne and Pasteur Institute, of the Curies, of Dumas and Berthelot and others of France; of Helmholtz, Bunsen, Hertz, Wöhler, Hofmann, Ostwald, Haber, and others, in German universities; of Berzelius, vant' Hoff, Mendelejeff, Arrhenius, and a score of men from the universities of other countries. Most of these are men of our time and none of our country. They were in some way supported in their research work by their country. How many such cases can we cite for America? In a few colleges, one or two men are now permitted to carry on a little research work, when it does not interfere with routine teaching. It was not long ago that research, if done at all in some of our colleges, had to be done surreptitiously. At this same time, other countries were paying their best scientists to continue research, and schools of research were being maintained in almost every large German and French city.

There is something distinctive in research which can best be covered by the word "trying." It seems to me to convey an impression of following the suggestions of Nature, instead of attempting to force some single, preconceived path, to the exclusion of others. Many of our real advances come to us through the development of new phenomena which are in no sense sought for the purpose. The foundation is laid at times when thought of the object gained is impossible. The knowledge may be stored a long time before the value of it is realized. It is the seeking of this kind of knowledge that we, as a whole, should encourage. In our various technical undertakings we make use of the direct method of attack. We try all the promising schemes which seem likely to lead us to the particular new end we have in mind, but this is not the way by which are produced our longest strides. It is not the way they have developed heretofore. When Professor Hertz was making observations which were based on the effect of one spark gap on another at a distance, and concluded that he was dealing with electric waves in space, he was not trying to improve the telegraph or telephone. He was like an inquisitive child, making what to him were interesting experiments. He was well trained to observe, but otherwise he was like a youth guided solely by the interest in the new things he was finding. When he had added to our knowledge the few simple facts which he observed, the results of trying things, he had laid the foundation for a Marconi. His ability was no accident, his service no unsought nor unsupported thing. He had been trained by Helmholtz, and all his life he was employed in German universities to do pure research work and to encourage others to do it likewise. This is the important point.

The reason why we should take most interest in this type of research is that it most needs help and understanding in America, and it most develops the people who support it. The American manufacturers are probably wise enough to measure the value of direct attack on their specific problems, and they will more and more effectually employ men to solve them as men appear who are competent. In this way much that is new will be discovered, but not enough, nor of the right kind. The discoveries in separate industries are usually those of further refinement, or improvement. The natural extensions of present known paths, the more or less obvious additions or economies, these are the studies of the industries. By industrial research as usually successfully carried on, few new fields of human endeavor are likely to be opened up.

I do not believe it is commonly realized (particularly in America) how generally the world's greatest discoveries were disclosed in their first stages by men who were highly trained and experienced in experimenting. I want to emphasize this point. We do not appreciate the fact that usually the long strides in advance are made by careful, painstaking observations of matters not at the time particularly promising or comprehensible to the layman. The foundations of advances are most often made by such men as experimenting science professors, who, with mind skilled in observation and keen in appreciation, have had opportunity to long continue the investigation of some phenomenon of Nature which they observed. We Americans must get out of our minds the thought that our part is always like harvesting the wheat we have grown on our virgin soils. Something has to be cultivated, something planted. We must learn that improvements of great human interest are not accidental, fortuitous, or free from extended exertion.

We are generally superficial. The interesting lives of a few exceptionally able American inventors have led us to overprize engineering short cuts. We are patenting inventions at the rate of nearly 50,000 a year, but very few Americans are advancing the sciences at all. We need to be told that beneath national supremacy must lie some sort of national foundations, and if we are considering technical, industrial, or engineering supremacy, we must expect to need some constructive work in bases of physics, chemistry, electricity, etc.

We do not need to confine our thoughts to narrow branches of endeavor. Let us look at fields of modern work, chosen at random. The underlying thought in these illustrations is that the great new strides were made by highly trained observers, that their power of scientific observation, supported by facilities for experiment, were the guaranties of subsequent useful developments.

The benefits of anaesthesia, for example, are due to the experiments of Priestley on gases, which led Davy to play with nitrous oxide. Then, by experiment, he discovered its power of producing insensibility to pain. Faraday showed that ether acted similarly; Dr. Morton, in Boston, also disclosed its applicability, and, finally, anaesthetics came into general use. The research men were at the time trained chemists merely trying things for the pleasure they obtained in learning something new, and they had been practising this scientific observation and chemical experimentation all their lives. Thus they appreciated the value of the new facts and tried many experiments to add to the knowledge already gained. And they had time to do it and were paid to do it. In this connection, Sir James Simpson, who introduced chloroform into anaesthesia, early showed a peculiar talent for medical observation and research. He was a well-known professor in Edinburgh, a trained experimenter. In 1847, after numerous experiments on himself and others, he disclosed the possibilities of chloroform as an anæsthetic. If we take a step further back in this field, we find the chloroform itself discovered as a new chemical compound by the well-known university professor, Liebig. He was trained and supported all his life for doing just such things. He was the first of a long series, and he made many such contributions to our welfare.

It is for such reasons that we want to see more chemists and physicists trained in our schools than are absorbed in our industries. We need them much more generally in scientific research laboratories, in the college or elsewhere, where the country's future interests are concerned.

The trying of new things which made the telephone possible was done by Faraday when he studied the effect of one electric current on another and disclosed the general laws of magnetic induction. His was no untrained mind suddenly awakened by a gracious Nature with a useful discovery in her outstretched hands. He was studying a lot of little effects which all practical men of his day would have said were meaningless and useless. He was keeping careful notes of every observation and continuing every experiment as the results of the last one led him onward. His trials of unknown combinations, each with its clear object, reached many thousands in number. To him they were full of mystery, and so interesting as to force him to continue them. The world holds an infinity of just such phenomena still unstudied, but it does not support many such investigators.

Speaking in the light of subsequent utilities and developments of his work, we can safely claim that such an investigator is worth thousands of ordinary men. Something must also be attributed to his opportunities and environment. Such things we can supply. Taught to experiment by a Davy, and retained in a position in the Royal Institution, he was in command of his own time and adequate apparatus for scientific research over a period of two score years. This cost the Royal Institution of Great Britain yearly not over $2500 for salary at his highest annual rate. We would not expect every such investment to be as productive. But, there are at this late day, in our own country, very few men employed to do research work as he was employed. In most of our institutions of learning, it is still difficult to obtain funds to permit of scientific research by teachers even for a small fraction of their time.

People have already nearly forgotten that aeronautics owes its present development to the trying of certain new things by Professor Langley. No one took any stock in his early studies on the rate at which little cardboard planes would fall, if given a certain slant and a certain lateral speed in the air. His studies had been published for years, but no one used them. At that time aviation certainly seemed more possible through the use of balloons, of lifting propellers, or of waving wings, than through any other means. Langely finally tried to show the application of the facts he had learned about air-floating-planes to aeronautics, and was scoffed at. Now we appropriate at once sixteen million dollars for such flying machines, to keep abreast of those who are using the principles disclosed by Langley.

But Langley's work, so far as his support by the country went, was one of our best American near-successes. He, too, was a highly trained physicist. He was early a professor of astronomy and physics, and was long an experimenting student of meteorology, both at Pittsburgh and Washington. His efforts for a time were supported by the government, but this support was withdrawn at the critical period when a successful aeroplane, as we now realize, was apparently actually at hand. For only a part of his work on other matters, such as the extension of the invisible solar spectrum or the bolometer, we ought to have rewarded him by aiding him to develop those other subjects, like aerodromics, in which he excelled.

Were his discoveries fortuitous? No. He was an active scientific investigator with years of training and experience. The kind of work he was doing is exactly what is needed for the foundation of such advances as we hope to make, but cannot now foresee. Unfortunately, we Americans were not wise enough to continue encouraging and supporting his work.

A Swedish professor in a lecture once noticed that a wire carrying electricity made a magnetic needle move when brought near it. He studied this little thing because he liked it. Another Professor, in France, quickly went on with this little phenomenon, finding out how in general electricity and magnets were related. Then a couple of Germans used the principle for communication at a distance, and we soon had electromagnetic telegraphy.

In addition to these, such men as our own Professor Henry contributed to the study of the electromagnet. Is it an accident that all of these men, Oersted, Ampere, Gauss, Weber, and Henry were in educational institutions, that they were mature and highly educated men? Perhaps the two names which first occur to the student of the electrical group are Volta and Galvani. Here again we have trained observers and teachers. Each of them, but two, was over forty when he did the work here referred to. I mention this to show that in such cases maturity in age and education has been common, and that we must get out of the way of thinking that great advances by original thought and work emanate usually from the young and untrained mind, or are accidents of time and environment.

Prior to the studies of Ampere, no one proposed trying currents in wires acting on magnets as a scheme for communication. The post did that work satisfactorily. No one knew telegraphy as a *want* at all. The use followed after the discovery. The discovery was made by a trained scientist. It was studied by a scientist, and scientists later steered it into useful directions and engineers made it commercial.

Most Americans probably imagine the great utilities now depending on the use of steam as traceable to the discovery of a lad who observed the steam pressure exerted in the kettle at the home fireside and who, with a little tinkering, soon set up the steam engine. This is what our newspaper men call the personal touch, or human element which is so necessary to effective popular science. But the truth is sacrificed to please us, for a cent. Hero of Alexander apparently made the first steam engine. He was one of the greatest scientists, students, teachers, and writers of his day, and his results were the work of most advanced and careful experimentation, carried out with remarkable support and conveniences. The methods of development of new things in Hero's time (130 B. C.) are necessary today.

We find in the researches which led to the engine becoming the combination of a cylinder, piston, and condenser, the work of Papin, a lifelong experimenter in physics, hydraulics, and pneumatics, and a professor at Marburg. He worked out the idea of the condenser. Apparently the aid of Robert Hooke, a professor at Gresham College and a lifelong research student of physics, enabled Newcomen to improve Papin's apparatus, so that an engine for mine pumping resulted, and then came Watt. He was aided by Glasgow professors, and the college gave him the position of mathematic instrument maker. In this position, with the help of the professor of chemistry, Black, and the professor of natural philosophy, Robison, he experimented on steam. He was at this work eight years before he made the advance of adding the vacuum to the earlier engines. It was not a flash of thought, but a long study.

And so I say, let us train more scientists, more men who can study new things and ask questions of Nature. We will be adequately supplied with good engineers, because the demand for them is obvious and the pay good.

It was a professor at Louvain, Minckelers, who apparently started us in the use of illuminating gas. He became interested in the distillation of coal. He was not aiming to illuminate houses, and his first uses gave no premonition of our present conditions. He was trying such gases in balloons, but he also tried lighting his lecture room by this means. The engineering development of this peculiar discovery did not take place for ten or more years, but it was the inquisitive mind of the trained physicist and chemist which made the engineering possible.

To take a well-known chemical field, let us review the way the facts were discovered and the steps taken in the fixation of nitrogen. No attempt will be made to give a complete account, but notice how generally it is the mature, highly trained man who makes the observations and carries the study to the point where obvious utility warrants others taking hold. The earliest work on the action of electric arcs in producing combination between the gases of the air, was the observations of Priestley and Cavendish, each of them a lifelong student of chemistry and physics. They showed that nitric oxides are produced. The refinements of technical development were due to the experiments of Bradley and Lovejoy in America, of Birkeland and Eyde in Norway, and of Schoenherr and Pauling in Germany and Austria. Another of the fixation processes is traceable to the discoveries of Moissan, an experienced chemist and teacher in Paris, who described the production of calcium carbide in the electric arc. It had been previously made, and the production of acetylene from it, by Wöhler, a teacher of chemistry in Leipzig, and at the time of Moissan's discovery was also discovered in America, by Willson, who developed it commercially. That this carbide was useful for the fixation of nitrogen was found by Caro and Frank. Ostwald, one of the most active physical chemists, became interested in catalysis and studied the oxidation of ammonia to nitric acid, when this reaction had only scientific value, and yet it is now used to help Germany in her manufacture of explosives. Professor Haber, another well equipped German teacher and investigator, also studied a number of gas reactions in the way which almost always puts the science, and sometimes the industries, ahead. He spent years studying and writing on the thermodynamics of gas reactions. His direct production of ammonia is now possibly the world's simplest way of getting ammonia, and from it, in turn, the very desirable nitric acid. Such a large part of this work has been due to the start given by the purely inquisitive experiments of well trained experts that this way of advancing seems a sure way.

Carl Scheele devoted his whole life to chemical experiment and investigation. The chemists of today are deeply indebted to him for his many studies. No one can properly inventory the work of such a man. His discovery of oxygen made his name forever known, but his studies of the coloration of certain silver salts by light laid the foundation for photography. How easily we accept as natural a condition such as this, where the greatest skill of a human copyist is perfectly transcended by a simple chemical process. But it was once unsuspected: the way was opened by inquisitive experiments by a good observer.

Surely there are many more just such widely interesting developments which only await the careful studies of the trained inquirer. The history of photography is filled with the names of chemical and physical investigators, most of whom contributed to this science only after long preparation in research work. Very little, or nothing seems here to have been accidental. Our position has resulted from gradual accretions of knowledge from many experimenters.

I do not claim that professors, when given time to carry on experiments and delve in some new field, have all started revolutionary utilities, nor do I believe that every new plane to which we have been lifted by human effort has been the result of some college professor's work, but it is right to realize that most of them have been. The illustrations are useful in showing that new knowledge is likely to come from the experiments of scientifically trained men who, removed from many of the interruptions of average life, can go more deeply into the unknown than most of us, and they make us question whether we are doing enough of trying new things.

As we ride in our automobiles, we realize that the explosion type of engine marked a new epoch. On account of the proximity, we cannot estimate the value of this step. Apparently, like the use of illuminating gas or magnetic induction, this foundation was also laid in the professor's lecture room. The first explosion type of engine was apparently that of a Professor Farish, at Cambridge, in 1820. In this case he used hydrogen and air mixtures, but the step to other gases, or gasoline, was only one of refinement. We call it engineering after the principles are founded.

During the past few years we have had our pleasure constantly increased by the thermos bottle. This may be a little step, but it must be attributed to the scientific work of a trained expert, Professor Dewar. His greatest service may be his work on the liquefaction of gases, but his need for such liquids as hydrogen prompted the development of the vacuum jacketed and silver coated glass apparatus now in daily use throughout the world.

We have already mentioned Davy, of the Royal Institute. His continued experiments led to many of the conveniences of today, but he also discovered and isolated the five metals, sodium, magnesium, calcium, barium, and strontium. His studies of fire damp and his safety lamp are also familiar, and his work on agricultural chemistry started the world on a line which is still under experiment. His attainments and those of his successor, Faraday, probably account for the permanency of publicly supported scientific research in England.

The Royal Institution of Great Britain maintains professors of natural philosophy, chemistry and physiology, and has good research laboratories under its direction. Other men who have been thus developed and maintained were Thomas Young, Tyndall, Frankland, and Rayleigh. Can any one question the wisdom of encouraging these particular men?

The London Royal Society was established and largely supported by contributions of its members, but it occupies a semi-official position as the scientific adviser of the Government. Parliament has long voted annually $20,000 towards its work.

Any attempt to cover the marked disclosures of science would be incomplete without reference to the work of the German schools of organic chemistry. But here the modern results of organized effort by the best educated chemists are well known. The number of useful dyes is almost infinite. The by-products in the way of new explosives, such as trinitro toluol, are familiar to all. So are countless medicinal products, like antipyrin and phenacetin, and special chemicals, such as photographic developers. There is surely no limit to the possibilities due to the careful and long continued studies of organic chemical reactions. The way the work was done is what insured its eternal usefulness.

The last contribution to our economies in artificial lighting was due to the purely scientific researches of Rayleigh and Ramsay, than whom no scientists were better trained. Their discovery of argon later permitted its use in incandescent lamps to improve the quality of the best then known.

We cannot go into the details of the discoveries which led to the telescope and microscope, but after the earliest simple lenses, they were the work of the investigating students of physics, whose names, like those of Hooke, Wallaston and Herschel, are well known. It is also worth while referring to the markedly practical case in which the German government supported the efforts of Professor Abbe, and thus aided in the production of those optical glasses and instruments which have made the reputation of the little town of Jena.

In biochemical fields there are countless examples of the value to the race of keeping able research men at work on questions of human welfare, the cure and prevention of disease, etc. The immense field of immunity studies which in the past quarter century have seen the strides made by Pasteur, Ehrlich, Metchnikoff, and their students, cannot be expressed in ordinary measures of value. They have called for the life study of many good men, and any less preparation would have been inadequate.

I have intentionally omitted the names of many men who accomplished much for mankind by devoting their lives to scientific investigation, usually in connection with some school. The cases chosen, while selected at random, are some of the relatively simple ones. The monumental work of such men as Helmholtz, Newton, Maxwell, Liebig, Bunsen, Kelvin, and scores of others, could scarcely be briefly treated, but in all of them the value of long continued application in new fields of physical knowledge is plain. They were all given time, opportunity, and support for the public good.

Readers of *Popular Mechanics* some time ago selected by vote the seven wonders of the modern world. The highest votes were received by wireless, the telephone, aeroplane, radium, antiseptics, antitoxins, spectrum analysis, and X-rays. How were these originated? All of them were produced by the indentical formula. In the first place, they were not the result of a direct attempt to accomplish what was really attained. The end was not visible when the foundations were laid. The real work was done by thoroughly well trained observers—not by laymen. They were professors in every case. They followed up a lead opened by an observation which was too insignificant to attract the attention of less trained men. The results now form a large portion of our human inventory, and we ask: Are other such additions possible? The answer is certainly, Yes, and by the same method. These disclosures are portions of an infinite nature. They seem insignificant until some strenuous and highly studious efforts are expended upon them, and then it slowly becomes apparent that they fit perfectly into our needs. As we could not have foreseen them, so we cannot foresee their followers, but with the extentions of knowledge the possibilities continually increase. The limitations are in us and in our finite vision. We will get ahead in proportion to our training for extending the realms of natural knowledge, and we will grow in proportion to our applications of modern methods used at the advancing boundary between known and unknown. This is the way it has always been done.

ANALYSIS OF SHORT-CIRCUIT OSCILLOGRAMS

By O. E. Shirley

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This article first points out the need of a short and accurate method of analyzing short-circuited alternator oscillographic test records that will facilitate, or rather make possible, the application of the general equation for short-circuit current. The theory leading up to the general equation for short-circuit current is reviewed, and the equation is applied to the particular case of a short circuit at the terminals, under which conditions factory tests are usually made. The constants determined from such oscillographic tests on any particular machine can be applied in the general equation to calculate the short-circuit current of that machine under any condition involving external impedance. A simple method of analyzing oscillographic records to determine these constants is described, and an example illustrating its application is given. Also, an approximate formula is given for obtaining the maximum possible short-circuit current from the armature reactance. —Editor.

The armature current of an alternating-current machine on sudden short circuit may be of symmetrical or unsymmetrical wave form, depending upon the point of the voltage wave at which the short circuit takes place. The maximum value of the unsymmetrical wave may be as great as twice the maximum value of the symmetrical wave. Since the stresses in the windings of the machine, in the transformers, and in the other parts of the external circuit are proportional to the instantaneous value of current, it is desirable to gain a knowledge of what will be the maximum value of the unsymmetrical short-circuit wave, that is, the worst possible condition to which the machine may be subjected. When short circuiting a machine in test, it is extremely difficult to time the placing of the short circuit so that it will occur at that point of the voltage wave which will give the maximum value of short-circuit current. Consequently a method of analysis from which constants can be obtained to calculate this maximum value from any short-circuit current oscillograph wave will be useful. The method of analysis given in this article has been found to give quite consistent results on a number of tests; and the values of armature reactance, the most important constant, have been found to check very closely when calculated from a number of oscillograms on the same machine.

General Theory

The useful flux in the magnetic circuit of an alternating-current machine is that corresponding to the normal open-circuit voltage combined vectorially with the impedance drop in the alternator. This flux is produced by the resultant m.m.f. of the direct-current field and the armature reaction of the alternating currents in the armature. When operating under steady short circuit the current in the armature will be proportional to the field current and of such a value that the back m.m.f. of the armature will be equal to the m.m.f. of the field minus the saturation ampere turns required to give the flux in the magnetic circuit. This flux will be that corresponding to the impedance drop in the machine. The impedance drop in machines of ordinary design varies from 15 to 25 per cent at the current corresponding to the normal rating. Hence, it will be seen that the flux in an alternator short circuited at normal voltage will drop from normal to about one-sixth or one-fourth this value in the interval between short circuit and the steady condition.

It will be assumed that the flux dies away approximately according to a simple exponential curve; and this may be expressed by the equation

$$\phi = \phi_o{}^{-\frac{r_o}{x_o}(\Theta-\Theta_1)}$$

Where

Θ = time expressed in radians based on the e.m.f. wave.
Θ_1 = time at which the short circuit occurs.
r_o = resistance in field circuit.
x_o = reactance in field circuit.
ϕ = flux at any time Θ
ϕ_o = initial value of flux at time of short circuit.

Let

E = maximum value of the normal voltage wave.
e = instantaneous value of the voltage wave after short circuit.
E_1 = maximum value of transient component of voltage wave.
e_1 = instantaneous value of transient component of voltage wave.
E_2 = maximum value of impedance voltage wave (corresponding to the flux in the machine under steady short circuit conditions).

Z_s = synchronous impedance of machine in ohms.

z = true armature impedance in ohms.

I = maximum value of steady armature current wave.

i = instantaneous value of short circuit current.

$$k=\frac{z}{Z_s}$$

r = resistance of armature circuit.

x = reactance of armature circuit.

Then, the following relations can be easily deduced.

$$E_2=Iz$$

$$E=E_1+E_2$$

$$E_2=E\frac{z}{Z_s}=k\,E \text{ and } E_1=(1-k)\,E$$

Also

$$e_1=E_1\,sin\,\Theta\,\epsilon^{\frac{-r_o}{x_o}(\Theta-\Theta_1)} \text{ (See equation for } \phi\text{)}$$

And

$$e=E_1\,sin\,\Theta\,\epsilon^{\frac{-r_o}{x_o}(\Theta-\Theta_1)}+E_2\,sin\,\Theta$$

$$=(1-k)E\,sin\,\Theta\,\epsilon^{\frac{-r_o}{x_o}(\Theta-\Theta_1)}+kE\,sin\,\Theta$$

Since the circuit contains only inductance and resistance, the following differential equation applies

$$e=ir+x\frac{di}{d\Theta}$$

Then

$$ir+x\frac{di}{d\Theta}=(1-k)\,E\,sin\,\Theta\,\epsilon^{\frac{-r_o}{x_o}(\Theta-\Theta_1)}+kE\,sin\,\Theta$$

From the integration of this equation and several transformations, the following formula for short-circuit current may be derived.

$$i=\frac{E}{x}\left\{\frac{X}{Z}(1-k)\epsilon^{-a_f(\Theta-\Theta_1)}sin\,(\Theta-\beta)-\epsilon^{-a_a(\Theta-\Theta_1)}\left[(1-k)\frac{X}{Z}sin\,(\Theta_1-\beta)+k\frac{x}{z}sin\,(\Theta_1-\beta_1)\right]+k\frac{x}{z}sin(\Theta-\beta_1)\right\} \quad (1)^*$$

Notation.

$$z=\sqrt{r^2+x^2}$$

$$\frac{R}{X}=\frac{r}{x}-\frac{r_o}{x_o}$$

$$Z=\sqrt{R^2+X^2}$$

$$\beta=arc\,tan\frac{X}{R}$$

$$\beta_1=arc\,tan\frac{x}{r}$$

$a_a=\frac{r}{x}$ (This is called the armature attenuation factor.)

$a_f=\frac{r_o}{x_o}$ (This is called the field attenuation factor.)

This equation is too complicated for ordinary use but it may be simplified considerably where the resistance is quite small compared to the reactance, as is the case with ordinary short circuits at the terminals of the machine.

Then

$$\beta=\beta_1=90°$$

$$\frac{X}{Z}=1$$

$$\frac{x}{z}=1$$

And

$$i=\frac{E}{x}\left\{(1-k)\epsilon^{-a_f(\Theta-\Theta_1)}(-cos\,\Theta)-\epsilon^{-a_a(\Theta-\Theta_1)}[(1-k)\,(-cos\,\Theta_1)+k\,(-cos\,\Theta_1)]+k\,cos\,\Theta)\right\}$$

$$=\frac{E}{x}\left[-(1-k)\,cos\,\Theta\,\epsilon^{-a_f(\Theta-\Theta_1)}+cos\,\Theta_1\,\epsilon^{-a_a(\Theta-\Theta_1)}-k\,cos\,\Theta\right] \quad (2)$$

The constants of a machine may be obtained from any short-circuit oscillogram by the following method of analysis. The peaks of the current waves are plotted against time. See Fig. 1. It will be noted that, ordinarily, the peaks above and below the zero line will be very much different during the first few cycles, due to the armature transient (it is possible, however, to obtain a perfectly symmetrical wave). Curves M and N should be drawn through these peaks and the average curve O of the upper and lower waves plotted. The difference between the average curve and either of the original curves will then give the armature transient curve P.

A straight line Q should then be drawn parallel to the time axis equal to the maximum value of the sustained short-circuit current; and the difference between this line and the average curve will give the peak value of the field transient curve T. It should be noted that the armature transient is a component always in the same direction but decreasing in

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* This equation for short-circuit current of an alternator was developed by Dr. E. J. Berg of Union College, and was first published by Mr. N. S. Diamant in the A. I. E. E. proceedings for September 1915.

value, while the field transient is the product of a similar transient and a sine function.

Returning to equation (2), it will be seen that $cos\ \Theta = 1$, since only the peaks of the current waves are considered. Consequently, the equation may be simplified to

$$i_p = \frac{E}{x}\left[-(1-k)\epsilon^{-a_f(\Theta-\Theta_1)} + k\, cos\, \Theta_1\, \epsilon^{-a_a(\Theta-\Theta_1)} - k\right] \tag{3}$$

Where i_p is the value of the peaks of the current waves.

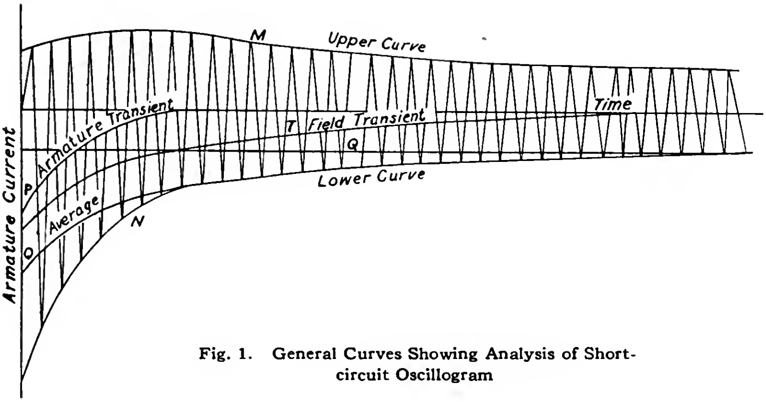


Fig. 1. General Curves Showing Analysis of Short-circuit Oscillogram

This method of analysis may be applied only to short circuits at the terminals of a machine, in which case the resistance is negligible as compared to the reactance, and

$$z = x \text{ and } Z = X$$

Equation (3) may then be divided into three parts giving the armature transient, the field transient, and the permanent short-circuit current.

$$\frac{E}{x}\,(1\text{-}k)\ \epsilon^{-a_f(\Theta-\Theta_1)} \quad \text{(Field transient)}$$

$$\frac{E}{x}\,k\ cos\ \Theta_1\ \epsilon^{-a_a(\Theta-\Theta_1)} \quad \text{(Armature transient)}$$

$$\frac{E}{x}\,k = \frac{E}{z}\,k = \frac{E}{Z_s} \quad \text{(Permanent short-circuit current)}$$

When $(\Theta\text{-}\Theta_1) = 0$, the exponential terms are equal to unity; hence, by projecting the armature and field transient curves back to the current axis, the value of the expressions $\frac{E}{x}(1-k)$ and $\frac{E}{x}\,k\ cos\ \Theta_1$ may be determined. The value of the armature reactance may be determined from the former and the value of $cos\ \Theta_1$ from the latter.

These curves may be projected back to the current axis by plotting the Naperian logarithm of the armature and field transients against time. Since these functions are exponential, these latter curves will be straight lines and may be projected to the logarithm axis. The numerical values of the constants may be determined from these curves, as will be illustrated in the example at the end of this article.

The values of a_a and a_f may be determined from these straight-line curves of Naperian logarithms against time.

Let

A_1 = value of armature transient at time Θ_2

A_2 = value of armature transient at time Θ_3

Then

$$A_1 = -\frac{kE}{x}\ cos\ \Theta_1\ \epsilon^{-a_a\Theta_2}$$

$$A_2 = -\frac{kE}{x}\ cos\ \Theta_1\ \epsilon^{-a_a\Theta_3}$$

$$\epsilon^{-a_a\Theta_2} = A_1\left(-\frac{x}{kE\ cos\ \Theta_1}\right)$$

$$\epsilon^{-a_a\Theta_3} = A_2\left(-\frac{x}{kE\ cos\ \Theta_1}\right)$$

$$-a_a\,\Theta_2 = log\ A_1 + log\left(-\frac{x}{k\ cos\ \Theta_1}\right)$$

$$-a_a\,\Theta_3 = log\ A_2 + log\left(-\frac{x}{k\ cos\ \Theta_1}\right)$$

$$-a_a\,\Theta_2 + a_a\,\Theta_3 = log\ A_1 - log\ A_2$$

$$a_a = \frac{log\ A_1 - log\ A_2}{\Theta_3 - \Theta_2}$$

In a similar manner a_f may be obtained from the field transient curves. It should be noted that Θ is espressed in radians, in obtaining a_a and a_f in the examples given, and that the time angles should be expressed in radians when these values are used.

Example

Fig. 2 is an oscillogram taken of a single-phase short circuit on a 700-kv-a., 60-cycle, 4000-volt alternator. Table I is taken from this oscillogram. The short-circuit current curves in Fig. 3 are plotted from this table and the constants of the alternator are derived in Table II and Fig. 3 by the method given in the "General Theory."

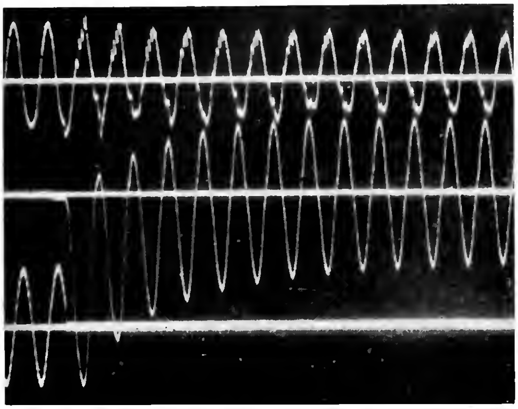


Fig. 2. Oscillogram Showing Waves of Current and Voltage with Single-phase Short Circuit on an Alternator. Upper Curve is Voltage Open Terminal to Neutral; Middle Curve is Short-circuit Current; and Lower Curve is Voltage between Short Circuit Terminal.

Discussion

The values obtained for armature reactance will usually show a variation from the mean value of from 6 to 8 per cent for any given voltage, and the lower values will be obtained on the more unsymmetrical armature current waves. This armature reactance shows also a tendency to decrease at the higher values of armature voltage, and a variation of 15 to 25 per cent from half-voltage to full-voltage is not unusual. This effect is probably due to the iron in the leakage paths around the armature coils becoming saturated at the higher voltages.

The values of the armature attenuation factor a_a are usually quite consistent, and the curve between the logarithm of the armature transient and time is nearly always a straight line.

The curves between the logarithm of the field transient and time do not usually follow a straight line, especially if the armature current is very unsymmetrical, but it can usually be approximated very closely by two straight lines. The first line should be drawn through the first point and the third or fourth one, and then the second will follow the remaining points quite closely.

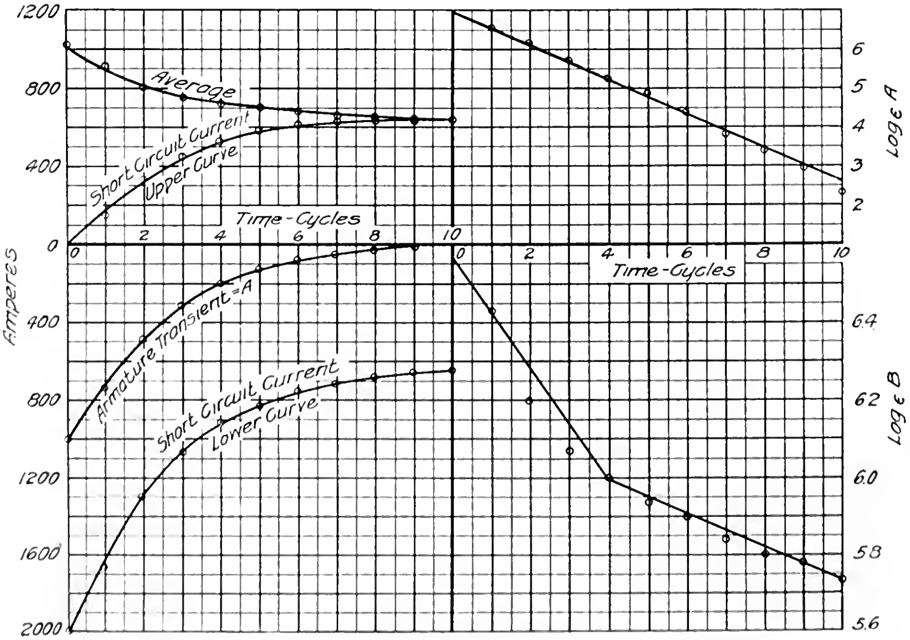


Fig. 3. Curves Derived in the Analysis of the Oscillogram Shown in Fig. 2

The values of the field attenuation factor will practically always show a very considerable variation; but, fortunately, the effect of this factor on the armature current during the first few cycles, when it is subject to so great variations, is very small. The variation is probably due to the eddy currents produced in the field structure and appears as a change in the effective resistance of the field.

It is very important in the analysis of a particular oscillogram that the straight line projected back to the time axis, when determining the value of the field transient for time O, should pass through the first point and very close to the second and third points. The condition will be fulfilled very satisfactorily by drawing this line through the first point and the third or fourth one. This will give the proper values for the armature attenuation factor and for the armature reactance.

TABLE I

SHORT-CIRCUIT CURRENT UPPER PEAKS MIDDLE CURVE FIG. 2		SHORT-CIRCUIT CURRENT LOWER PEAKS MIDDLE CURVE FIG. 2		Cycles
m.m.	amp.	m.m.	amp.	
4.0	150	44.0	1670	1
9.0	340	34.0	1290	2
12.0	460	28.0	1060	3
14.0	530	24.0	910	4
15.0	570	22.0	840	5
16.0	610	20.0	760	6
16.2	620	19.0	720	7
16.5	630	18.0	680	8
16.5	630	17.5	660	9
16.5	630	17.0	650	10

Single-phase. No external resistance in armature circuit. Effective normal voltage 3996.

Armature current 1m.m. = 38 amperes.

Amperes field 44.0.

Sustained short-circuit current $\begin{cases} = 223 \text{ amperes effective} \\ = 320 \text{ amperes maximum.} \end{cases}$

TABLE II

Cycles	UPPER CURVE	LOWER CURVE	Sum	Aver.	Arm. Trans. $=A$	$\text{Log}_\epsilon A$	Sust. $S.-c.\ c.$	Field Trans. $=B$	$\text{Log}_\epsilon B$
	Amperes								
0	40	2000	2040	1020	980	6.90	320	700	6.56
1	180	1670	1850	925	755	6.63	320	605	6.43
2	320	1290	1610	805	485	6.18	320	485	6.20
3	440	1060	1500	750	310	5.73	320	430	6.07
4	520	920	1440	720	200	5.29	320	400	6.00
5	570	820	1390	695	125	4.83	320	375	5.93
6	600	760	1360	680	80	4.38	320	360	5.88
7	615	710	1325	665	45	3.81	320	345	5.84
8	620	680	1300	650	30	3.40	230	330	5.80
9	620	660	1280	640	20	2.99	320	320	5.78
10	620	640	1260	630	10	2.30	320	310	5.74

$$E = 3996\sqrt{2} = 5650$$

$$\frac{E}{x} = 1020 \qquad x = 5.53$$

$$\cos \Theta_1 = \frac{980}{1020} = 0.96 \qquad \Theta_1 = 16^0$$

$$a_a = \frac{6.9 - 5.3}{4 \times 2\,\pi} = 0.064$$

$$a_f = \frac{6.56 - 5.99}{4 \times 2\,\pi} = 0.0224 \text{ (first 4 cycles)}$$

$$a_f = \frac{5.99 - 5.82}{4 \times 2\,\pi} = 0.0068 \text{ (after first 4 cycles)}$$

$$k = \frac{320}{1020} = 0.314 \qquad (1 - k) = 0.686$$

$$i = 1020\,(-0.686\,\epsilon^{-0.0224\,(\Theta - \Theta_1)} \cos \Theta + \epsilon^{-0.064\,(\Theta - \Theta_1)} \cos \Theta_1 - 0.314 \cos \Theta) \quad \text{(first 4 cycles)}$$

$$i = 1020\,(-0.686\,\epsilon^{-0.0068\,(\Theta - \Theta_1)} \cos \Theta + \epsilon^{-0.064\,(\Theta - \Theta_1)} \cos \Theta_1 - 0.314 \cos \Theta) \quad \text{(after first 4 cycles)}$$

It will be possible to obtain very much more consistent values of the field attenuation factor by approximating the curve over a period of twenty or thirty cycles; and, if this value is used with the average values of armature reactance and armature attenuation factor, the calculated values of armature short circuit will check the test within 8 or 10 per cent.

The effect of variations in the attenuation factors during the first cycle or so are not very great and the maximum value of the armature current can be approximated quite closely from the following formula, when the armature reactance is known.

$$i = \frac{2.0\,E}{x}$$

Where

i = maximum instantaneous value of current.

E = maximum value of normal voltage wave, that is, $\sqrt{2}\,E_{effective}$.

x = armature reactance in ohms.

GROUP STREET LIGHTING SYSTEM FOR THE CITY OF CHICAGO

By William G. Keith

Commissioner of Gas and Electricity, Chicago, Ill.

This article describes a system of group street lighting that is novel for large installations, and that has proved very satisfactory and economical in installation and operation. It is planned to add about 25,000 100 candle-power Mazda lamps by this scheme of distribution to the existing lighting system of Chicago.—Editor

The City of Chicago has been extending its street lighting system for several years, and has made use of a large number of 100 candle-power Mazda series lamps placed on posts about ten feet above the ground. Plans are now under preparation for adding about 25,000 of these to the existing system.

To continue placing high potential within reach of the public was not considered safe, and to eliminate this hazard it was decided to use individual transformers at each lamp location. Further analysis showed that the placing of lamps in series groups of about twenty to the group, and operating these from series transformers located in manholes, would reduce the costs by over 13 per cent. Plans have been prepared to carry out the work in this way.

The typical circuit for street lighting in Chicago will consist of an impedance regulator in series with a 5050-volt, 60-cycle source of energy, and approximately 22,000 feet of underground conductor insulated for 5050-volt operation. Located in manholes central to the territory to be lighted, with their primaries in series with each other and the high tension cable, will be series transformers of suitable capacity.

The secondary of each transformer, with a permanent connection to earth at the center of the winding, will be connected to a series circuit of approximately 3,800 feet of conductor insulated for 600-volt operation. Approximately twenty 100-c.p., 6.6-ampere Mazda "C" series lamps, equipped with 100-volt film cutouts, will be connected in series with each of these secondary circuits.

The large saving in cost over the individual transformer method is due to the use of low voltage cable in place of high voltage, and the centralizing of the transformer capacity. The transformer vaults tend to offset this saving, while labor is approximately the same, making a net saving of over 13 per cent.

The substation transforms from 12,000 volts, 60 cycle, three-phase delta to 5,050 volts to neutral, 60 cycle, three-phase Y, with neutral grounded. Group lighting circuits are run from each phase through a 6.6 ampere constant-current impedance regulator, through the series transformers, and back to grounded neutral in the substation. A typical external circuit is shown diagramatically in Fig. 1, and consists of the following material:

A source of 60-cycle, 5050-volt energy:

(a) One overload and underload automatic oil switch.

(b) One 6.6 ampere constant current regulator.

(c) 8000 ft. No. 8 B.&S. solid copper conductor, insulated with a $\frac{3}{16}$ in. wall of saturated paper for 5000/8660-volt operation, and surrounded by a $\frac{1}{8}$ in. lead sheath.

(d) 16 (4 groups of 4) 6.6/6.6-ampere series transformers, each to operate twenty 100-c-p., 6.6-ampere series Mazda "C" lamps, in series with 3800 feet of No. 8 B.&S. solid copper conductor insulated and armored for 600-volt operation.

(e) 3000 ft. (3 lengths of 1000 ft.) No. 8 B.&S. copper conductor, armored, $\frac{3}{16}$ in. varnished cloth insulation for 5000-volt operation.

3,000 ft. of 5000-volt armored cable as item (e).

8000 ft. of No. 8 B.&S. solid copper conductor, as item c. This conductor terminates through an air brake switch, on the grounded neutral bus.

This method of operating street lamps has never been tried on a large installation, and several questions arose as to the operating difficulties that might be encountered. A thorough consideration of the subject, supplemented by tests, established the following facts.

Phenomena with Open Circuited Secondary of Series Transformer

The first consideration is the effect on the operating circuit when from any cause the secondary circuit of any transformer opens.

Practically all the current drawn is due to resistance load, and sine wave of e.m.f. would therefore send sine wave of current through the circuit. In the event that one of the group transformer secondaries should open, full 6.6 ampere sine wave current would be forced through the primary, with the result that a peaked e.m.f. wave would be induced in the secondary and impressed on the open group. Fig. 3 shows this voltage wave.

By the graphical method shown in Fig. 5, the magnitude of this e.m.f. has been found to be 1.95 volts per turn per square inch of core, and the root-mean-square value 0.568 volts per turn per square inch of core. As a transformer of this size will have approximately 182 turns secondary and 5¾ square inches of core, we can expect a maximum voltage of 2040, or a root-mean-square voltage of 595 volts to be impressed on the secondary circuit until such time as the short circuiting devices provided shall operate.

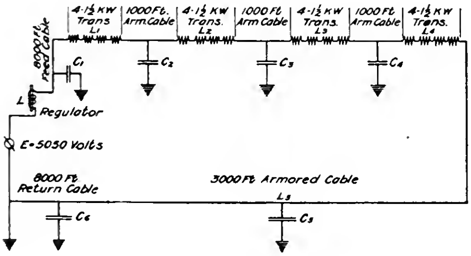


Fig. 1. Group Lighting Circuit

As the cables are tested for five minutes with a root-mean-square voltage of 1500 volts, or a maximum voltage of 2120 volts, there will be no danger of cable failure.

To guard against this potential remaining on the secondary circuit during the period of open circuit, each lamp will be provided with a film cutout that will puncture and short circuit the lamp at a potential of approximately 100 volts. In addition to this, each transformer will be provided with a short-circuiting device that will operate to short circuit the secondary when the potential reaches 400 volts. This protection is designed to operate when for any reason the secondary circuit is interrupted at some point not protected by the lamp cutouts, as for example, a post falling and breaking the conductor.

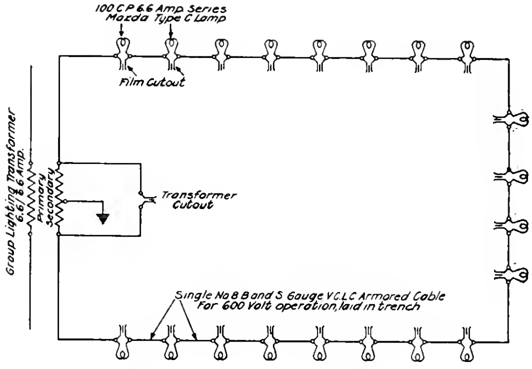


Fig. 2. Secondary Lamp Circuit

Fig. 6 shows diagramatically the electrical system from prime mover to street lights.

Induction

Tests on the cable to be used for the 5000-volt circuit show that the steel armor forms such a good path for the magnetic flux that little or no benefit can be expected by placing the sides of a circuit in the same trench, while the armor in place makes impossible the transmission of electrostatic disturbances from one cable to another.

Charging Current

When the original series tungsten circuits were placed in service, a marked difference in the value of the current at the two ends of the circuit was observed. This difference was due to a charging current combining with the line current and it was found necessary to correct the difference by inserting reactance at the point where the circuit connected to its return conductor.

Fig. 5 is a diagram of the various currents in the different parts of the proposed circuit combined in their vector relationship. This shows that while there is a difference in current value of 0.07 of an ampere between the two station ends of the circuit, the actual difference of current between the first and last transformer is only 0.033 of an ampere and is negligible.

Fig. 5 also shows the relation of voltage to current in all portions of the primary circuit and illustrates how the charging current improves the power-factor of the whole.

Power-factor

The transformers with their lamp load have a power-factor better than 98½ per cent; the cable has a power-factor of 95.8 per cent as against 91.2 for that used in former installations. The regulator power-factor is very low, making a combined power-factor of 81.3. The charging current combines to correct this to 89 per cent. This is 1 per cent better than that of straight series tungsten lighting and 1½ per cent better than 600 c-p. series compensator circuits, and in addition has the advantage over straight series tungstens of localizing lamp outage when post failures occur.

Size of Conductors

The wire sizes selected for the group lighting circuits was determined by equating the interest and depreciation on the cost of cable against the cost of losses when using such cable.

These calculations resulted in sizes considerably smaller than the No. 8 selected, but the latter size was chosen for mechanical reasons rather than the small size.

Transients

The fact that the Department of Gas and Electricity has for three years operated circuits containing reactance in series with cable capacity, and that such operation has not indicated the presence of critical relationship between such reactance and capacity, it is only necessary to show that the relationship between reactance and capacity in the proposed circuits is such as to give an equal or more stable operating condition, to prove that the proposed system does not present an operating hazard in excess of that usually acceptable.

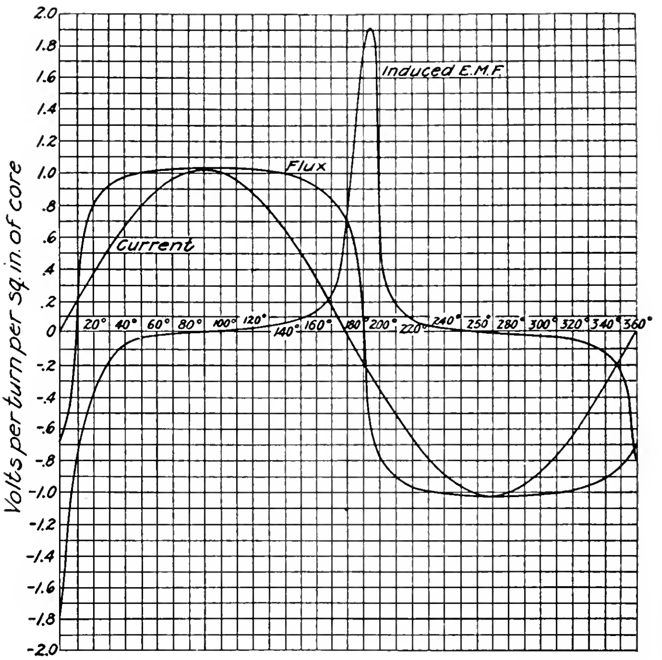


Fig. 3. Primary Current, Flux, and Induced Secondary Voltage of Series Transformer on Open Circuit

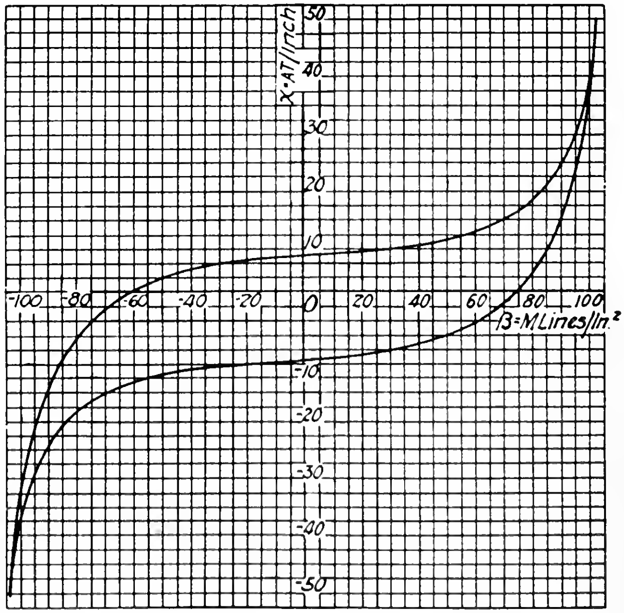


Fig. 4. Hysteresis Loop of Core Material of Series Transformer

The present circuits may be represented diagramatically as in Fig. 1, where E is a grounded source of alternating-current electromotive force of 5050 volts, 60 cycles; L is the reactance of the regulation device; L_1, L_2, L_3, L_4, L_5, and L_6 are the distributed reactance of the underground cable and transformers; and C_1, C_2, C_3, C_4, C_5, and C_6 are the distributed capacities of the underground cable.

The critical frequency of this circuit can be expressed thus:

$$N_o = \frac{1}{2 N L_o C_o}$$

where

L_o = the sum of all the reactances.

C_o = the sum of all the capacities.

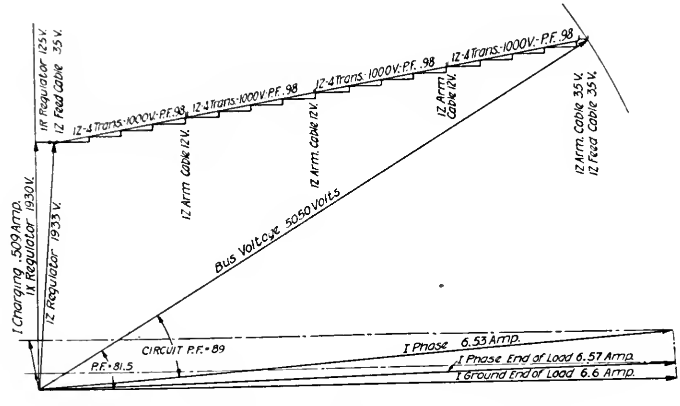


Fig. 5. Vector Diagram of Currents in Group Street Lighting Circuit

In the case of the present circuit we will consider the worst possible condition when the sum of all the reactances is in series with the capacity of the 8000 feet of return wire in the multi-conductor cable, and the ground connection removed.

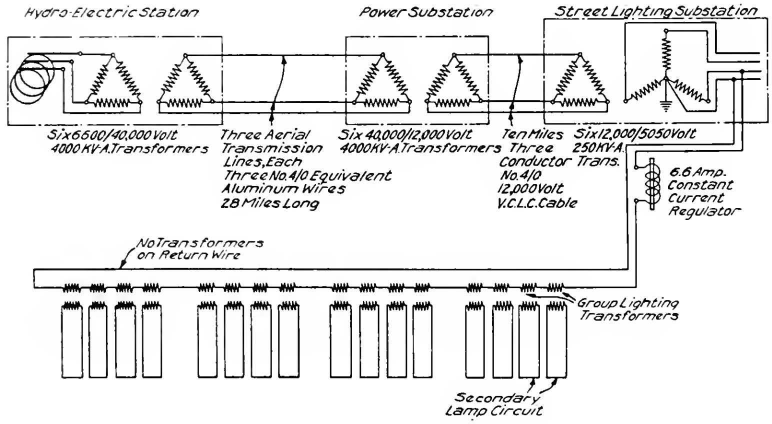


Fig. 6. Connections of System from Prime Mover to Street Lights

$L_o = 1.058$ henrys.

$C_o = 0.000000409$ farads.

$N_o = 240$, which is an even harmonic of 60 cycles and does not combine to produce transients.

In the proposed circuits the inductance of the regulator in series with the cable and transformer inductance will be considered as being in series with the capacity of 3000 feet of the armored cable and 8000 feet of return conductor in the multi-conductor cable.

$L_o = 1.085$ henrys.

$C_o = 0.000000579$ farads.

$N_o = 201$

This is practically 3.4 times fundamental frequency, and will not combine to produce transients.

From the foregoing, it will be seen that because of the better oscillation constant of the proposed circuit liability to self-induced surges is reduced.

The conditions that might exist, were an operating secondary circuit to open, have been met by automatic protective devices that will short circuit the secondary before an excessive potential can be reached.

SMALL ALTERNATING CURRENT GENERATORS

By J. J. Kline

Fort Wayne Works, General Electric Company

The generators described in this article are specially suited for small communities situated beyond the economical reach of large distribution systems. One of these machines installed in a small town will satisfactorily supply the local interior lighting direct from the generator bus, series street lighting through transformers and regulating apparatus, and more remote service through standard step-up and step-down lighting transformers. These machines are made in many forms, to fulfill practically all ordinary requirements.—Editor.

Three forms of standard alternating current polyphase generators are built at the Fort Wayne Works. These are the Form ML, or belted, revolving armature, self excited alternators of 7½, 15 and 25 kv-a. at 1800 r.p.m.; the Form PB, or larger belted revolving field alternators ranging from 30 kw., 1200 r.p.m. to 240 kw., 600 r.p.m.; and what is locally known as the Form D (elsewhere referred to as Types TRE and QRE), ranging from 30 kv-a., 300 r.p.m. to 375 kv-a., 120 r.p.m. These machines are all standard for 60-cycle circuits.

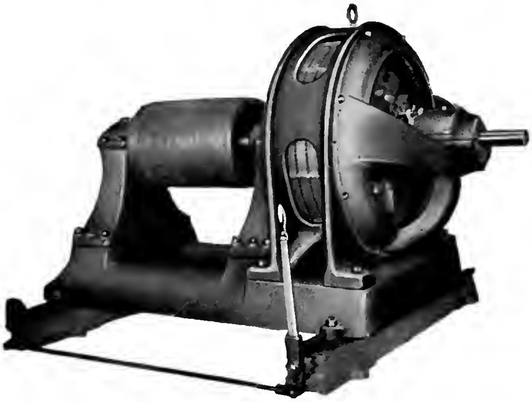


Fig. 1. Three Bearing, 200-kw., 600-r.p.m., Form PB Alternator

Form ML Alternators

This line of machines was developed some years ago from the line of Type ML direct current generators in order to supply the demand for alternating current in the small widely-scattered towns and villages in the agricultural districts, where direct current is not suitable because of the heavy drop in voltage in the long distribution lines.

By installing a small engine and one of these alternators, wound for 120 volts or 240 volts, a lighting station can be started in a town at small expense. The distribution in the immediate vicinity of the station is carried directly on the machine through a simple switchboard, and no transformers are required. However, as the radius of the distribution increases, or in case a particular customer or group of customers located at some distance from the station want service, a pair of standard lighting transformers may be installed to step up and step down the voltage to take care of that particular circuit; or it may be desired to install a Mazda series circuit for street lighting, and such a circuit can be supplied by the same alternator that supplies the ordinary multiple lighting circuits. Such a variety of circuits is not possible with the ordinary direct current generator.

These alternators may be employed for small isolated manufacturing plants, and a number of them are in successful service in such installations. There are certain limitations in design, however, which call for special consideration in the selection of these alternators for work of this character. The size of induction motors that may be used with them, on power loads only or on mixed lighting and power loads, either with or without starting compensators, is limited.

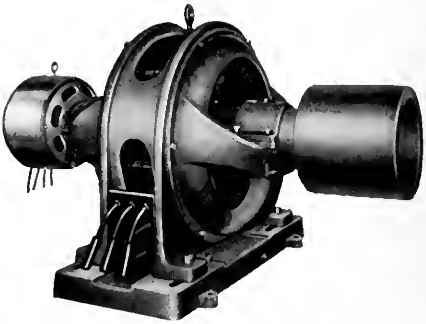


Fig. 2. Form PB Alternator with Direct-connected Exciter

This limitation on the size of the induction motors should not be assumed as a defect in the alternator, for it is not entirely the fault of the alternator. It is an inherent characteristic of an induction motor that it draws an abnormally heavy current from the line upon starting, and this current is the more severe on the source of supply because it is at low power-factor. Without a starting compensator a motor will draw $3\frac{1}{2}$ to 5 times its normal running current to deliver full load starting torque. This means a very heavy momentary demand on the generating station to accelerate a motor of a size that approaches the generator capacity. Furthermore, this is a much more severe load than would at first appear, for the power-factor is very low, perhaps 40 per cent. It can readily be seen that the heavy wattless component of this load will produce an abnormal armature reaction in the alternating current winding which will destroy the direct current field, and the voltage on the line will fail.

By introducing a starting compensator in the motor circuit the starting current is reduced to 2 or 3 times the normal full load current instead of four or five times, and conditions are very much relieved; but even under these conditions the demand for current on the small alternator may create sufficient armature reaction to disturb the voltage and perhaps demagnetize the alternator.

Fig. 3. 24-pole, 50-kw., 2300-volt Revolving Field Alternator

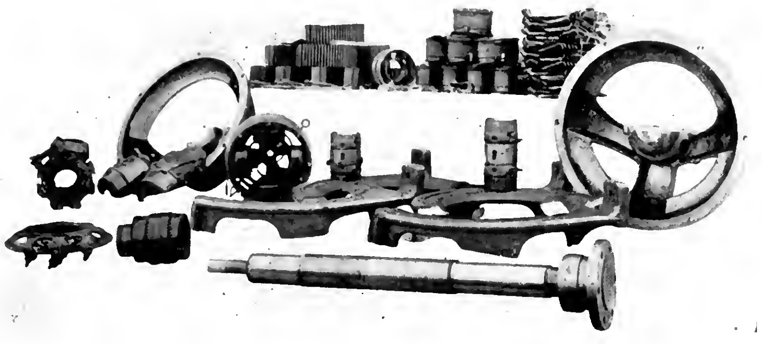


Fig. 4. Parts of a 120 Kw. Alternator and Direct Connected Exciter Constructed for Muleback Transportation, no part of which weighs more than 300 Lb.

Construction of Form ML Alternators

The field is stationary and quite similar to that of a shunt wound direct current generator, although some modifications have been introduced which will not permit of the substitution of one of these alternator fields for a direct current field of the same frame size, or vice versa, as some have wanted to do. The armature consists of the usual slotted core and two windings in the slots. The alternating current winding is placed in the bottom portion of the slots, and with the insulation practically fills them. This winding is connected to suitable collector rings by proper taps to give quarter-phase four-wire, or three-phase three-wire or four-wire service, at the standard voltages of 120, 240, 480 or 600 volts. They are not built for higher potentials than 600 volts because of the exposed collector rings and the difficulties of insulating for the higher voltages, the danger to the operator, etc.

In the same slots with the a-c. winding and superposed upon it, with suitable insulation between, is placed the direct current exciter winding. This exciter winding is connected in the usual manner to a small commutator which is mounted on the shaft between the core and the collector rings. The current from the commutator is collected through suitable carbon brushes mounted on four brush studs and delivered to the shunt field winding, just as in the case of any shunt field direct current generator. The current from the main winding on the armature, immediately below the exciter winding, is taken off through the brushes which bear upon the collector rings.

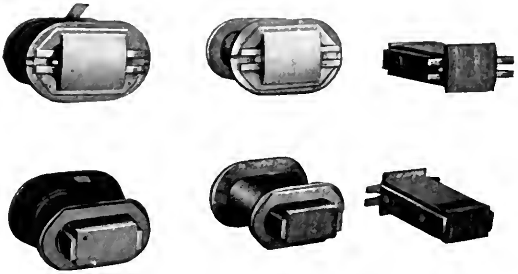


Fig. 5. Pole Piece of 24-pole, 50-kv-a., 300-r.p.m. Alternator Showing Construction

The unit is very similar to an alternator equipped with a direct-connected exciter, and yet it is not quite the same. In the form ML machine the alternator field and the exciter field are common; hence any change in field strength affects both the a-c. and the d-c. armature windings simultaneously, which is not true of the alternator with direct-connected exciter. Because of this common field, the form ML machine is not adapted for service with the Type TA generator voltage regulator.

These machines may be used as synchronous motors or as synchronous condensers by fitting the stationary poles with a suitable collar and bridge winding, which acts in a manner similar to the amortisseur winding on a revolving field machine.

The fields of the self-excited alternators are wound for 115 volts or lower excitation, so that they may be separately excited from any 115-volt source of direct current by removing the brushes from the commutator and making proper connections to the field circuit. A different field rheostat may be found necessary in some cases.

Form PB Alternators

The Form PB belted alternators are the result of years of effort to obtain a low priced, sturdy, simple, and highly efficient belted alternator for all classes of service on multiphase sixty-cycle circuits.

All machines of this line are rated on the basis of full output at 0.8 power-factor continuous duty with a rise in temperature of any part guaranteed not to exceed 50 deg. C. Every standard machine may be equipped with a direct-connected exciter, mounted upon the bearing housing on the collector end; and any machine may be converted into a synchronous motor or synchronous condenser by the addition of an amortisseur winding and a suitable starting compensator. The exciter and the amortisseur winding may be fitted to the machine after delivery to the user, for the bearing housing is prepared for the exciter, the field poles are punched for the amortissuer winding, and the field winding is insulated for high potential test for synchronous motor duty before the alternator leaves the factory.

In some cases where belting conditions are severe, or for some other reason, a third bearing may be desired. To take care of these cases the 10-pole and 12-pole machines may be furnished as shown in Fig. 1. This three-bearing machine may be furnished with or without direct-connected exciter, as is the standard two-bearing unit. (Fig. 2.) The stator is standard except that a ring is fitted on the pulley end in place of the bracket. The shaft is changed, of course, and a base, two pedestals and two rails with rachet device are added. Only the 10-pole and 12-pole frames have been built in this manner.

The Form PB units may be used in motor-generator work with one or two bearings; in waterwheel work, with a guarantee to stand double speed; and for similar service.

Fig. 6. 24-pole, 50-kv-a., 300-r.p.m. Form D Alternator with Direct Connected Exciter

Sometimes the installation of a waterwheel unit requires a sole plate or cap plate on the top of the foundation, and in such cases the regular belted type base should be furnished, omitting the rachet device if desired.

Some frames of the Form PB alternators have been built for mule-back transportation, i.e., so divided that no piece of the shipment will weight more than about three hundred pounds. Fig. 4 shows the various parts of an ATB-8-120-kw., 900-r.p.m. alternator and direct-connected exciter ready for packing for such a shipment.

Engine Type Alternators

As previously mentioned, these machines are designated Type TRE and QRE, but are known locally at the Fort Wayne Works as Form D. The terms Type TRE and QRE are really the remains of a former suggestive nomenclature used to indicate the physical appearance and the specifications of the alternator. *T* represents three-phase; *Q*, quarter-phase; *S*, single-phase; *R*, revolving field; *E*, engine type, i.e., without base, shaft or bearing or with but one bearing; *C*, coupled, i.e., shaft, two bearings and base or suitable sole or cap plates—a self-contained unit for coupling to another machine; *B*, a belted machine, i.e., with base, bearings, shaft and pulley and some sort of a belt-tightening device. The mechanical design of the line was represented by Form D; i.e., a cast iron rotor with spokes and a particular type of pole piece and stator construction. When the amortisseur winding was added, the form became DS; when used for vertical shaft drive, DV.

The construction of the stator is quite similar to that used in the Form PB line; viz., two ring-like castings which are drawn together by bolts which pass through extensions on the back of the laminations holding them in place and clamping them between the frame castings. The stators are ventilated by ducts in the core and the teeth are supported at the ends by steel fingers. The stator windings have a concentrated winding (one coil per phase per pole), however, while the Form PB machines have a distributed winding.

The construction of the rotor is very different from that used in the PB line. In the latter the spider is shaped as a hexagon, an octagon, a decagon, or a dodecagon, depending on the number of poles, and consists of steel laminations riveted together. In the Form D, or engine type machines, however, the spider consists of a hub through which the shaft passes, and on which the collector rings are mounted; and cast with the hub are a series of spokes which hold in place a ring upon which the laminated poles are mounted in suitable recesses which are milled into the periphery.

The spider is cast iron, machined on the outer ring and at the hub. Each pole piece consists of a laminated core riveted together and having on each end a heavy piece of steel bar which is properly bent at the end and cut to form a two fingered prong to support the ends of the coil and to provide for the amortisseur winding if such be furnished. All pole laminations are punched for amortisseur winding, so that it can be added later if desired for gas engine service or synchronous motor duty.

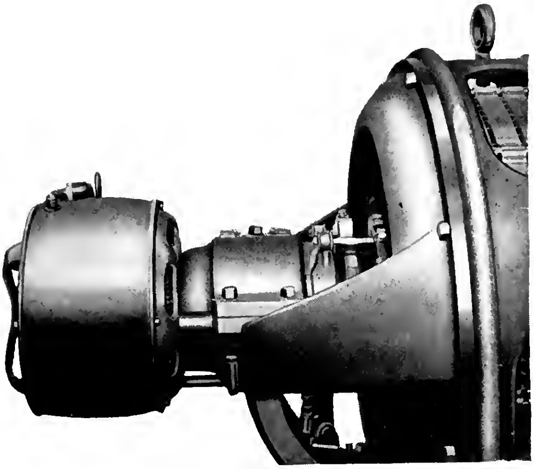


Fig. 7. Exciter Direct Connected to 200-kv-a., 720-r.p.m., Form B Alternator

The field winding on all but the largest frames consists of double cotton covered copper wire which is wound directly upon the pole core after the latter has been insulated. In some of the larger frames the edgewise copper coil, which is slipped over the pole core, is still used because of better economy of copper and the fact that space is more plentiful on the machines of greater diameter. Such excellent results are obtained from the wire-wound field coils, however, that the use of the edgewise ribbon coil is becoming more and more infrequent.

The laminations of the pole core are left entire, except for a small triangular notch at the bottom and on each side. After the winding is in place and the individual pole is completed it is mounted in the milled slot in the periphery of the spider, and between each pair of poles a steel dovetail is inserted to engage the triangular notch mentioned above. This steel block is drawn down toward the spider rim by suitable cap screws so that the pole is held securely in place in the recess in the spider rim by the steel block on each side. The lamination of the core is not affected through the introduction of solid steel in the form of a bar or bolt; the cap screw threads engage the solid metal of the steel retaining blocks, and these blocks form a magnetic path in parallel with the cast iron of the spider rim, thereby increasing the magnetic material.

Another feature of interest in this line of machines is the method employed to get the exciting current to the revolving field. Formerly it was the practice to mount the collector rings on the engine shaft, and the brush-holder studs on the cap of the engine builder's pillow block, or else to furnish a separate brush-holder stand. These practices had many objections and were the source of very serious trouble in preparing stock in advance of a definite order. A mounting for the collector rings has been adopted which consists of an extension of the rotor hub, the brush-holders being supported on an arm or stand which is rigidly attached to the stator frame. Sufficient stock is left in the hub casting so that it may be bored for any size engine shaft within wide limits; this procedure making it possible to completely finish an engine type generator for stock, and leaving as the only operations to be done, the boring of the rotor for the size of the engine shaft, and the pressing of the shaft into the rotor, if the shaft is delivered to the factory.

Direct Connected Exciters

Where a direct-connected exciter is wanted on a Form D alternator, an extension is required on the engine shaft on which to mount the exciter armature, and also a pair of brackets, or other means for supporting the exciter field frame on the outside of the engine base and engine bearing. No extra bearing for the exciter is required, as the machine is furnished without base, shaft, or bearings.

Synchronous Motors

Through recent improvements in the design and construction of air compressors, an interesting line of work has developed in the direct connection of synchronous motors to these compressors. The motors are built without base, shaft or bearings, and the rotors, fitted with suitable amortisseur winding, are pressed on the shafts of the compressors. Such installations are proving very successful in many lines of work.

These motors may also be furnished in the coupled type, i.e., with base, shaft and bearings; but the call for these extra parts is not usual because the direct-connected compressor set makes a much more attractive unit at a lower cost.

Fig. 8. 150-kv-a., 120-r.p.m. Waterwheel Driven Generator

The Form D machines have found a wide field of application for Diesel engine installations. They have usually been supplied with base, shaft and two bearings, and these extra parts are developed for all but the largest frames.

Vertical Machines

Through recent improvements in vertical shaft hydraulic turbines there has developed an increased demand for small low speed alternators for direct connection to wheels of this character. The Form D alternator lends itself remarkably well to this work, and various adaptions are shown in the illustrations.

The rotor and waterwheel, if need be, are suspended from the spring plate bearing mounted in the top of the unit, where there is also a steady bearing. Depending upon the arrangement of the waterwheel part of the unit, a steady bearing may or may not be provided below the revolving field. The generator shaft is generally made with its half of the coupling forged upon the lower end.

Various methods of driving the exciters are adopted, depending upon the conditions which may exist in the power station. In some cases the exciter is direct connected, as in Fig. 6. The exciter armature is pressed on the alternator shaft, between the revolving field and the thrust bearing, and the exciter field is within the quadruped which supports the bearing.

In other cases the exciter may be belt-driven, in which case the power is taken off a pulley installed below the revolving field, as shown in Fig. 8. If the exciter is an ordinary horizontal shaft machine, the exciter belt is usually brought out through the base ring of the alternator, and over an idler pulley so as to permit of a quarter turn in the belt. However, a vertical shaft belted exciter may be used, and in that case no turning of the belt is needed.

Sometimes extra weight is wanted in the rotor, to increase the moment of inertia of the entire revolving element and improve the governing of the waterwheel. This extra material may be very easily and effectively added to the rotor rim.

MAGNETIC RELUCTIVITY

By Charles P. Steinmetz

Consulting Engineer, General Electric Company

This article is a review and discussion of magnetic reluctivity under the following headings: 1, Fröhlich's and Kennelly's laws; 2, The critical points or bends in the reluctivity line of commerical materials; 3, Unhomogenuity of the material as cause of the bends in the reluctivity line; 4, Reluctivity at low fields, the inward bend, and the rising magnetic characteristic as part of an unsymmetrical hysteresis cycle; 5, Indefiniteness of the B-H relation. The alternating magnetic characteristic. Instability and creepage; 6, The area of B-H relation. Instability of extreme values. Gradual approach to the stable magnetization curve; 7, Production of stable values by superposition of alternating field. The linear reluctivity law of the stable magnetic characteristic.—Editor.

Fröhlich's and Kennelly's Laws

1. Considering magnetism as the phenomena of a "magnetic circuit," the foremost differences between the characteristics of the magnetic circuit and the electric circuit are:

(*a*) The maintenance of an electric circuit requires the expenditure of energy, while the maintenance of a magnetic circuit does not require the expenditure of energy, though the starting of a magnetic circuit requires energy. A magnetic circuit therefore can remain "remanent" or "permanent."

(*b*) All materials are fairly good carriers of magnetic flux, and the range of magnetic permeabilities is therefore narrow, from 1 to a few thousands, while the range of electric conductivities covers a range of 1 to 10^{18}. The magnetic circuit thus is analogous to an uninsulated electric circuit immersed in a fairly good conductor, as salt water: the current or flux can not be carried to any distance, or constrained in a "conductor," but divides, "leaks" or "strays."

(*c*) In the electric circuit, current and e.m.f. are proportional in most cases; that is, the resistance is constant and the circuit can therefore be calculated theoretically. In the magnetic circuit, in the materials of high permeability, which are the most important carriers of the magnetic flux, the relation between flux, m.m.f. and energy is merely empirical; the "reluctance" or magnetic resistance is not constant, but varies with the flux density, the previous history, etc. In the absence of rational laws most of the magnetic calculations therefore have to be made by taking numerical values from curves or tables.

The only rational law of magnetic relation which has not been disproven is Fröhlich's (1882):

"The permeability is proportional to the magnetizability."

$$\mu = a\,(S - B) \qquad (1)$$

where B is the magnetic flux density, S the saturation density, and $S - B$ therefore the magnetizability, that is, the still available increase of flux density over that existing.

From (1) there follows, by substituting:

$$\mu = \frac{B}{H} \qquad (2)$$

and re-arranging:

$$B = \frac{H}{\alpha + \sigma H} \qquad (3)$$

where

$\sigma = \frac{1}{S} =$ *saturation coefficient*, that is, the reciprocal of the saturation value S of flux density B, and

$$\alpha = \frac{1}{a\,S} = \frac{\sigma}{a}$$

For $B = O$, equation (1) gives:

$$\mu_0 = a\,S = \frac{1}{\alpha};\ \alpha = \frac{1}{\mu_0} \qquad (4)$$

that is, α is the reciprocal of the magnetic permeability at zero flux density.

A very convenient form of this law has been found by Kennelly (1893) by introducing the reciprocal of the permeability, as reluctivity ρ:

$$\rho = \frac{1}{\mu} = \frac{H}{B}$$

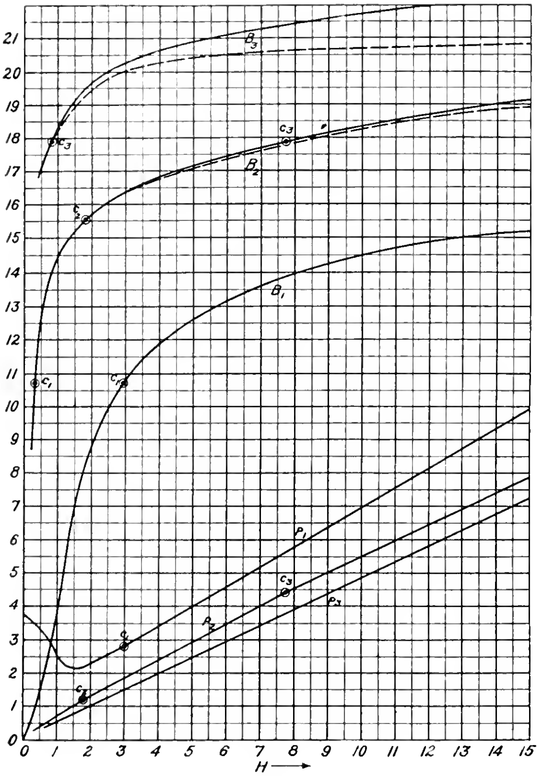


Fig. 1

in the form, which can be derived from (3) by transposition:

$$\rho = \alpha + \delta H \qquad (5)$$

As α dominates the reluctivity at lower magnetizing forces, and thereby the initial rate of rise of the magnetization curve, which is characteristic of the "magnetic hardness" of the material, it is called the *coefficient of magnetic hardness.*

The Critical Points or Bends in the Reluctivity Line of Commercial Materials

2. When investigating flux densities B at very high field intensities H, it was found that B does not reach a finite saturation value but increases indefinitely; that, however,

$$B_0 = B - H \qquad (6)$$

reaches a finite saturation value S, which with iron is usually not far from 20 kilolines per cm², and that therefore Fröhlich's and Kennelly's laws apply not to B but to B_0. The latter then is usually called the *metallic magnetic density* or *ferromagnetic density.*

B_0 may be considered as the magnetic flux carried by the molecules of the iron or other magnetic material, in addition to the space flux H, or flux carried by space independent of the material in space.

The best evidence seems to establish the fact that, with the exception of very low field intensities (where the customary magnetization curve usually has an inward bend, which will be discussed later) in perfectly pure magnetic materials, iron, nickel, cobalt, etc., the linear law of reluctivity (5) and (3) is rigidly obeyed by the metallic induction B_0.

In the more or less impure commercial materials, however, the $\rho - H$ relation, while a straight line, often has one and occasionally two points where its slope, and thus the values of α and σ, change.

Fig. 1 shows an average magnetization curve of good standard iron with field intensity H as abscissae and magnetic induction B as ordinates. The total induction is shown in drawn lines, and the metallic induction in dotted lines. The ordinates are given in kilolines per cm², the abscissae in units for B_1, in tens for B_2, and in hundreds for B_3.

The reluctivity curves for the three scales of abscissae are plotted as ρ_1, ρ_2, ρ_3, in tenths of milli-units, in milli-units, and in tens of milli-units.

Below $H = 3$, ρ is not a straight line, but is curved due to the inward bend of the magnetization curve B in this range. The straight line law is reached at the point c_1, at $H = 3$, and the reluctivity is then expressed by the linear law:

$$\rho_1 = 0.102 + 0.059 H \qquad (7)$$

for:

$$3 < H < 18$$

giving an apparent saturation value:

$$S_1 = 16{,}950$$

At $H = 18$, a bend occurs in the reluctivity line, marked by point c_2, and above this point the reluctivity follows the equation

$$\rho_2 = 0.18 + 0.0548 H \qquad (8)$$

for:

$$18 < H < 80$$

giving an apparent saturation value:

$$S_2 = 18{,}250$$

At $H=80$, another bend occurs in the reluctivity line, marked by point c_3, and above this point, up to saturation, the reluctivity follows the equation:

$$\rho_3 = 0.70 + 0.0477\,H \qquad (9)$$

for:

$$H > 80$$

giving the true saturation value:

$$S = 20.960$$

Point c_2 is frequently absent.

Fig. 2 gives once more the magnetization curve (metallic induction) as B, and the dotted curves B_1, B_2 and B_3 representing magnetization curves calculated from the three linear reluctivity equations (7), (8), (9). As seen, neither of the equations represents B even approximately over the entire range, but each represents it very accurately within its range. The first equation (7) probably covers the entire industrially important range.

Unhomogenuity of the Material as Cause of the Bends in the Reluctivity Line

3. As these critical points c_2 and c_3 do not seem to exist in perfectly pure materials, and as the change of direction of the reluctivity line is in general greater, with increase of impurity of the material, the cause seems to be lack of homogenuity of the material; that is, the presence, either on the surface as scale or in the body as inglomerate, of materials of different magnetic characteristics: magnetic, cementite, silicide. Such materials have a much greater hardness, that is, higher value of α, and would therefore give the observed effect. At low field intensities H the harder material carries practically no flux, all the flux being carried by the soft material. The flux density therefore rises rapidly, giving low α, but tends towards an apparent low saturation value, as the flux carrying material fills only part of the space. At higher field intensities the harder material begins to carry flux; and while in the softer material the flux increases at a lesser rate, the increase of flux in the harder material gives a greater increase of total flux density and a greater saturation value, but also a greater hardness as the resultant of both materials.

Thus, if the magnetic material is a conglomerate of fraction p of soft material of reluctivity ρ_1 (ferrite) and $q=1-p$ of hard material of reluctivity ρ_2 (cementite, silicide, magnetite):

$$\left.\begin{aligned} \rho_1 &= \alpha_1 + \sigma_1 H \\ \rho_2 &= \alpha_2 + \sigma_2 H \end{aligned}\right\} \qquad (10)$$

At low values of H the part p of the section carries flux by ρ_1 and the part q carries flux by ρ_2; but as ρ_2 is very high compared with ρ_1 the latter flux is negligible and is:

$$\rho' = \frac{\rho_1}{p} = \frac{\alpha_1}{p} + \frac{\sigma_1}{p} H \qquad (11)$$

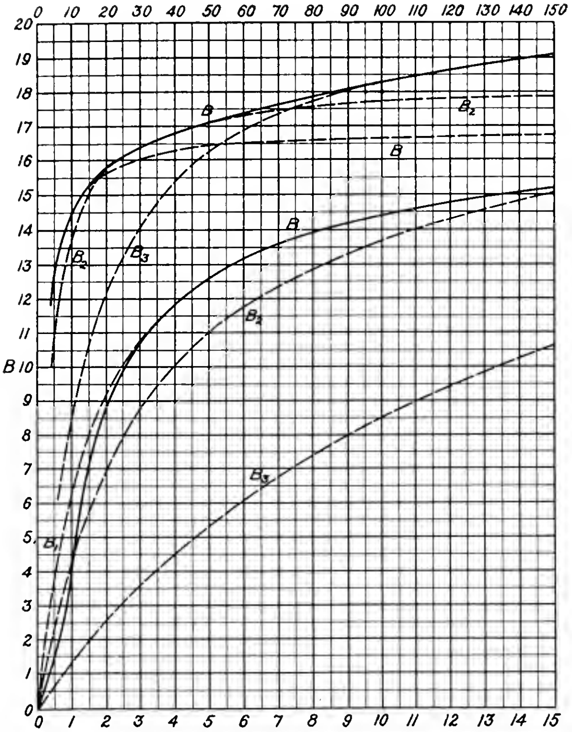


Fig. 2

At high values of H, the flux goes through both materials, more or less in series, and thus is:

$$\rho'' = p\,\rho_1 + q\,\rho_2 = (p\alpha_1 + q\alpha_2) + (p\,\sigma_1 + q\,\sigma_2)\,H \qquad (12)$$

If we assume the same saturation value σ for both materials, and neglect α_1 compared with α_2, it is:

$$\rho'' = q\,\alpha_2 + \sigma\,H \qquad (13)$$

Substituting, for instance (7) and (9) into (11) and (13) respectively, gives:

$$\frac{\alpha_1}{p} = 0.102$$

$$\frac{\sigma}{p} = 0.059$$

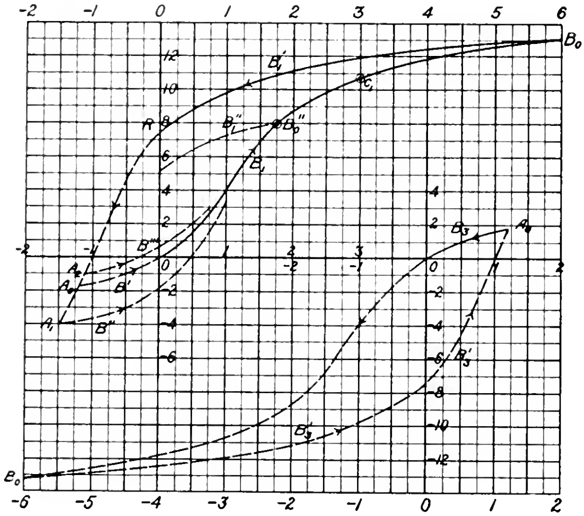
$$q\,\alpha_2 = 0.70$$

$$\sigma = 0.0477$$

Hence:

$$p=0.80:\ \rho_1=0.082+0.0477\ H$$
$$q=0.20:\ \rho_2=3.5+0.0477\ H$$

However, the saturation coefficients σ of the two materials probably are usually not equal.



Figs. 3 and 4

The deviation of the reluctivity equation from a straight line, by the change of slope at the critical points c_2 and c_3 thus probably is only apparent, and is the outward appearance of a change of the flux carrier in an unhomogeneous material; that is, the result of a second and magnetically harder material beginning to carry flux.

Such bends in the reluctivity line have been artificially produced by Mr. John D. Ball in combining by superposition two different materials which separately gave straight line ρ curves, but which when combined gave a curve showing the characteristic bend.

Very impure materials, like cast-iron, may give throughout a curved reluctivity line.

Reluctivity at Low Fields, the Inward Bend, and the Rising Magnetic Characteristic as Part of an Unsymmetrical Hysteresis Cycle

4. For very low values of field intensity ($H<3$), however, the straight line law of reluctivity apparently fails, and the magnetization curve in Fig. 1 has an inward bend which gives a rise of ρ with decreasing H.

This curve is taken by ballistic galvanometer, by the step-by-step method; that is, H is increased in successive steps, and the increase of B observed by the throw of the galvanometer needle. It is thus a "rising magnetization curve."

The first part of this curve is reproduced as B_1 in Fig. 3, in twice the abscissae and half the ordinates so as to give it an average slope of 45 degrees, as with this slope curve shapes such as the inward bend of B_1 below $H=2$, are best shown ("Engineering Mathematics," 2d edition, p. 286).

Suppose now that at some point $B_0=13.15$ we stop the increase of H, and decrease again to 0. We do not return on the same magnetization curve B_1, but on another curve B_1', the "decreasing magnetic characteristic," and at $H=0$ we are not back to $B=0$, as residual or remanent flux is left, (Fig. 3: R=7.4).

Where the magnetic circuit contains an air gap, as in the field circuits of electrical machinery, the decreasing magnetic characteristic B_1' is very much nearer to the increasing one B_1 than in the closed magnetic circuit of Fig. 3, and practically coincides for higher values of H.

There appears no theoretical reason why the rising characteristic B_1 should be selected as the representative magnetization curve, rather than the decreasing characteristic B_1', except the incident that B_1 passes through zero. In many engineering applications, for instance, the calculation of the regulation of a generator (the decrease of voltage under increase of load), it is obviously the decreasing characteristic, B_1', which is determining.

Suppose we continue B_1' into negative values of H, to the point A_1, where $H=1.5$ and $B=-4$, and then again reverse. We get a rising magnetization curve B'', which passes $H=0$ at a negative remanent magnetism. Suppose we stop at point A_2, where $H=-1.12$ and $B=-1.0$; the rising magnetization curve B''' then passes $H=0$ at a positive remanent magnetism. There must thus be a point A_0, between A_1 and A_2, such that the rising magnetization curve B', starting from A_0, passes through the 0 point $H=0$, $B=0$, and thereby runs into the curve B_1.

The rising magnetization curve, or standard magnetic characteristic determined by the step-by-step method, B_1, is thus nothing but the rising branch of an unsymmetrical hysteresis cycle, traversed between such limits $+B_0$ and $-A_0$ that the rising branch of the hysteresis cycle passes through the zero point.

Indefiniteness of the B-H Relation. The Alternating Magnetic Characteristic. Instability and Creepage

5. The characteristic shape of a hysteresis cycle is a loop, pointed at either end and thereby having an inflexion point about the middle of either branch. In the unsymmetrical loop $+B_0$, $-A_0$ of Fig. 3, the zero point is fairly close to one extreme, A_0, and the inflexion point, characteristic of the hysteresis loop, thus lies between 0 and B_0; that is, on that part of the rising branch which is used as the "magnetic characteristic" B_1, thereby producing the inward bend in the magnetization curve at low fields, which has always been so puzzling.

If, however, we should stop the increase of H at B_0'', we would get the decreasing magnetization curve B_1'', and still other curves for other starting points of the decreasing characteristic.

Thus, the relation between magnetic flux density B and magnetic field intensity H is not definite, but any point between the various rising and decreasing characteristics B'', B_1, B''', B_1'', B_1', and for some distance outside thereof, is a possible $B-H$ relation. B_1 has the characteristic that it passes through the zero point, but it is not the only characteristic which does this. If we traverse the hysteresis cycle between the unsymmetrical limits $+A_0$ and $-B_0$, as shown in Fig. 4, we see that its decreasing branch B_3 passes through the zero point, that is, has the same feature as B_1. It is interesting to note that B_3 does not show an inward bend, and the reluctivity curve of B_3, given as ρ_3 in Fig. 6, apparently is a straight line.

Magnetic characteristics are frequently determined by the method of reversals, by reversing the field intensity H and observing the voltage induced thereby by a ballistic galvanometer, or by using an alternating current for field excitation and observing the induced alternating voltage, preferably by the oscillograph to eliminate wave shape error.

This "alternating magnetic characteristic" is the one which is of consequence in the design of alternating current apparatus. It differs from the "rising magnetic characteristic" B_1 in giving lower values of B for the same H—materially so at low values of H. It shows the inward bend at low fields still more pronounced than B_1 does. It is shown as curve B_2 in Fig. 5, and its reluctivity line is given as ρ_2 in Fig. 6. At higher values of H (from $H=3$ upwards) B_1 and B_2 both coincide with the curve B_0 representing the straight line reluctivity law.

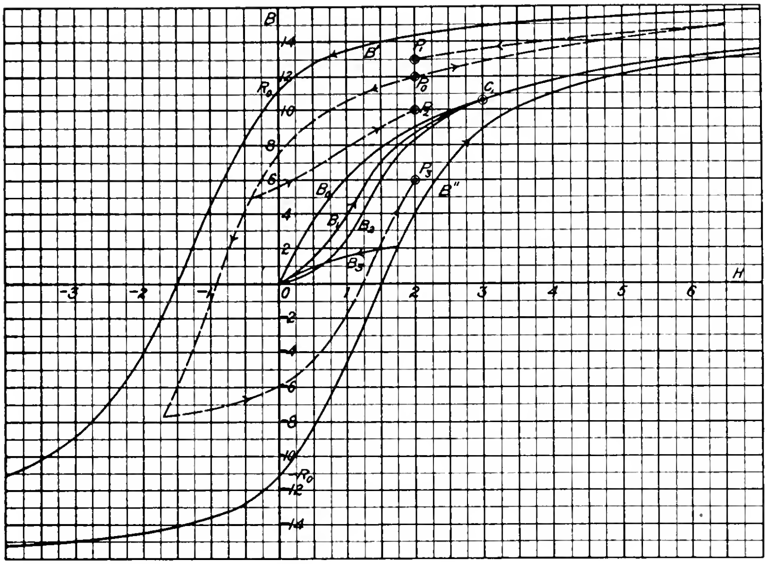


Fig. 5

The alternating characteristic B_2 is not a branch of any hysteresis cycle. It is reproducible and independent of the previous history of the magnetic circuit, except perhaps at extremely low values of H, and in view of its engineering importance as representing the conditions in the alternating magnetic field, it would appear the most representative magnetic characteristic and is commonly used as such.

It has, however, the disadvantage that it represents an unstable condition. Thus in Fig. 5, an alternating field $H=1$ gives an alternating flux density $B_2=2.6$. If, however, this field strength $H=1$ is left on the magnetic circuit the flux does not remain at $B_2=2.6$, but gradually creeps up to higher values, especially in the presence of mechanical vibrations or slight pulsations of the magnetizing current. To a lesser extent the same thing occurs with the values of curve B_1, and to a greater extent with B_3. At very low densities this creepage due to instability of the $B-H$ relation may amount to hundreds of per cent and continue to an appreciable extent for minutes, and with magnetically hard materials for many years. Thus steel structures in the terrestrial magnetic field show immediately after erection only a small part of the magnetization which they finally assume after many years.

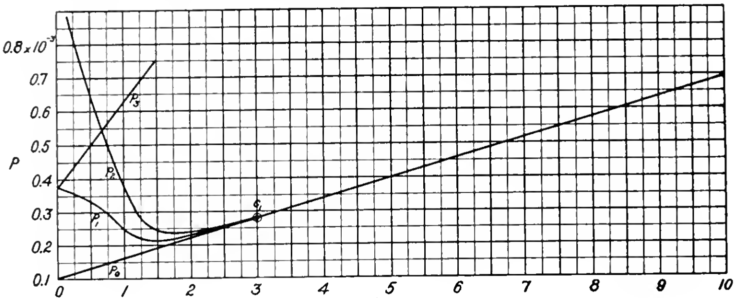


Fig. 6

Thus the alternating characteristic B_2, however important in electrical engineering, cannot, owing to its instability, be considered as representing the true physical relation between B and H, any more than can the branches of hysteresis cycles B_1 and B_3.

The Area of B-H Relation. Instability of Extreme Values. Gradual Approach to the Stable Magnetization Curve

6. Correctly, the relation between B and H thus cannot be expressed by a curve, but by an area.

Suppose a hysteresis cycle is performed between infinite values of field intensity: $H = \pm\infty$, that is, practically, between very high values, for instance such as are given by the isthmus method of magnetic testing (where values of H of over 40,000 have been reached, and where very much lower values probably give practically the same curve). This gives the magnetic cycle shown in Fig. 5 as $B' - B''$. Any point H, B within the area of this loop between B' and B'' of Fig. 5 then represents a possible condition of the magnetic circuit, and can be reached by starting from any other point H_0, B_0, such as the zero point, by gradual change of H.

Thus, for instance from point P_0, the points P_1, P_2, P_3, etc., are reached on the curves shown in the dotted lines in Fig. 5.

As seen from Fig. 5, a given value of field intensity, such as $H = 1$, may give any value of flux density between $B = -4.6$ and $B = +13.6$, and a given value of flux density, such as $B = 10$, may result from any value of field intensity between $H = -0.25$ and $H = +3.4$.

The different values of B corresponding to the same value of H in the magnetic area, Fig. 5, are not equally stable, but the values near the limits B' and B'' are very unstable and become more stable towards the interior of the area. Thus the relation of point P_1, Fig. 5, $H = 2$, $B = 13$, would rapidly change with a decrease in flux density to P_0, slower to P_2, and then still slower; while from point P_3 the flux density would gradually creep up.

It thus follows that somewhere between the extremes B' and B'', which are most unstable, there must be a value of B which is stable, that is, represents the stationary and permanent relation between B and H, and towards this stable value B_0 all other values would gradually approach. This then would give the true magnetic characteristic—the stable physical relation between B and H.

At higher field intensities, beyond the first critical point c_1, this stable condition is rapidly reached, and therefore is given by all the methods of determining magnetic characteristics. Hence the curves B_1, B_2, B_0 coincide there, and the linear law of reluctivity applies. Below c_1, however, the range of possible B values is so large and the final approach to the stable value so slow as to make it difficult of determination.

Production of Stable Values by Superposition of Alternating Field. The Linear Reluctivity Law of the Stable Magnetic Characteristic

7. For $H = 0$, the magnetic range is from $-R_0 = -11.2$ to $+R_0 = 11.2$; the permanent value is zero. The method of reaching the permanent value, whatever may be the remanent magnetism, is well known. It is by "demagnetizing," that is, placing the material into a powerful alternating field, a demagnetizing coil, and gradually reducing this field to zero; that is, describing a large number of cycles with gradually decreasing amplitude.

The same procedure can be applied to any other point of the magnetization curve. Thus for $H = 1$, to reach permanent condition, an alternating m.m.f. is superimposed upon $H=1$ and gradually decreased to zero, and during these successive cycles of decreasing amplitude, with $H=1$ as mean value, the flux density gradually approaches its permanent or stable value. (The only requirement is, that the initial alternating field must be higher than any unidirectional field to which the magnetic circuit had been exposed.)

This seems to be the value given by curve B_0, that is, by the straight line law of reluctivity. In other words, it is probable that:

Fröhlich's equation, or Kennelly's linear law of reluctivity, represents the permanent or stable relation between B and H, that is, the true magnetic characteristic of the material over the entire range down to $H=0$, and the inward bend of the magnetic characteristic for low field intensities and corresponding increase of reluctivity ρ is the persistance of a condition of magnetic instability, just as are remanent and permanent magnetism.

In approaching stable conditions by the superposition of an alternating field, this field can be applied at right angles to the unidirectional field, as by passing an alternating current lengthwise, that is, in the direction of the lines of magnetic force, through the material of the magnetic circuit. This superimposes a circular alternating flux upon the continuous length flux and permits observations while the circular alternating flux exists, since the latter does not induce in the exploring circuit of the former. Some twenty years ago Ewing showed that under these conditions the hysteresis loop collapses, the inward bend of the magnetic characteristic practically vanishes, and the magnetic characteristic assumes a shape like curve B_0.

To conclude, it is probable that in pure homogeneous magnetic materials the stable relation between field intensity H and flux density B is expressed, over the entire range from zero to infinity, by the linear equation of reluctivity:

$$\rho=\alpha+\sigma H$$

where ρ applies to the metallic magnetic induction, $B-H$.

In unhomogeneous materials, the slope of the reluctivity line changes at one or more critical points, at which the flux path changes by reason of a material of greater magnetic hardness beginning to carry flux.

At low field intensities the range of unstable values of B is very great, and the approach to stability so slow that considerable deviation of B from its stable value can persist, some times for years, in the form of remanent or permanent magnetism, the inward bend of the magnetic characteristics, etc.

INDUSTRIAL CONTROL

PART VII

MAGNETIC CONTROL AS APPLIED TO LARGE MINE HOISTS

By E. C. Gooch

Industrial Control Department, General Electric Company

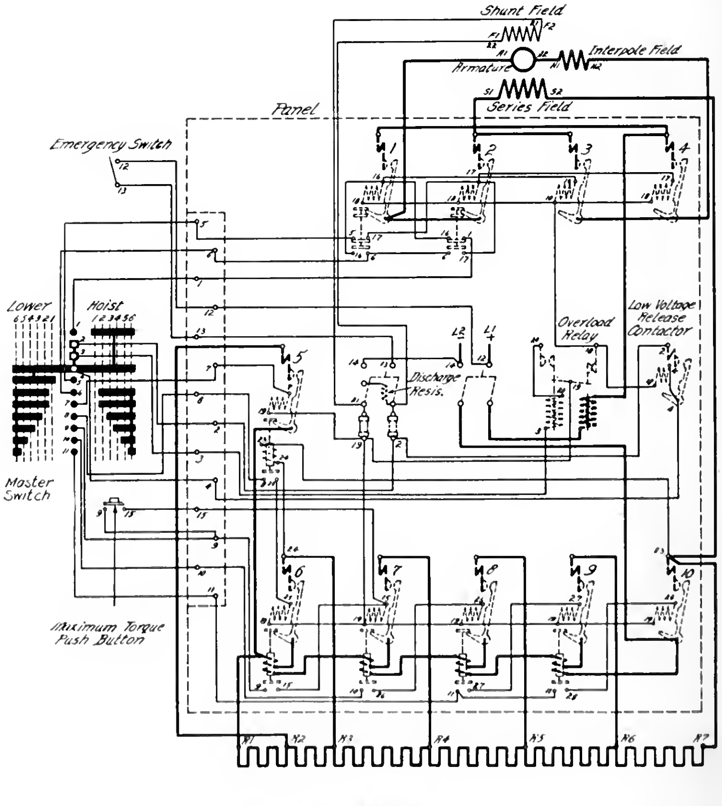
The present installment of this series is confined entirely to the application of magnetic control apparatus to mine hoists. A summary is first given of the control for various types of motor drive and then the most commonly used type is made the subject of the remainder of the article. The parts of the apparatus are described and illustrated, their functions explained, their connections given, and curves showing the charateristics of operation are included.—Editor.

This article is confined entirely to a discussion of magnetic control equipments as applied to mine hoists; the characteristics of motors will be discussed only in so far as is necessary to describe the control.

A mine hoist may be considered as a sort of elevator which must run according to a definite schedule. It may be driven in any of several ways:

1. The Ward Leonard System in which a shunt-wound hoist motor is direct connected electrically to a direct-current generator of a motor-generator set. With this method of control the speed of the hoist motor can be varied, by weakening or strengthening the generator field, in about the same ratio as the generator voltage.
2. A direct-current motor geared directly to the hoist controlled by means of a resistance in series with the armature, cut in and out of circuit either by a manually operated drum controller or by magnetic contactors operated by a master switch. Fig. 1 shows the connections of a typical straight reversible magnetic direct-current control equipment. (In this system dynamic braking may be used for lowering unbalanced loads.)
3. A slip-ring induction motor geared directly to the hoist drum, the speed of the motor being varied by changing the amount of resistance in the secondary circuit. This resistance may be varied either by a liquid rheostat* or by cast grids or other metallic resistors, cut in and out of circuit either by manually operated controllers or by magnetic contactors operated by a master switch. This is one of the most commonly used systems for the electric drive of mine hoists.

The connection diagram shown in Fig. 2 is of a typical high-voltage control equipment for a slip-ring induction motor. This equipment includes the following: two three-pole mechanically and electrically interlocked primary reversing contactors, shown in Fig. 3; secondary contactor panel, shown in Fig. 4; overwind protection, using geared and track type limit switches; potential interlocking



Back view of panel
Mechanical interlocks between contactors 1 and 2; 3 and 4

Fig. 1. Diagram of Connections of Typical Straight Reversible Magnetic Contactor, Operated by Master Switch

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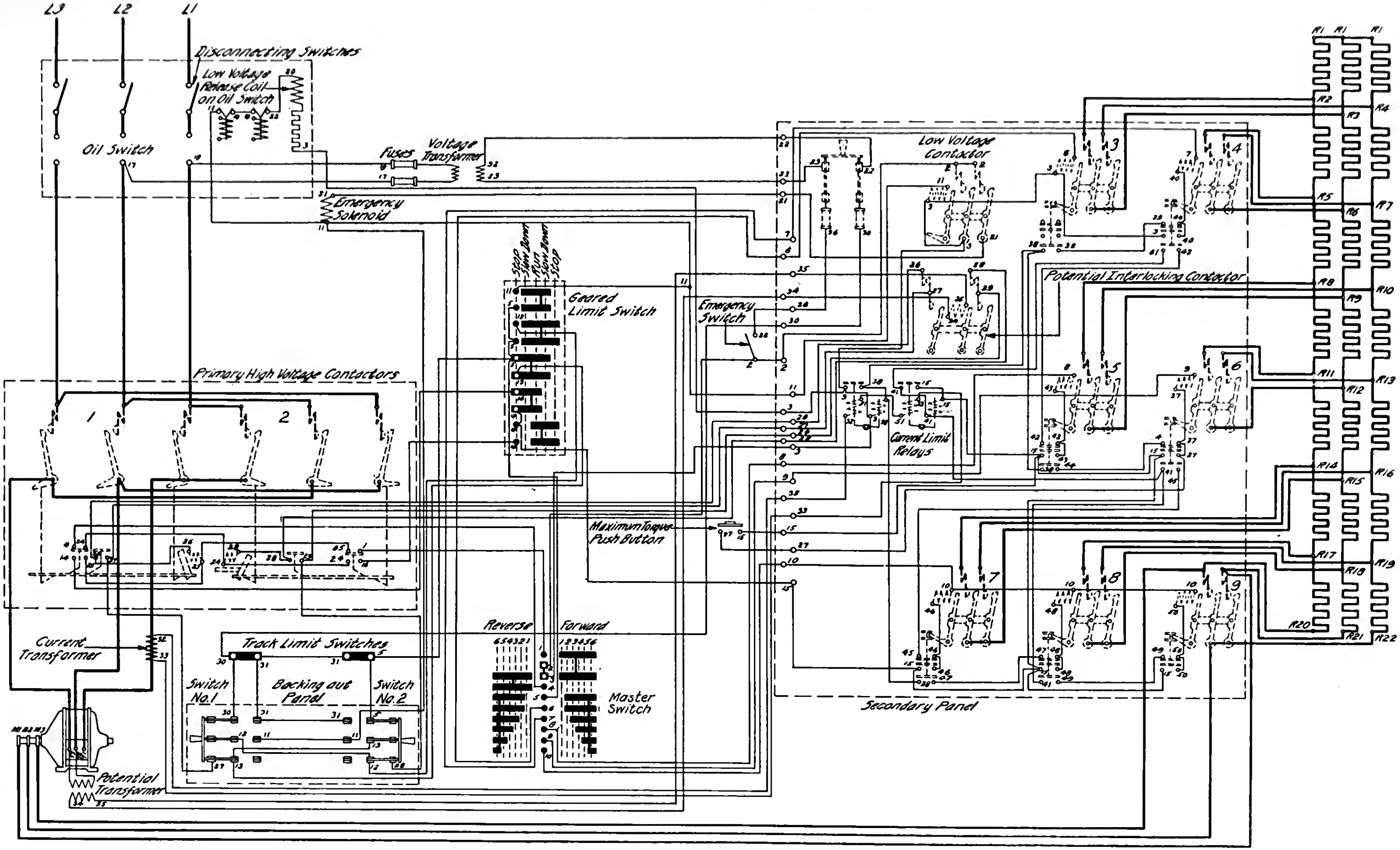
*See "Liquid Rheostats for Mine Hoists," by G. H. Dorgeloh, General Electric Review, May, 1912, page 305.



Back view of panels
In case of over travel, which drops out contactor No.1 it will be necessary to throw No.1 T.P. Switch inward in order to reverse hoist
If No.2 contactor drops out, No.2 Switch must be thrown inward to reverse hoist
Both switches must be in outward position for normal running
Mechanical interlock between contactors 1 and 2

Fig. 2. Connections of Typical High Voltage Control Equipment for Slip-ring Induction Motor

feature; low-voltage protection; emergency cutout switch; maximum torque push button; emergency solenoid; master switch; current and voltage transformers; and secondary resistance.

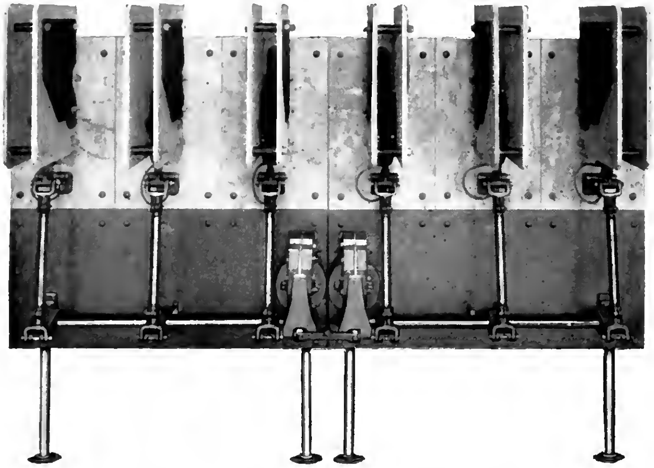


Fig. 3. Two Mechanically Interlocked High-voltage Triple-pole Contactors

The equipment just outlined furnishes eight control points both for hoisting and lowering as indicated on the speed-torque curves in Fig. 5. These curves are based on the assumption that the breakdown torque of the motor is at least 250 per cent of the torque required to hoist the maximum load.

With the six-point master switch and the eight-point control equipment (Fig. 2), the speed torque curves (Fig. 5), show the acceleration of the motor. Curves *A*, *B*, *C*, *D*, *E*, and *H* are of hand control by the master switch. Curves *B*, *C*, *D*, *E*, *F*, *G*, and *H* are of automatic control by the current-limit relays. When the master switch handle is thrown from the "off" position to the full "on" position, automatic acceleration is obtained as indicated on the curves and vertical lines by *C*, *D*, *E*, *F*, *G*, and *H*. The curves show that the current-limit relays operate at 125 per cent of full-load torque. (This value should be from 15 to 25 per cent above the torque required to hoist maximum load at full speed.) With a four-point master switch and a seven-point control equipment, the torque curves are exactly the same as in Fig. 5, except that curve *B* is omitted.

Referring to Fig. 2, the geared limit switch provides for opening contactors *3*, *4*, *5*, *6* and *7* at a predetermined distance from each end of the travel, thus allowing the motor to operate at a reduced speed just before the load reaches the dumping horns of the hoist. The amount of resistance that should be cut back into circuit by the geared limit switch depends upon the maximum load hoisted and upon the permissible speed of the hoist cage at the time it reaches the dumping horns. Obviously, the same amount of slow down cannot be obtained for all conditions of load, and in the case of an overhauling load the motor will speed up when resistance is cut into circuit. This limit switch also provides for opening the hoisting or lowering contactors and sets the emergency solenoid. It does not however open the oil switch, for this is not intended as a service operation.

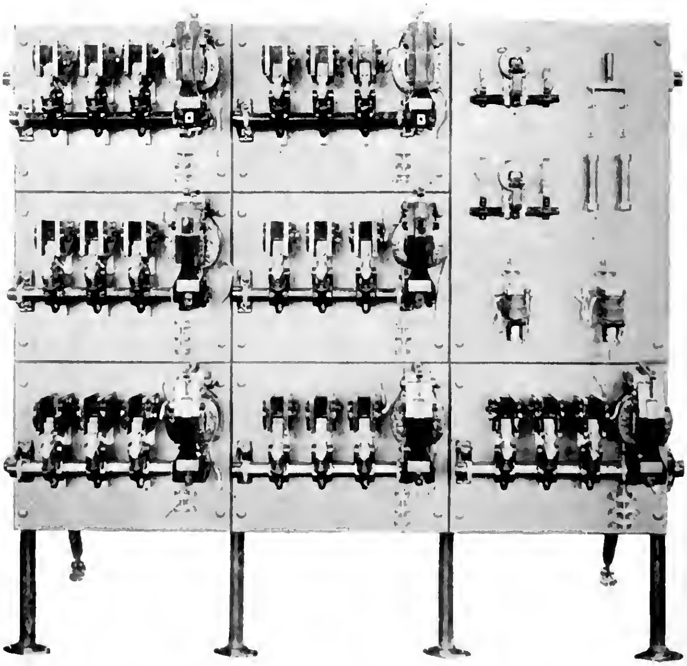


Fig. 4. Secondary Contactor Panel

The track limit switches are located so as to be tripped by the hoist cage above the point where the geared limit switch operates to cut off power, and they are so connected as to open the main line oil switch and all contactors, thus completely cutting off power from the motor.

The "backing-out" panel consists of two three-pole double-throw switches connected so that for normal operation both switches must be left in the outward position. In case of an overtravel, which drops out a main line contactor, the corresponding switch must be thrown inward before the hoist can be operated in the other direction.

Low-voltage protection is provided as a part of the control equipment, in addition to that embodied in the oil switch. The double-pole low-voltage release contactor shown on the secondary panel, Fig. 4, completes the control circuit to all contactors and is so connected that its magnetizing coil is energized when the master switch is in the "off" position. When it closes, it establishes a holding circuit through one of the contact tips, the other tip being used for the emergency solenoid.

The potential interlocking scheme consists of a small transformer having its primary circuit connected across one primary phase of the hoist motor and its secondary circuit connected to the coil of the normally closed contactor shown on the secondary panel, Fig. 2. The magnetizing circuit of the primary reversing contactors is completed through the normally closed contacts of the contactor just mentioned, and the holding circuit is completed through interlock disks on the primary reversing contactors. That is, in order to close a main line contactor the potential interlocking contactor must be deenergized. Just as soon as one main line contactor is closed this potential interlocking contactor is energized and remains energized until the main line contactor is entirely open and the arcs broken. If an arc should hang on any phase after the main contactor is open, the interlocking contactor will remain energized and will effectively prevent the other main contactor from being closed and a short circuit occurring.

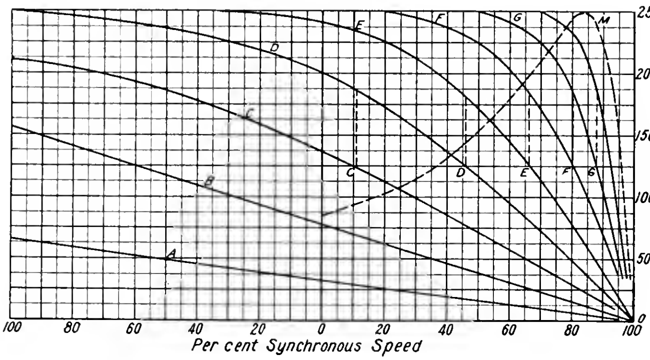


Fig. 5. Speed-torque Curves as Given by Six-point Switch and Eight-point Control Equipment

The emergency switch, Fig. 2, is of a simple single-pole type and is intended to be used in case of emergency so that the equipment can be shut down with the least possible delay. The switch has no exposed electrical parts and should be located within easy reach of the hoist operator.

The purpose of the maximum torque push button is to by-pass the current-limit relays and close the secondary resistance contactor which allows the motor to exert its maximum torque.

The emergency solenoid is not intended for service operation but is connected so that it will trip in case of overload, low voltage, and overwind, and also be the emergency switch.

The resistance is designed to give 33 per cent full-load torque at standstill on the first controller point, 77 per cent torque on the second, and 130 per cent torque on the third. The last four resistance steps are designed for accelerating the motor with peaks of about 225 per cent full-load current.

THE APPLICATION OF ELECTRICITY TO MINING IN THE COEUR D'ALENES

By Ben Olsen

Spokane Office, General Electric Company

The importance attaching at present to the mining industry makes this description of the application of electricity to the operation of one of the largest mining districts in the country of special interest. The Coeur D'Alenes installed its first electrical equipment in 1903, with a substation capacity of 275 kv-a., and a yearly energy consumption of 288,000 kw-hrs. In 1915 the output of this mining group had increased by 75 per cent, while the substation capacity had increased to 4250 kv.a, and the energy consumption to 10,979,000 kw-hrs. Besides the many advantages of electric power from the operating standpoint, it has proved to be the most economical system, and in many instances the only one practicable.—Editor.

It will undoubtedly be of general interest to the engineering profession to know how electricity is applied and to what extent it is used in one of the largest and richest mining districts in the United States, namely, the Coeur d'Alenes. The purpose of this article is to describe its various applications in this camp.

The dividends paid by sixteen of the leading mines in this territory for the year 1915 were approximately $9,222,394.00, and the total dividends paid by them up to January 1, 1916, have been approximately $54,601,000.00. Owing to the high prices of metals, 1916 will probably be the banner year to date.

The table of statistics on page 147, taken from the records of the county assessors' statement for 1915, gives a good detailed account of various costs chargeable to the extraction and

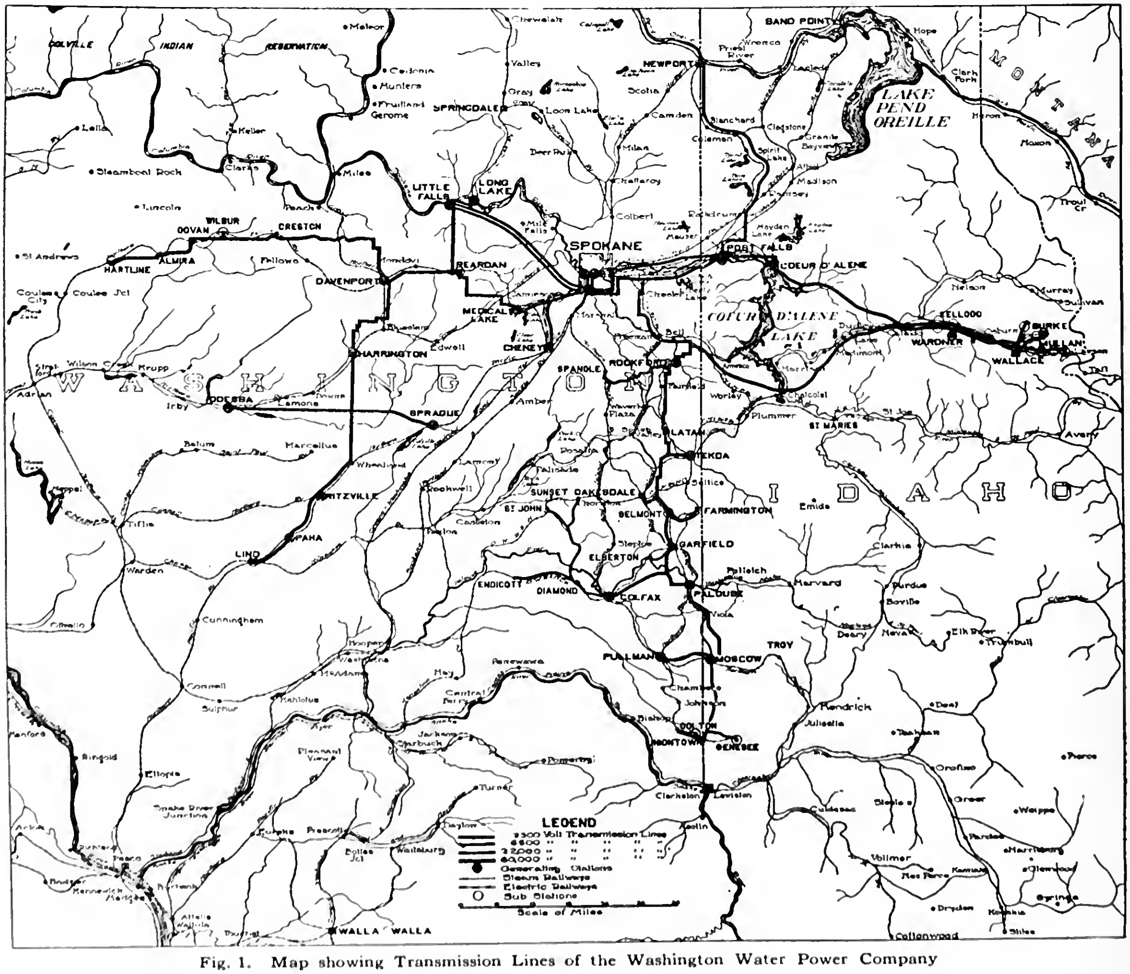


Fig. 1. Map showing Transmission Lines of the Washington Water Power Company

milling of ores and it is gratifying to note how small the power bill is compared to other charges.

The Coeur d'Alenes territory was served exclusively by the Washington Water Power Company until recently when the Montana Power Company extended their lines into the camp and took over a part of the load, namely, the Federal properties and those of the Day Interests. Fig. 1 shows the Washington Water Power Company's distributing system.

The metallurgical problems of this camp vary considerably. Some of the mines produce ores that are quite complex, while others produce ores that are easily separated and respond readily to the ordinary treatment.

Fig. 2 gives the flow sheet of the mill at the Gold Hunter mine at Mullan, showing approximately a standard system of milling practice. Their ore is rather complex, containing galena, pyrite tetrahedrite, siderite, stibnite, and the gangue materials, such as quartz, siderite and calcite. (Engineering & Mining Journal, Dec. 25, 1915.)

Practically this same system is used with but few variations in nearly all the mills of this camp and it is readily seen that a cheap and reliable form of power is necessary to obtain efficient results, as a great deal of power is required in the milling operations alone.

STATISTICS ON SHOSHONE MINES COMPILED FROM ASSESSORS' STATEMENT FOR 1915

	Net Profits Accessors' Report	Gross Tonnage Assessors' Report	Gross Val. Assessors' Report	X Paid for Power 1915	Kw-hrs. Consumed
B. H. & S. (Silver King)	‡1,145,854.85	454,205	177,819.20	72,722.85	10,979,000
Caledonia	761,797.08	42,628	1,246,859.65	9,036.02	1,478,040
Ontario	223,724.67	81,208	689,392.54	1,282.66	191,100
Federal (Wardner)	47,370.41	136,180	620,682.06	30,400.00	3,424,654
Gold Hunter	31,662.64	118,764	614,590.47	24,402.78	3,506,320
Hecla	593,680.40	146,675	1,422,578.55	26,444.77	3,967,900
Interstate Cal.	2,921,487.94	*113,795	4,540,671.56	29,238.42	3,350,840
D. W. Peoples	46,354.47	15,159	110,328.00	1,957.47	168,297
Success	898,935.93	*21,867	1,255,801.78	18,704.74	2,442,560
Totals 1915	6,670,868.39	1,130,481	10,678,723.81	214,189.71	29,508,711

	Cost of Extraction From Assessors' Report	Cost of Reduction of Transportation From Assessors' Report	Total Cost Assessors' Report
B. H. & S. (Silver King)	1,119,584.24	1,793,275.92	2,912,860.16
Caledonia	107,575.30	378,960.35	486,535.65
Ontario	265,728.32	199,939.55	465,667.87
Federal (Wardner)	369,083.09	204,228.56	575,311.65
Gold Hunter	368,612.59	72,992.50	446,605.09
Hecla	388,340.00	393,587.51	781,927.51
Interstate Cal.	849,240.85	643,863.00	1,493,103.85
D. W. Peoples	63,973.55		63,973.55
Success	†356,865.85		356,865.85
Totals 1915	3,889,003.79	3,686,847.39	7,582,851.18

* Shipping product. † Includes freight, treatment and betterments. ‡ Includes 17,642.00 royalties.
Note X "Total Cost" column does not include betterment and repairs.

Per cent cost of power to net profits of mines	3.22 per cent
Cost of power per gross ton mined	$0.1895
Kilowatt hours consumed per gross ton mined	26.1
Per cent power bill to gross value of product	1.46 per cent
Per cent power bill to cost of extraction	5.52 per cent
Cost per gross ton mined for extraction (all charges)	$3.44
Per cent power bill to total cost of extraction, reduction and transportation	2.82 per cent
Cost per gross ton mined for extraction, reduction and transportation	$6.71

These statistics do not include the large Hercules mine and several of the smaller properties, figures for these not being available.

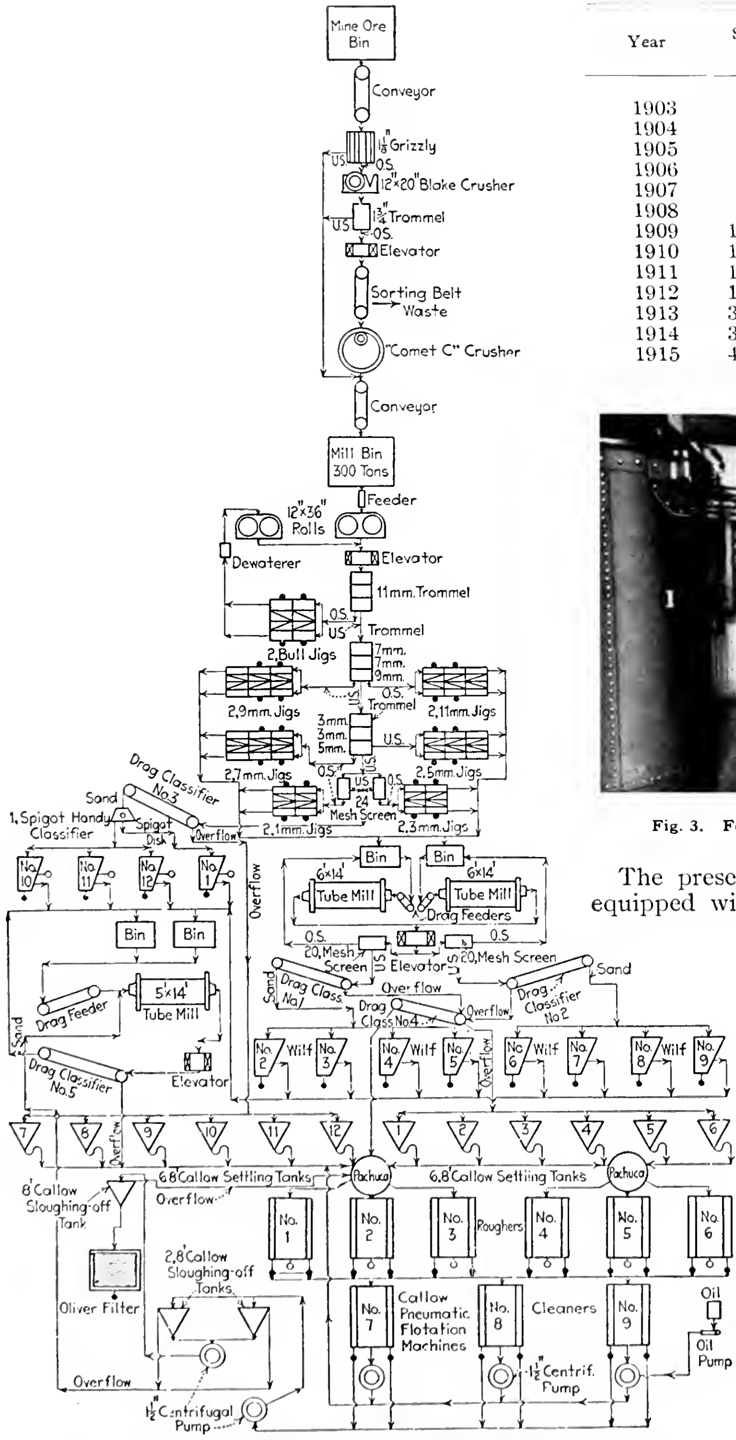


Fig. 2. Flow Sheet of Mill at Gold Hunter Mine. This Method of Handling Ore Represents Practically Standard Practice

Year	Substation Capacity	Kilowatt-hours for Year	Tons Ore Mined
1903	275-kv-a.	288,000	260.900
1904	500-kv-a.	915,100	288.332
1905	550-kv-a.	1,050,800	304,380
1906	600-kv-a.	1,456,000	347,300
1907	650-kv-a.	2,470,600	336,330
1908	950-kv-a.	2,885,650	335,070
1909	1260-kv-a.	4,866,550	345,270
1910	1900-kv-a.	6,973,180	377,530
1911	1900-kv-a.	7,892,000	432,290
1912	1900-kv-a.	7,992.000	434,800
1913	3250-kv-a.	8,629,500	435,000
1914	3760-kv-a.	9,244,300	440,000
1915	4250-kv-a.	10,979,000	455,000

Fig. 3. Feeder Switches and Transformer Room

The present station, shown in Fig. 4, is equipped with seven 650 kv-a. three-phase transformers which step the voltage down to 2300 volts. Fig. 3 shows the substation feeder switches and Figs. 5 and 6 show the distributing panels at the power house. The a-c. switchboard distributes the current to the various motor circuits at 2300 volts and only the smaller motors below 20-h.p. are supplied with 220 volts.

In the power house is installed a 750-kw. vertical Curtis turbine (Fig. 7). This is purely an auxiliary for use in case the power on the line should fail. In case of emergency this unit would take care of the hoist and the necessary pumping. It has rarely been found necessary to throw any load on this unit due to failure of outside service.

As the Bunker Hill & Sullivan Co. is the largest individual mine of the Coeur d'Alenes, as well as one of the largest lead silver mines in the world, it may be of interest to briefly describe the applications of electricity to their mining and milling operations.

In 1901 the Washington Water Power Company canvassed the district and secured enough contracts to justify building their 60,000-volt high-tension lines to supply this camp. In 1903 the lines were completed and the Bunker Hill & Sullivan Co. substation was equipped with one 275-kv-a. transformer.

The table on page 148 shows how rapidly the kilowatt-hours used in mining and milling operations have increased with respect to the tons mined at the Bunker Hill & Sullivan Co's. plant.

The milling operations require the largest percentage of the load. In this department are installed 33 motors having a connected load of 1897 h.p. Fig. 8 shows a 250 h.p. Form P motor used to drive the vanner and table floor, while the 200 h.p. Form P motor on the left is used to drive the jigs, rolls, etc. in West Mill No. 1. The West Mill No. 2 motor installation is practically identical.

The device shown standing close to the rope shieve is called a motor tell-tale device and was invented by Mr. M. J. Bottenelli, electrical foreman at the mine. Its operation is as follows: When a strand in the driving rope breaks, it flies out due to centrifugal force when traveling around the periphery of the shieves, and engages the small horizontal bar which is set at right angles to the hollow upright supporting rod and parallel to the face of the shieve. A trigger arrangement allows a small weight to drop, short circuiting the contacts in the supporting base and energizing a solenoid coil mounted under the toggle mechanism of the oil switch (Fig. 9), the armature of this coil tripping out the oil switch. Fig. 10 shows the contact for a bell alarm mounted on the back of the

Fig. 4. View in Substation of Bunker Hill & Sullivan Company Showing Seven 650 kv-a. 60,000/2300-volt Transformers

Fig. 5. Alternating-current Switchboard in Substation

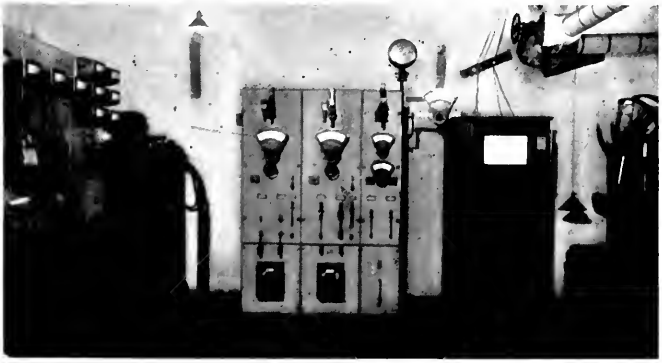


Fig. 6. Direct-current Switchboard in Substation

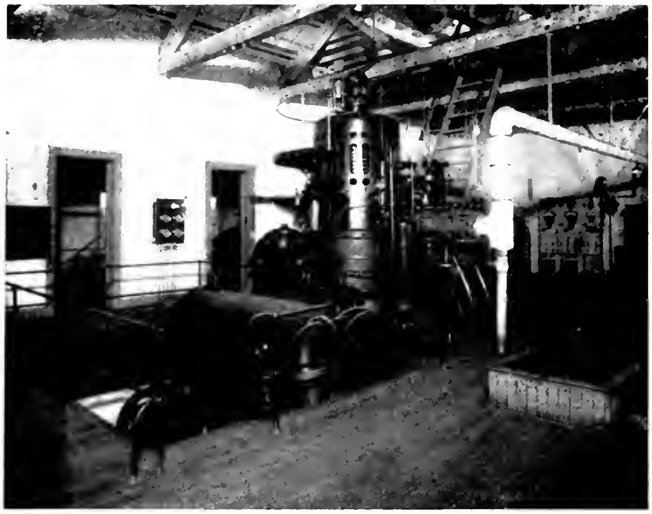


Fig. 7. 750-kw. Curtis Steam Turbine for Emergency Use

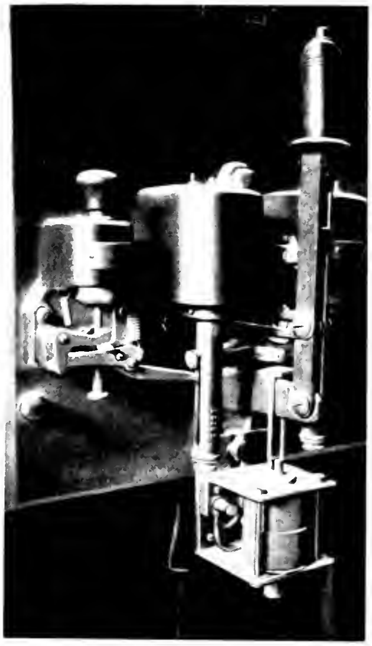


Fig. 9. Toggle Tripping Mechanism of Oil Switch, Operated by Device Shown in Fig. 8

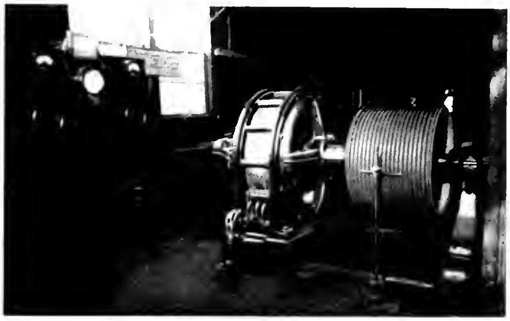


Fig. 8. 250-h.p. Induction Motor Operating Vanner and Table Floor. The Device Shown Close to the Rope Pulley is a Tell-tale Device to Indicate the Breaking of a Strand in the Drive Rope

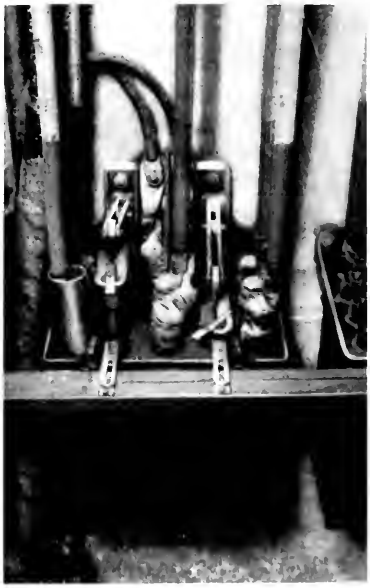


Fig. 10. Contacts for Alarm Bell Mounted on Back of Oil Switch. When Oil Switch is Tripped by Tell-tale Device at the Motor Pulley the Switch is Tripped and the Alarm is Sounded

Fig. 11. 36-inch Electromagnet for Extracting Pieces of Steel from Ore before it Enters the Crushers

switch. When the switch trips out the alarm rings.

This simple mechanism has been the means of eliminating long and costly shutdowns; it has also done away with serious breakdowns that were not infrequent before its installation.

In the rock house at the end of the conveyor belt is installed a 36 in., 250-volt electromagnet (Fig. 11) which extracts all large pieces of steel before they can enter the crushers. A varied collection of drills, hammers, spikes, monkey wrenches, car links, spectacles and numerable tobacco cans are gathered at this point.

Mine Pumping

One of the most important applications of electrical energy is in connection with mine pumping. For this work there are installed two independent lead covered cables carrying 2300-volt current from the power house to the collar of the shaft, a distance of approximately 12,500 ft. These cables also carry current for the hoist, but their capacity is great enough so that either cable can carry the total load.

Fig. 12. Electric Air Heater for Hoist

There are five motors installed for mine pumping having an aggregate connected load of 535-h.p. Fig. 13 shows a quintuplex pump driven by a 150-h.p., 2200-volt Form M motor on the 13th level. A similar installation is installed at the No. 1 shaft station on the same level.

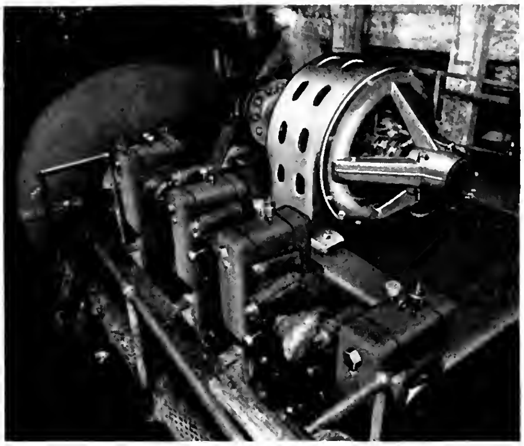


Fig. 13. Quintuplex Pump Driven by 150-h.p., 2200-volt Motor, Thirteenth Level

Each pump circuit is equipped with a curve-drawing ammeter which records in red ink during the 24 hours the time of starting and stopping, as well as any irregular action of the pump. By close inspection of these charts careless starting, condition of valves, and other mechanical conditions are revealed.

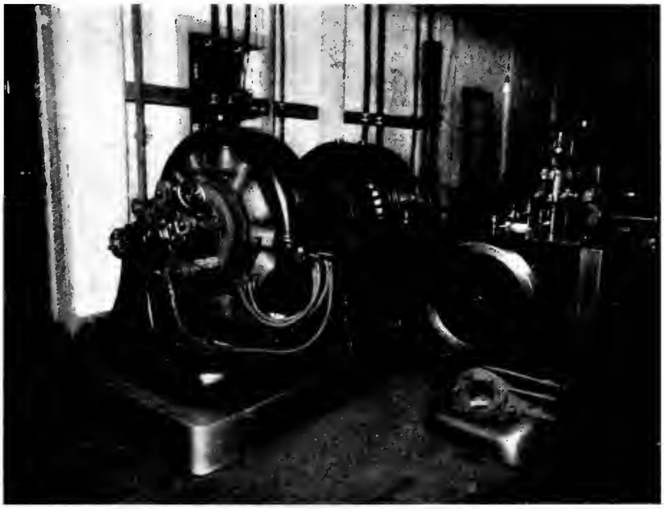


Fig. 14. Motor-generator Set Furnishing 500-volt Direct-current for Mine Locomotives

The daily cost of pumping 595,150 gallons from the shaft is only $17.12 for electric current.

To attempt to pump this water 10,000-ft. away from the portal of the tunnel by any other means under existing conditions would be impractical to say the least, and nearly impossible if costs were to be considered.

Fig. 15. Loading Ore Cars in Mine. Tail Lamp Consists of Edison A4 Cell and Incandescent Lamp Mounted in Iron Box

Fig. 16. 8-ton, 24-inch Gauge, 500-volt Locomotive and Train of Ore Cars

Continuous and reliable service surely could not be obtained by other means comparable to that resulting from using electricity. About three years ago a fire started at the collar of the shaft, disabling the pump circuits. The pump and motor shown in Fig. 13 were submerged under a 200-ft. vertical head of water and remained there for three weeks. After the shaft had been pumped out, low voltage was applied to the motor for three days, and hot air blasts supplied by electric heaters were blown through the windings. The motor was not taken from its foundation nor taken apart, and the fourth day the unit was started and has been in continuous service since.

Hoisting

The first successfully operated induction motor hoist in this camp is still in operation at this mine. It is installed near the collar of the inclined shaft and is rated at 200-h.p. curve-drawing instruments are connected in the hoist circuit so that a check can be made on the frequency of hoisting trips, and an accurate record of time of accidents, etc., secured.

Fig. 17. Train of Ore Cars at Dumping Bins

Fig. 18. 4-ton Storage Battery Locomotive Used for Gathering Loaded Cars Underground and Hauling them to the Shaft

During 1915 there was hoisted 422,853 tons with an average consumption of 1.0473 kw-hrs. per ton, at a cost of 0.00679 cents per ton for electrical energy.

The old air hoist which the electric hoist displaced is still maintained for emergency operation. The air for this hoist is reheated by electricity in a double heater, Fig. 12, which was built at the mine. These heaters require 90 amperes each at 110 volts and are provided with switches which permit six different heats. The heat required for the air at the various demands of the hoist can be readily regulated by these switches.

Traction

All ore, timbers and men are hauled in and out of the mine by electric locomotives. The main tunnel is approximately two miles long to the collar of the shaft, and 18 locomotives are kept busy most of the time gathering the ores underground and hauling them to the mills. Several of the smaller locomotives are used around the yards. Fig. 14 shows the motor-generator set which furnishes the 500-volt direct current for this haulage system.

The ore is loaded from chutes into cars of 47 cu. ft. capacity, and 17 cars make up the average train. Fig 15 shows the cars being loaded, and in passing it is of interest to note the type of tail light used. This consists of an Edison A4 cell and an incandescent lamp mounted in a strong iron box fitted with a regulation caboose red lens.

Fig. 19. 4-ton Storage Battery Locomotive Shown in Fig. 18 Receiving a Charge During Noon Hour

These cells require charging only once every thirty days.

Fig. 16 shows the standard 8-ton, 24-in. gauge, 500-volt locomotive starting with a train for the portal of the tunnel, and Fig. 17 shows a train arriving over the dumping bins. The total length of trolley lines around the mine and yards is approximately 11 miles.

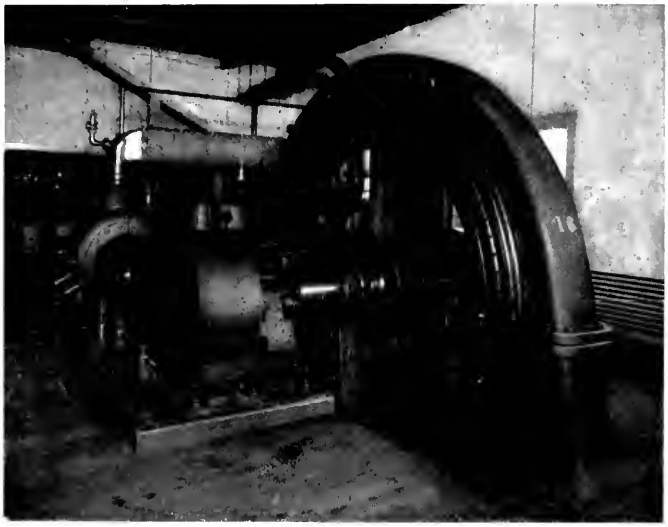


Fig. 20. 2400 Cubic Foot Ingersoll-Rand Air Compressor Driven by 400-h.p., 2200-volt Induction Motor

In the lower levels of the mine, where the head room is limited along the drifts and crosscuts, four storage battery locomotives are used and the results obtained from them are highly satisfactory. The proposition of keeping up trolley wires and bonding rails

Fig. 21. 300 kw. Motor-generator Set for Electric Metallurgical Processes, which Consists of a 4000 Ampere Direct-current Generator Driven by a 450-h.p. Squirrel-cage Induction Motor

in the lower levels had become expensive and the ever present danger of the 500-volt trolley to the miners was serious. With storage battery locomotives this was done away with.

Fig. 22. "Safety-first" Sign to Impress upon the Miners the Importance of Observing Greatest Care in Operating all Equipment

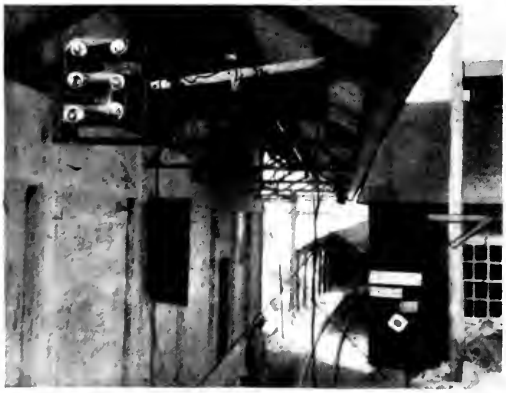


Fig. 23. Manually Operated Switch at Portal of Main Tunnel for Controling Block Signal System

Fig. 24. Block Signal Lamps

A 4-ton storage battery locomotive, shown in Fig. 18, is at present being used underground for gathering loaded cars and hauling them to the shaft. The average haul for these locomotives is 1000-ft. and the trains average eight cars each of 34 cubic feet capacity. The batteries generally receive a boosting charge during the noon period (Fig. 19).

Compressed air

Fig. 20 shows a 2400 cu. ft. Ingersoll-Rand compressor driven by a 400-h.p., 2200-volt, Form P motor. This is the largest electrically driven compressor at the mine. Additional air is furnished by a 3300 cu. ft. combination steam and waterwheel driven compressor which was installed before the advent of electric power.

Electrometallurgy

The Bunker Hill & Sullivan Co. have experimented quite extensively with several electrometallurgical processes and have installed quite a complete electrical equipment for this work. The main unit, Fig. 21, is a 300-kw. motor-generator set with a 4000 ampere d-c. generator connected to a 450-h.p., 2200-volt Form K motor. It was deemed advisable to enclose this unit in a concrete room because of the harmful fumes which were liberated during a certain stage of the process.

Safety-first Features

To impress upon the several hundred miners that they are to observe "safety-first" rules, a large electric sign is placed inside the main tunnel (Fig. 22). The moral effect of this sign upon the miners since its installation has unquestionably been beneficial.

A block signal system has been designed and built by the electrical department, and although not elaborate it has been the means of doing away with all wrecks outside of those caused by derailments. The manually operated switch, Fig. 23, is mounted outside of the portal of the main tunnel. The motormen on the trains going in pull the switch, which throws in circuit a series of green lamps in the tunnel (Fig. 24). In the same manner the outcoming train crew throw a series of red lamps in circuit, and upon arriving at the portal of the tunnel this circuit is opened. If both green and red lamps are lighted at the same time it would indicate two trains in one block, and the last train to enter would hurriedly back out in the clear. It seems that this system, not being automatic, would introduce a certain amount of error, but in the three years of its operation no mistakes have been made by train crews.

All hoist bells and telephone signals, Figs. 25 and 26, are operated by 110-volt alternating current. Electric lights are used in connection with all signals so that any one in the vicinity can check the number of rings by looking at the flashes of the lamps.

Fig. 25. Hoist Signaling Mechanism

The calls and answers on the telephones are most easily checked by this system. The telephones are fitted with Russel horns instead of bells and these make a weird sound that can be readily heard above the noise of pumps and escaping air.

In Fig. 27 is shown a home-made combination bell and light indicator which is used to show high or low water levels in tanks or flumes. (Note the Russel horn on the top of the panel.)

This concludes most of the interesting electrical applications at the Bunker Hill & Sullivan Co. plant. They are at present building a smelter close to the mine and this will also be electrically operated throughout. To commence operation here approximately 1000-h.p. additional will be required.

Fig. 26. Installation of Telephone

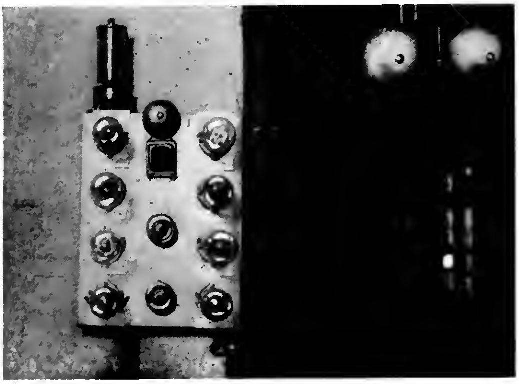


Fig. 27. Improvised Combination Bell and Light Indicator to Show High or Low Water Levels in Tanks or Flumes

The writer is indebted to Mr. W. C. Clark, electrical engineer for the Bunker Hill & Sullivan Co., for the figures and data given in this article.

LITERATURE OF THE NITROGEN INDUSTRIES, 1912-1916

By Helen R. Hosmer

Research Laboratory, General Electric Company

The first installment of this article contained a table of contents of the entire series, as general introduction, and a review of the literature on descriptions and chemistry of the several processes, including the oxidation processes, reduction processes and the Ostwald process. The present installment has reference to the production of nitrogen compounds by the different processes and their consumption in the manufacture of munitions of war, general manufacturing and agriculture.—Editor.

Part II: PRODUCTION

GENERAL

1914 Kubierschky (66) gives the average yearly increase in production of fertilizer materials during the past few years. The figures for several items are as follows:

	Years	Ave. Annual Increase Per Cent
Cyanamide	1907–12	212.0
Norway saltpeter	1903–11	170.0
Ammonium sulphate	1901–11	10.5
Chile saltpeter	1901–11	6.8

The world's production in 1913 is given by
1914 reference (80) as follows:

	Metric Tons
Ammonium sulphate	1,365,000
Chile saltpeter	2,740,000
Lime nitrogen	80,000
Norwegian nitrate [$Ca(NO_3)_2$]	30,000

Chile Saltpeter

1915 Summers (50) gives the present annual output of Chile nitrate as 2,500,000 tons, of which the United States takes from 600,000 to 700,000 tons. The government tax has netted Chile about $500,000,000 in the last 30 years.

1913 Reference (93) gives the yearly production from 1902 to 1912.

1912 Bernthsen (109) gives figures for the exports, price, and value of Chile nitrate for each year from 1900 to 1912, and for the world production, etc., of ammonium sulphate for certain years during the same period.

1912 Scott (124) gives the annual exportations of nitrate from Chile at intervals during the years 1830 to 1911, in which time it has increased from 935 tons (long?) to 2,420,400 tons.

Ammonium Sulphate

1916 Turrentine (6) advocates reliance by the United States upon the coke-oven by-product for both the war time and agricultural consumption of nitrogen products, and gives statistics of the present and probable future production. He states that the 68 per cent wasted in 1914 equals 350,000 tons of ammonia from which 300,000 tons of 100 per cent nitric acid might be made. He also estimates that from the surplus coal gas now wasted 800,000 continuous horsepower could be generated with which 1,400,000 tons of ammonium sulphate could be produced by nitrogen fixation processes in time of emergency. He mentions special measures that should be taken which would further increase this production.

In a later reference (5) he discusses the matter in much greater detail, giving statistics of the past development of the coke-oven by-product industry and estimates of its future. He gives the production of ammonium sulphate in the United States for each year from 1900–17 and both the probable and possible increase by 1920. He states that at the present (1916) rate of increase the total production from coke-ovens alone will be 800,000 tons of ammonium sulphate. In time of emergency he would withdraw all of the supply going into fertilizers. From the output at the rate normal on April 1, 1916, nitric acid could be made by the Ostwald process equivalent to 271,000 tons of sodium nitrate, (the importation of sodium nitrate during 1915 was 577,000 tons) which would

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(66) Kubierschky, Journal, Industrial and Engineering Chemistry, *6*, 692 (1914).

(80) Zeitschrift, Vereines Deutschen Ingenieure, *58*, 980 (1914).

(50) Summers, Transactions Amer. Electrochemical Society, *27*, 339–83 (1915).
Proceedings, Amer. Institute of Electrical Engineers, *34*, 337–81 (1915).
Abstract, Metallurgical and Chemical Engineering, *13*, 241–4 (1915).

(93) Montgomery & Co., Report. Abstract, Journal, Industrial and Engineering Chemistry, *5*, 260 (1913).
Chemical Engineer, *17*, 78 (1913).

(109) Bernthsen, Transactions, 8th International Congress of Applied Chemistry, *28*, 182–201 (1912).
Journal, Industrial and Engineering Chemistry, *4*, 760–7 (1912).

(124) Scott, "Manufacture of nitrates from the atmosphere." Smithsonian Report for 1913, pp. 359–84, (1914). (Publication 2291). Reprinted from Journal, Royal Society of Arts, (London) *60*, No. 3104 (1912).

(6) Turrentine, Jl. Industrial and Engineering Chemistry, *8*, 584–5 (1916).

(5) Turrentine, Jl. Industrial and Engineering Chemistry, *8*, 923–6 (1916).

more than supply the needs for explosives, in times of peace. His conclusion is that such a supply of nitrogen compounds is adequate for the United States for both times of peace and of war.

Lymn also (25) gives curves showing the consumption and production of ammonium sulphate in the United States between 1900 and 1913, together with imports and world production.

1916 Reference (10), a pamphlet issued by the by-products interests, gives data on the rate of production, and arguments intended to show that the ammonium sulphate produced is sufficient to insure a supply of nitric acid in time of war. The objections to depending upon such a supply are not mentioned, far less answered. The pamphlet objects to government manufacture of nitrates on the ground that it will lower the price of sulphate and discourage the by-product industry.

Porter (2) gives almost the same data and conclusions as Turrentine (6) and continues with arguments against recent legislation for the government's establishing a plant for nitrogen fixation. He gives a list of the by-product coke plants in the United States in September, 1916. In connection with Porter's statement that at the outbreak of the war Germany had almost reached the limit in the production of by-product ammonia, its of interest to note that reference (7) says that at that time only 1/5 of her coal was coked. The coking industry has been much extended since but yet it has been found necessary to make ammonia by the Haber process in quantities placed at 300,000 tons per year. In other words, the proposal made by Turrentine (6) that the United States government should meet an emergency by going into the coke business does not seem to have been economical there.

1916 Washburn (12) discusses the availability of by-product coke oven ammonia as a source of nitric acid in time of war, and points out that its extreme variability, depending upon the fluctuations of the iron industry, and the fact that the supplies must be gathered from scattered localities, are important drawbacks. The present maximum output, from 21 widely scattered points, is equivalent to only about 120,000 tons of concentrated nitric acid, which is perhaps two-thirds of a minimum safe reliance for war. 37 per cent of this total production is used for refrigeration and so could not be diverted, particularly in time of war. 10 per cent is already used in explosives and chemicals, and the remaining supply is used in agriculture, where it could be ill spared at a time when imported fertilizer materials were cut off.

Germany, with the greatest metallurgical industry in Europe, and making 90 per cent of her coke supply in by-product ovens, had to turn to atmospheric nitrogen for war supplies.

Childs (28) gives the probable increase in 1916
production of ammonium sulphate in the United States during 1916 as 30,000 to 40,000 tons. He gives the statistics of production, imports and consumption, in the United States from 1902 to 1915, and states that the present production from coking is only 29 per cent of that possible if by-product ovens were universally used. He discusses the future of coke by-products, mentioning the probable competition after the war of German products from their highly developed fixation processes. He states that the semi-direct method is the one used mostly in the United States. He also discusses the uses and demand for various by-products.

Landis (44) points out that the supply of 1915
ammonia from coke ovens has the disadvantages inherent in by-product sources. A ton of coal yields only 5 to 6 lb. of ammonia. Any industrial depression, and particularly such as results from war [see Mineral Industry *23*, 412–13, 417–422 (1914)], cuts down the supply at once. In Germany, regulations prohibiting the use of coal were passed, in order to force the production of coke and its by-products.

Clarke (8) gives an up to date list of by- 1915
products coke ovens built or under construction in the United States. He states that tar and ammonia yields are much lower here than in Europe.

The annual production of ammonium sulphate is now about 1,250,000 tons, practically all coming from by-product coke ovens or from gas-house retorts. The production in the United States per year is equivalent to about

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(25) Lymn, Journal, Amer. Society Mechanical Engineers, *37*, 253–66 (1915).

(10) Koppers Co., Pittsburg, Pa., "By-products of the Coking of Coal in America." (1916) (Pamphlet issued to oppose government nitrate plant.)

(2) Porter, Metallurgical and Chemical Eng'g. *15*, 470–5 (1916)

(6) Turrentine, Jl. Industrial and Engineering Chemistry, *8*, 584–5 (1916).

(7) Frankfurter Handelsblatt, May 29, 1916, Abstract, Engineering, (L.) *101*, 576 (1916).

(12) Washburn, "The Facts in the Nitrogen Case." (1916).

(28) Childs, Amer. Iron and Steel Institute, May 1916.
Abstract, Metallurgical and Chemical Engineering, *15*, 38–41 (1916).

(44) Landis, Journal Industrial and Engineering Chemistry, *7*, 433–8 (1915).
Metallurgical and Chemical Engineering, *13*, 213–8 (1915).

(8) Clarke, Abstract, Metallurgical and Chemical Eng'g. *14*, 601–3 (1916).

70,000 tons, and is increasing annually at the rate of some 15 per cent (47). 1915

1915 In discussing Peacock's (47) paper Johnson states that the production of ammonia possible in the United States, if all coking were done in by-product ovens, is about 225,000 tons annually. Only 30 per cent of this amount is saved at present.

1915 American coals (50) contain from 0.9 to 1.4 per cent or 18 to 28 lb. of nitrogen per ton, of which 20 per cent, or from 4½ to 7 lb. of ammonia per ton of coal distilled is recovered. This yields 18 to 28 lb. of ammonium sulphate per ton of coal.

1916 Lymn(25) gives a table of the nitrogen content of coals from different parts of the United States.

The Mond producer gas system recovers 75 per cent or from 15 to 20 lb. of nitrogen, or 60 to 80 lb. of ammonium sulphate per ton of coal consumed. This plant, although installed abroad, is not very extensively used in America, as the expense of installation is relatively high.

1916 Wagner (32) gives the yields per ton of various American coals in tar, ammonia, sulphur and naphthalene. The ammonia yield varies from 4.33 per cent for Alabama coal to 9.60 for Oak Creek, on the basis of ash and moisture free coal. He discusses the subject of coke and coal and furnaces for coal distillation, etc., very fully but says little about by-products.

The world production for 1914 is estimated by the American Coal Products Company
1915 (55) to have been 1,300,000 to 1,350,000 metric tons against 1,409,000 in 1913. England produced 426,413 tons, or about 6200 tons less than in 1913. Figures could not be obtained for Germany. (See Consumption, Ammonium Sulphate).

In the United States 183,000 tons, or 12,000 tons less than in 1913 were produced. This decrease was mostly during the last six months, and was due to the depression in the iron and steel trade caused by the war. The recovery possible from the coal now coked is
1915 700,000 tons. (55)

The principal source, and the one promising the greatest extension in the near future, is the by-product coke oven. The Coal Gas Works have the next largest total output, though the unit production is much smaller and widely scattered. Other sources are the by-product recovery gas producer, shale oil distillation, and the English blast furnaces
1915 using splint coal. (55)

Tutwiller (71) gives a table showing the rate of production and value of coke, tar, ammonium sulphate, etc., from 1903–1908. 1914

Reference (80) gives the world's production of ammonium sulphate in 1913 as 1,365,000 tons, compared with 1,214,000 tons (metric) in 1912. The production of the various countries in thousands of tons was as follows: 1914

	1913	1912
Germany	549	492
England	420	379
United States	177	151
France	75.4	69
Belgium	48.6	50

In 1913 (73) the production of ammonia in terms of ammonium sulphate, in the United Kingdom was about 420,000 tons (long). The exports were 325,000 tons. 1914

Canada produced in 1913 (73) 10,608 tons of ammonium sulphate from coke ovens. 1914

The production in 1910 and 1911 in the United Kingdom (111) calculated as sulphate was 367,500 and 378,500 tons (long). 1912

The production of Great Britain in 1911 and 1912, calculated as sulphate, was as follows:

	TONS (LONG)	
	1911	1912
Gas works	169,000	166,000
Iron works	20,000	20,000
Shale works	61,000	61,000
Coke, carbonizing works and producer gas plants	135,000	132,000
	385,000	379,000

Bradbury and Hirsch (82) 1913

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(47) Peacock, Transactions, Amer. Electrochemical Society, *27*, 409–17 (1915).

(50) Summers, Transactions Amer. Electrochemical Society, *27*, 339–8[illegible] (1915).

Proceedings, Amer. Institute of Electrical Engineers, *34*, 337–81 (1915).

Abstract, Metallurgical and Chemical Engineering, *13*, 241–4 (1915).

(25) Lymn, Journal, Amer. Society Mechanical Engineers, *37*, 253–66 (1915).

(32) Wagner, "Coal and Coke" (1916) (McGraw-Hill Book Co.)

(55) Metallurgical and Chemical Engineering, *13*, 638–9, (1915).

(71) Tutwiller, Journal, Franklin Institute, *178*, 383–416 (1914).

(80) Zeitschrift, Vereines Deutschen Ingenieure, *58*, 980 (1914).

(78) Journal, Society Chemical Industry, *33*, 134 (1914).

(73) Chemical Trade Journal, May 9, 1914.

Abstract, Journal, Society of Chemical Industry, *33*, 541 (1914)

(111) Bradbury, Hirsch, Journal, Society of Chemical Industry, *31*, 71; 716 (1912).

(82) Bradbury, Hirsch, Abstract, Journal, Society of Chemical Industry, *32*, 84 (1913).

1913 The figures given in another reference (105) are:

	1912	1911	1910
Gas works	172,094	168,783	167,820
Iron works	17,026	20,121	20,139
Shale works	62,207	60,765	59,113
Coke oven works	104,932	105,343	92,665
Producer gas and carbonizing works	32,049	29,964	27,850
	388,308	384,976	367,587

1912 Scott (124) gives similar data for 1906, 1909 and 1910.

A comparison of the export trade of England and Germany during 1912 and 1913 gives the following totals in metric tons:

	1912	1913
Germany	56,897	74,318
Great Britain	285,134	270,697

1914 The amounts exported to each country are given (75).

1911 Tufts (141) reviews briefly the various commercial sources of ammonia. He believes that the by-product coke oven cannot long be a leading factor in the situation as the world's demand for ammonia is increasing at a rate that in seven years will take almost all the production possible if all the world's coke were made in by-product ovens. A corresponding rate of increase in coke consumption cannot be expected.

OXIDATION PROCESSES

1916 Washburn (12) states that the world's yearly fixation of nitrogen by the arc process is some 32,000 net tons compared to 200,000 tons by the cyanamide process. The former process is practically confined to Norway, while the latter has been applied in Norway, Sweden, Germany, Austria, France, Japan, and Canada.

1916 He (16) also states that there are employed in the World's Nitrogen Fixation industry 1,000,000 continuous horse-power, and he gives the distribution as follows:

Canada	30,000
Germany	350,000
Norway	450,000
Dalmatia, Italy, Switzerland, Japan, France	150,000
	980,000

From the condition of operating no arc processes, Germany has developed in 18 months an industry producing nearly 10,000 tons of nitric acid per year (19). 1916

1915 James B. Duke (30) is accredited with the statement that the Southern Electro-Chemical Company will shortly be producing at Great Falls, S. C. by the Pauling process, nitric acid at the rate of 4 tons per day. The product will be placed on the market at a price lower than that of acid made from sodium nitrate (30). The plant uses 3000 kw. and is the only nitrogen fixation plant in the United States.

Reference (130) mentions that operation of a plant using the Pauling process with an estimated capacity of 8 tons of calcium nitrate has been begun by the Southern Electrochemical Company at Nitrolee, S. C.

1912 Earlier press notices (131) stated that this plant, which was designed to use the surplus power of the Southern Power Company, would turn out 5 tons of nitric acid or 8 tons of calcium nitrate per day with a possible later development to a capacity of 50 tons.

1915 Baur (34) in a table of the power consumption of the electrochemical industries of the world gives the following figures for nitrogen fixation:

Process	Power kw.	Yearly Production Metric Tons	Yield per kw-hr.
Nitric acid from air	295,000	180,000 $=40,000\ N$ $=310,000\,Ca(NO_3)_2$ $=270,000\ Na\ NO_3$	1 kg $N=65$ kw-hr. or 1000 kg N as nitrate **7.5** kw-yr.
Lime nitrogen	55,000	150,000 $=30,000\ N$	1 kg $N=17.5$ kw-hr. or 1000 kg N as lime nitrogen 2 kw-yr.

(1 kw-yr. = 1750 kw-hr.)

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(105) Forty-ninth annual report on Alkali. Proceedings during the year 1912.
Abs., Journal, Society of Chemical Industry, *32*, 786–8 (1913).

(124) Scott, "Manufacture of nitrates from the atmosphere." Smithsonian Report for 1913, pp. 359–84, (1914). (Publication 2291). Reprinted from Journal, Royal Society of Arts, (London) *60*, No. 3104, (1912).

(75) Chemiker Zeitung, *38*, 593 (1914).
Abstract, Journal Industrial and Engineering Chem. *6*, 597 (1914).

(141) Tufts, Journal, Industrial and Engineering Chemistry, *3*, 295–9 (1911).

(12) Washburn, "The Facts in the Nitrogen Case." (1916).

(16) Washburn, Statement before Senate Committee on Agriculture and Forestry, 1916. (S. 4971).

(19) Landis, Metallurgical and Chemical Eng'g. *14*, 260 (1916).

(30) Duke, Engineering and Mining Journal, *101*, 149 (1916).
Manufacturer's Record, *68*, 54 (1915).

(130) Metallurgical and Chemical Engineering, *10*, 126 (1912)

(131) Newspaper clippings. Times, Raleigh, N. C. June 14, 1912, Wall Street Journal, July 25, 1912.

(34) Baur, Schweizerische Wasserwirtschaft, *7*, No. 16 and 17.
Elektrotechnische Zeitschrift, *36*, 694–5 (1915).

Installations of the arc process at Rjukanfos have already reached 185,000 kw. and with the completion of the works at Tyin and Matre nearly 300,000 kw. will be applied to the production of calcium nitrate. Plants for the production of nitric acid by the Moscicki process using 74,000 kw. are being installed in Switzerland. The arc processes, because of the relatively small power consumption of each unit, and the ease of starting and stopping, is especially applicable to intermittent water powers.

Calcium nitrate will probably soon disappear from the market, as it cannot compete with Chile nitrate, nor with ammonium sulphate, even when the latter is made from cyanamide (44). 1915

1915 Scott (49) states that in Norway alone nearly a quarter of a million horse-power is employed for making nitric acid from the air. One factory uses 140,000.

1915 Washburn (51) gives the annual productive capacity of the oxidation processes as over 30,000 tons of fixed nitrogen, worth at the normal average value about $250 per ton. This is about half of the amount of nitrogen fixed by the cyanamide process. The single factory at Nigara Falls has a capacity equal to one-half of the total world's installed capacity by arc processes.

1914 Baekeland (56) states that the Norway factories alone are using, for the production of nitrates, over 200,000 electrical horse-power with a capital investment of $27,000,000 and are contemplating an expansion to 500,000 horse-power.

1912 Scott (121) gives the horse-power consumption of the successive installations of the Birkeland-Eyde process year by year as follows:

Year	H.P.	Installation
1903	25	Experimental plant, Frognerkilens
1903	160	Experimental plant, Ankerlökken
1904	660	Arendal
1905	45000	First Notodden (Svaelgfos)
1910	15000	Second Notodden (Lienfos)
1912	140000	First Rjuken Installation
1913	120000	Second Rjuken Installation
1914	70000	Vamma
1915	80000	Matre
1916	70000	Tyin

1912 Scott (124) states that (in 1912) Great Britain was not fixing an "ounce" of nitrogen.

REDUCTION PROCESSES

Haber Process

It is claimed that the Badische factory is at present producing ammonium sulphate at the rate of 300,000 to 350,000 tons a year, an increase of 200,000 tons over the usual rate. (26)

1916 Reference (21) confirms this figure and estimates that the total production by the Haber process in 1917 will be 500,000 tons, compared with 30,000 tons in 1913.

It is also stated that at the beginning of the war the German government subsidized the Badische factory to the amount of 100,000,000 M. to avoid a shortage (26). 1916

1914 It was estimated (75) that the minimum production for 1914 would be 30,000 metric tons.

1914 It was stated in 1914 (74) that the Badische Analin und Soda Fabrik was increasing its capital by 900,000 £ to cover the cost of erecting a plant to be capable of producing 130,000 tons of ammonium sulphate annually by the Haber process.

Cyanamide Process

The Canadian factory of the American Cyanamide Company has a capacity for fixing nitrogen equivalent to 90,000 lb. of ammonia per day, and is increasing its capacity up to 110,000 lb. in 24 hours (23).

1916 Two plants in Germany, one in Bavaria, and another near Cologne, are producing 45,000 tons between them (26).

1916 Another plant is being erected in Westphalia, which will use 10,000 h.p. and is expected to produce 200,000 tons of concentrated nitric acid per year (26).

1916 1916 Landis (19) states that at the beginning of the war Germany had three factories, with a total capacity of about 50,000 tons of

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(41) Landis, Journal Industrial and Engineering Chemistry, *7*, 433–8 (1915).
Metallurgical and Chemical Engineering, *13*, 213–8 (1915).

(49) Scott, Journal, Society of Chemical Industry, *34*, 113–26 (1915).

(51) Washburn, Transactions, Amer. Electrochemical Society, *27*, 385–402 (1915).
Metallurgical and Chemical Engineering, *13*, 309–14 (1915).

(56) Baekeland, Journal, Industrial and Engineering Chemistry, *6*, 769–78 (1914).
Metallurgical and Chemical Engineering, *12*, 559–60 (1914).

(21) Skerrett, Iron Age, *97*, 359 62 (1916).

(26) Nature, *96*, 537 (1916).

(121) Scott, "Manufacture of nitrates from the atmosphere." Smithsonian Report for 1913, pp. 359 84, (1914). (Publication 2291). Reprinted from Journal, Royal Society of Arts, (London) *60*, 3104, (1912).

(75) Chemiker Zeitung, *38*, 593 (1914)
Abstract, Journal Industrial and Engineering Chem. *6*, 597 (1914).

(74) Chemiker Zeitung, Apr. 23, 1914.
Abstract, Journal, Society of Chemical Industry, *33*, 590 (1914).

(23) Landis, Journal Industrial and Engineering Chemistry, *8*, 156–60 (1916).

(19) Landis, Metallurgical and Chemical Eng'g, *14*, 260 (1916).

cyanamide per year, but within 18 months was producing almost 500,000 tons. (See also Baur, above, under Arc Processes.)

During 1914 the world production of cyanamide in 14 factories was some 300,000 tons, averaging over 20 per cent nitrogen (44). 1915

1915 An article in the Engineering News of January 1915 (53) gives a list of the factories of the world and the output of each. The total product is given as 333,500 short tons.

1914 The Cyanamide industry (56) represents an investment of $30,000,000 in 14 factories, three in Germany, two each in Norway, Sweden, and Italy, and one each in France, Switzerland, Austria, Japan and Canada. The horse-power employed is 200,000, and the annual amount was valued at $15,000,000. An English Company was comtemplating installations of 600,000 h.p. in Norway, and 400,000 in Iceland.

1914 Kubierschky (66) in a lecture on artificial fertilizer materials gives the cyanamide production for each year from the beginning of the industry in 1906 at 500 tons to 208,000 tons in 1914. The average yearly increase between 1907 and 1912 was 212 per cent.

1914 Haber (62) gives the amount of nitrogen fixed by this method as 36,000 tons.

1913 Pranke (95) states that the world's production in 1913 was estimated at 120,000 tons per year in 16 factories, four each in Germany and Italy, two in France, and one each in Austria, Norway, Sweden, Switzerland, Japan and Canada.

Scott (124) (125) gives a list of the factories and outputs therefrom of calcium cyanamide in 1912. 1912

Ammonia and Nitric Acid from Cyanamide

Washburn (51) states that no ammonia is being made from cyanamide in America outside of the American Cyanamide Company's laboratory. European plants are producing it at the rate of 15 tons per day, and there is ready for operation in Norway a plant designed to transform 60 tons of cyanamide per day into ammonia to be combined with the nitric acid from the Birkeland-Eyde factories. 1915

Kaiser (31) states that the B. and A. Masch. A-G. built during 1915 over 30 plants for the oxidation of ammonia from the Frank-Caro process, capable of handling over 12,000,000 kg. of ammonia, and have under construction apparatus for 17,000,000 kg. 1916

The foundation in England of a company with a capital of $10,000,000 to manufacture nitric acid from ammonia, the latter being derived from calcium cyanamide, by the Ostwald process, is mentioned in Reference(106). 1913

It is stated (107) that the plant at Odda is capable of consuming 80,000 tons (long) per year of calcium cyanamide. Plants are projected with the following capacities: 1913

Aura, Norway	200,000 tons $CaCN_2$
(Contro's power for 2,000,000 tons)	
Dagenham, England	12,000 HNO_3
Trafford Park	12,000 HNO_3
Manchester, Scotland	9,000 HNO_3
Ireland	3,000 HNO_3

PART III: CONSUMPTION

GENERAL

1916 In the year before the war (33) Germany consumed 217,000 metric tons of inorganic nitrogen from the following compounds:

	Metric Tons
Chile saltpeter (imported)	100,000
Calcium nitrate (imported)	5,000
Ammonium sulphate (domestic production)	95,000
Calcium cyanamide (⅓ imported)	17,000

During the first year of the war only 12½ per cent of this quantity was obtained or produced.

By the aid of a government grant of 7,500,000£ large quantities of cyanamide and ammonium salts were made for military purposes (33). 1916

England's consumption of ammonium sulphate in 1914 was 106,000 tons and exports

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(44) Landis, Journal Industrial and Engineering Chemistry, *7*, 433–8 (1915).
Metallurgical and Chemical Engineering, *13*, 213–8 (1915).

(53) Engineering News, *73*, 16–21 (1915).

(56) Baekeland, Journal, Industrial and Engineering Chemistry, *6*, 769–78 (1914).
Metallurgical and Chemical Engineering, *12*, 559–60 (1914).

(66) Kubierschky, Journal, Industrial and Engineering, Chemistry, *6*, 692 (1914).

(62) Haber, Jour., Society of Chemical Industry, *33*, 52–4(1914).

(95) Pranke, Chemical Engineer, *12*, 113–5. (1913).

(124) Scott, "Manufacture of nitrates from the atmosphere." Smithsonian Report for 1913, pp. 359–84, (1914). (Publication 2291). Reprinted from Journal, Royal Society of Arts, (London) *60*, 3104, (1912).

(125) Scott, Nature, *89*, 463 (1912).
Abstract, Journal, Industrial and Engineering Chemistry, *4*, 619 (1912).

(51) Washburn, Transactions, Amer. Electrochemical Society, *27*, 385–402 (1915).
Metallurgical and Chemical Engineering, *13*, 309–14 (1915).

(31) Kaiser, Chemiker Zeitung, *40*, 14 (1916)
Abstract, Chemical Abstracts, *10*, 806 (1916).

(106) Metallurgical and Chemical Engineering, *11*, 438 42 (1913).

(107) Times Engineering Supplement, Oct. 15, 1913.
Abstract, Journal, Society of Chemical Industry, *32*, 1008 (1913).

(33) Vogel, Chemiker Zeitung, *40*, 12–3 (1916).
Abstract, Journal Society of Chemical Industry, *35*, 431 (1916).

313,877 tons. German sales of the Deutsche
Ammoniak-Verkaufs-Vereinigung for home
consumption was 321,404 tons. Her exports
for the year were 75,868 metric tons, and
1915 imports 34,628 metric tons (55).

1914 In 1913 (78) the United Kingdom consumed
ammonia calculated as ammonium sulphate
to the amount of 97,000 tons (long).

The estimated home consumption in Great
1913 Britain was 90,000 tons. (105).

1912 The consumption (111) of ammonia in the
United Kingdom in 1911, calculated as
sulphate, was 85,500 tons.

The consumption in the United States was
272,000 tons, compared with 262,000 in 1913
1915 (55).

The world consumption in 1913 is given by
1914 reference (80) as follows:

	Metric Tons
Germany	460,000
United States	235,000
Japan	115,000
England	97,000
France	90,000

The world consumption of sodium nitrate
1913 (92) for 1910–12 is given as follows in long tons:

	1910	1911	1912
Shipments from South America	2,300,000	2,412,000	2,478,000
Consumption in U.K.	120,000	132,000	130,000
Consumption on Continent	1,531,000	1,564,000	1,778,000
Consumption in U. S.	501,000	556,000	481,000
Consumption in other countries	89,000	103,000	115,000
Consumption in World	2,241,000	2,355,000	2,504,000

1913 Reference (93) gives the yearly consumption
from 1902 to 1912.

1912 Bernthsen (109) discusses the increasing
demand for nitrogen compounds, giving the
world production, increase, and price for
sodium nitrate, and ammonium sulphate
during the ten years from 1900.

1911 Lamy (138) gives the growth in exports of
nitrates from South America as follows:

1830	800 tons	1880	300,000 tons
1835	7,000 tons	1890	800,000 tons
1850	20,000 tons	1900	1,300,000 tons
1860	70,000 tons	1905	1,500,000 tons
1870	150,000 tons	1909	2,000,000 tons

The approximate consumptions in 1910 were:

France	250,000
Great Britain	100,000
Germany	500,000
Belgium	200,000
United States	400,000

USES

Washburn (12) states that even the Allies 1916
are employing 500,000 continuous horse-power
in the fixation of nitrogen for explosive
materials.

Washburn (12, 16) estimates that a war 1916
supply of nitric acid for the United States
should amount to at least 180,000 tons per
year, which is (22) two-thirds of the estimated 1916
consumption of the German army.

He also points out what Germany has accomplished by the liberal use of fertilizer, that is, in quantities seven times as large per average acre cultivated as is the practice in the United States. From an area less than 80 per cent that of the State of Texas, she now raises 95 per cent of the food for a population nearly 70 per cent as large as that of the United States. In ten years our exportation of wheat and flour has fallen from 31 to 13 per cent of the production, and general crop production has increased only 10 per cent, while the population increased 21 per cent. From less than one-half the area Germany harvested in 1907 over double the quantity of grain and potatoes. While cost of food rose 80 per cent in the United States it increased only one-half as much there.

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(55) Metallurgical and Chemical Engineering, *13*, 638-9, (1915).

(78) Journal, Society Chemical Industry, *33*, 134 (1914).

(105) Forty-ninth annual report on Alkali. Proceedings during the year 1912.
Abs., Journal, Society of Chemical Industry, *32*, 786-8 (1913).

(111) Bradbury, Hirsch, Journal, Society of Chemical Industry, *31*, 71; 716 (1912).

(80) Zeitschrift, Vereines Deutschen Ingenieure, *58*, 980 (1914).

(92) Montgomery & Co., Report. Abstract, Journal, Society Chemical Industry, *32*, 84 (1913).

(93) Montgomery & Co., Report, Abstract, Journal, Industrial and Engineering Chemistry, *5*, 260 (1913).
Chemical Engineer, *17*, 78 (1913).

(109) Bernthsen, Transactions, 8th International Congress of Applied Chemistry, *28*, 182-201 (1912).
Journal, Industrial and Engineering Chemistry, *4*, 760-7 (1912).

(138) Lamy, Metallurgical and Chemical Engineering, *9*, 99-104 (1911).

(12) Washburn, "The Facts in the Nitrogen Case." (1916).

(16) Washburn, Statement before Senate Committee on Agriculture and Forestry, 1916. (S. 4971.)

(22) Washburn, Statement before House Committee on Military Affairs, Feb. 11, 1916.
Statement before House Committee on Agriculture, Feb. 1, 1916.

1916 Reference (7) gives the German consumption of nitrogen for 1913 as follows:

	Tons	Tons of Nitrogen
Ammonium sulphate..........	460,000	92,000
Nitrate of lime (Norwegian)....	35,000	4,500
Nitrate of lime..............	30,000	6,000
Ammonia, Haber process......	20,000	4,000
Nitrate of soda..............	750,000	116,000

The consumption of Chile nitrate increased from 155,000 tons in 1885 to 747,000 tons in 1913, of ammonium sulphate, from 125,000 tons in 1900 to 460,000 tons in 1913. The yield of wheat per hectare has doubled in Germany while increasing only 1/10 in France in which latter country only 1/15 as much potash and ½ as much nitrate of soda is used per hectare as in Germany.

1916 Landis (19) gives the present annual nitric acid consumption of Germany as 250,000 to 300,000 tons for munitions, besides the equivalent of 850,000 tons of sodium nitrate, 40,000 tons of nitrate of lime, and about 20,000 tons of Norwegian cyanamide, for agricultural and manufacturing pruposes. The last items are estimated from the normal improtation, which is now wholly cut off, and replaced by domestic production. The investment involved is over $100,000,000. It is quite possible, however, that the agricultural consumption is curtailed.

During 1912 Germany consumed 750,000 tons of Chile saltpeter, 425,000 tons of ammonium sulphate, 50,000 tons of lime nitrogen, and 50,000 tons of Norwegian
1916 saltpeter (18).

The imports of nitrates into Germany and Austria amount to about 750,000 tons annually. The consumption during the war is estimated at 750,000 tons of nitric acid for each side. This is based on an average consumption of 5 tons (3 to 10) of nitric acid per ton of explosives made, and 150,000 tons of
1916 explosives used per year (18).

1913 Christopher (83) mentions that in Germany practically the whole production of ammonium sulphate is used on the soil, while in England, out of a productions of 369,000 tons a year, only 70,000 tons is so used.

Sodium nitrate and ammonium sulphate constitute 80 to 85 per cent of the value of the raw nitrogen compounds produced in the world amounting in 1913 to nearly $200,000,000. Of this it is estimated that 80 per cent went for agricultural purposes. The farmers' purchases of nitrogen used east of the Mississippi during 1914 came to about $75,000,000, of which more than 90 per cent was in the form of ammonia. The normal annual consumption of nitric acid in the same region is about $7,000,000. The price per unit of nitrogen and the present rate of increase of consumption (10 per cent) is about the same for the two forms (51). 1915

The fertilizer question is one of great
importance to the United States (51). In the 1915
ten years from 1900 to 1910 population has increased 21 per cent, and the crop production only 10 per cent. Beef production fell 32 per cent, and the importation of food stuffs more than doubled, with a marked decrease in the exports. Food stuffs advanced in cost by 80 per cent between 1896 and 1912, and the increase in the cost of living was 59 per cent.

These figures indicate the necessity for increasing yields, as has been done in Europe, where the yield per acre is from 50 to 100 per cent greater than the United States, chiefly becuase of the use of fertilizers, which in Germany is, for instance, per acre, 15 times, in value in the United States, the average used on cultivated lands east of the Mississippi. Experiments in Indiana and Illinois have shown an increase in yield of wheat valued at from 2 to 3 times the cost of the fertilizer.

The present artificial fertilizers, however, contain from 85 to 90 per cent of material having no fertilizer value. To meet the conditions of long distance transportation and haulage over roads nearly impassable in the spring, it is essential that for the present mixtures should be substituted a concentrated substance of the proper composition and with the required physical and chemical properties.

Peacock (47) emphasizes the necessity of 1915
lowering the present prohibitive price of nitrogen products to check this increase in price of farm products.

Washburn (51) points out that arc methods 1915
of fixation cannot supply ammonia, and so must be limited to supplying the relatively small demand for nitric acid. The ammonia processes, on the other hand, supply a product for the conversion of which into nitric acid

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(7) Frankfurter Handelsblatt, May 29, 1916, Abstract, Engineering, (L) *101*, 576 (1916).

(19) Landis, Metallurgical and Chemical Eng'g, *14*, 260 (1916).

(18) Scientific American, *112*, 216 (1916).

(83) Christopher, Journal, Society Chemical Industry, ***32***, 115-24 (1913).

(51) Washburn, Transactions, Amer. Electrochemical Society, *27*, 385-402 (1915).
Metallurgical and Chemical Engineering, ***13***, 309-14 (1915).

(47) Peacock, Transactions, Amer. Electrochemical Society, *27*, 409-17 (1915).

processes have already been sufficiently developed to leave little doubt of their ultimate success, even through as yet no thoroughly workable commercial plant is perfected, or in entirely satisfactory operation (in the U.S.).

Furthermore, the product of the arc processes, nitric acid, is not suited to the long distance transportation from the remote localities where power is cheap enough to permit of its manufacture. Calcium nitrate is too hygroscopic for fertilizer purposes.

Washburn tends to the conclusion that the most promising solution of the fertilizer problem lies in the production of an ammonium phosphate compound deriving its ammonia from the cyanamide process.

Peacock (47) gives the annual nitrogen consumption of the fertilizer industry in the United States as equivalent to more than 100,000 tons of ammonia, increasing by about 8 per cent each year. 1915

About 50 per cent of the Chili nitrate imported into the United States is used in the manufacture of explosives, and another 25 per cent in the arts requiring nitric acid (50). 1915

(47) Peacock, Transactions, Amer. Electrochemical Society, *27*, 409-17 (1915).

(50) Summers, Transactions Amer. Electrochemical Society, *27*, 339-83 (1915).
Proceedings, Amer. Institute of Electrical Engineers, *34*, 337-81 (1915).
Abstract, Metallurgical and Chemical Engineering, *13*, 241-4 (1915).

PHANTOM CIRCUIT SYSTEM FOR CONTROLLING STREET LIGHTS

By A. H. Davis

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An outline of the operation and a detailed description of a very ingenious equipment for controlling street lights, that are tapped from house lighting circuits, are given in this article. Also, the advantages of the scheme are enumerated.—Editor.

In the suburban districts of cities using a multiple system of street lighting, it frequently happens that there is not sufficient load to warrant the running of feeders exclusively for street-lighting; consequently, these lights are connected to the service or house-lighting feeder. Since house-lighting service must be continuous, the problem of turning the street light on and off immediately presents itself. Usually, the cost of an extra wire for controlling a switch is prohibitive and switches that are operated by clock mechanism are unreliable.

Fig. 1. Automatic Oil Switch for Connecting and Disconnecting Street Light Circuits to Feeders

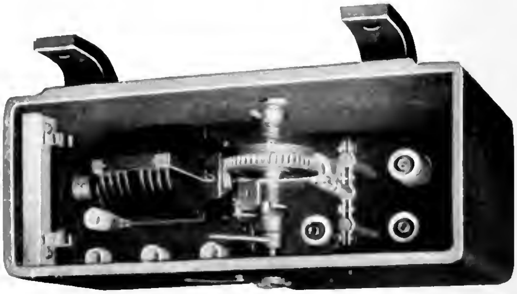

Fig. 2. Motor Mechanism for Operating Oil Switch

To secure the desired control, an inexpensive and reliable apparatus has been developed by means of which the street lights can be turned on or off at will from the power station. This apparatus can be used on any alternating-current lighting system where the 2300-volt feeders are not grounded. If the system has a grounded neutral on the 2300-volt lines, the apparatus can still be used, if it is allowable to disconnect the ground wire momentarily while turning the street lights on or off.

A ground on the 110-volt lines does not interfere with the switching operation. No control wire is required and there is absolutely no variation in voltage on the house lights while the switch is being operated.

The oil switch, Fig. 1, used to control the street lights, is usually connected in the primary circuit of the transformer from which these lights are run. This switch is operated by a small direct-current motor that has a permanent magnet field, and the switch mechanism is so arranged that a reversal in the direction of the motor's rotation operates the switch in opposite directions. One terminal of the motor is connected to the middle point of a reactance coil and the other terminal is grounded. The ends of the reactance are connected to the two wires of the 2300-volt feeder. The function of the reactance is to allow a direct current to flow from the 2300-volt mains through the motor to ground and at the same time to hold back the 2300-volt alternating current. The magnetizing current of the reactance is only a few milliamperes and therefore the coil does not ground the 2300-volt system.

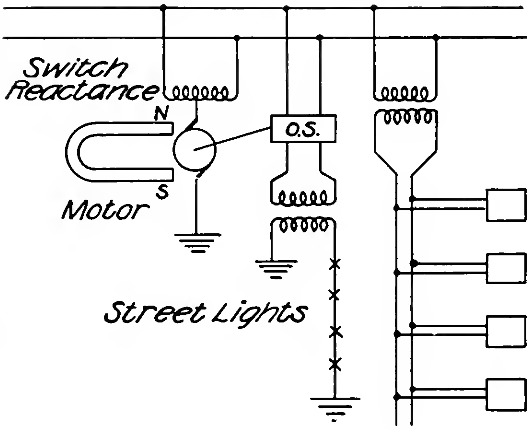

Fig. 3. Connections of Automatic Oil Switch

If a direct current is put on the alternating-current mains in such a direction that the mains are positive, when referred to ground, the street lights will be turned on. If the direct-current on the mains is made negative, the street lights will be turned off. This operation of the switch in opposite directions is produced by the reversal of the direct-current motor when its armature current is reversed.

The direct current is not left on continuously but is only applied to produce the switching operation. The switch is so arranged that after being operated in one direction by an application of direct current a subsequent application without reversed polarity will cause the motor in the switch to run idle, thus not affecting the position of the switch. However, as soon as the polarity of the direct current is changed, the switch operates in the opposite direction, and as soon as the limit

Fig. 4. Reactance Coil

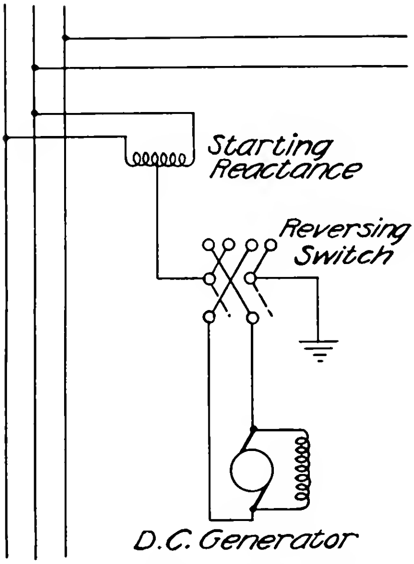

Fig. 5. Connections of Station Mechanism for Operating Oil Switch

of motion of the switch is reached the motor will again run idle until the direct current is removed.

The station apparatus is shown in Fig. 4. It is exceedingly simple, consisting of only a second reactance which allows direct current to be put on the alternating-current system without affecting the alternating-current potential between wires, and of a reversing switch for conveniently changing the polarity of the direct current. By closing the reversing switch for about two seconds the oil switch on the street lights is operated, even though miles away.

Any source of direct current can be used, provided it is allowable to momentarily ground either side of the circuit. If there is no direct current available, a small generator or rectifier can be installed and run from the alternating-current lines.

Any number of switches can be operated simultaneously. In case it is desired to operate switches independently a few parts can easily be added to the switch so that its mechanism will be inoperative the first time the direct current is put on the system with polarity such that it tends to operate the switch but will operate the second time the direct current is put on with the same polarity. If this special switch is used in conjunction with a standard switch, the standard switch will operate the first time the direct current is thrown on and the special switch the second time. Of course the switches will always operate in the same sequence. A control switch having this special feature can be made to operate the first time the direct current is thrown on by lifting its cover and closing a single-pole knife switch.

Briefly, the advantages of this system of controlling street lights are:

1. Sturdy construction of switch made possible, as motor has ample power to operate heavy parts.
2. Absolute reliability.
3. Negligible attention to switch while in service.
4. Street lights under the control of the station operator at all times.
5. All switches can be controlled simultaneously by the station operator.
6. If desired, different groups of switches can be operated in sequence.
7. No flicker in house lights while switch is being operated.
8. As there is no timing clock, it is no longer necessary to visit the switch at frequent intervals to reset it to conform with a constantly changing schedule.

THE ELECTRIFICATION OF THE RED ORE MINES OF THE TENNESSEE COAL, IRON & R. R. COMPANY

By Howard M. Gassman

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The properties described in this article form another example of the advantages and economy that result from electrification. The mines were originally operated by steam power; but, as stated by Mr. Gassman, who was until recently Chief Electrical Engineer for the Tennessee Coal, Iron & Railroad Co., electrification was undertaken to reduce the cost of mining the ore, to increase output, and to provide additional protection during the wet season. The change from steam to electric power was very much simplified by the advent of the Alabama Power Company into the district, this company furnishing the power for all operations.—Editor.

The state of Alabama is quite famous for its mineral resources, of which the large deposits of coal and red ore are of the greatest commercial importance on account of both their magnitude and location. The red ore is the Rockwood formation and probably is the same as the Clinton ore of New York State and Pennsylvania. This formation comprises approximately 200 feet of measures, principally of shale and sandstone. There are four beds of iron ore, two of which are of commercial importance. The main one now being worked in the district is known as the Big Seam, which, in some of the properties of the Tennessee Coal, Iron and Railway Company, averages as much as 22 ft. in thickness, of which the upper 12 feet only is being mined at the present time.

The extent of the red ore deposits in the Birmingham district is hardly appreciated by those not familiar with the district. The government report shows that in the Birmingham district alone there is available under present working conditions, 358,470,700 long tons of ore, and nearly one-half billion tons more that is not available under present conditions. Recent developments show that these figures are very conservative and that there is fully one billion tons of ore reserves in the Birmingham district. It is also estimated that at the rate the present ore is being mined in the Birmingham district, the Big Seam alone will furnish ore for one hundred years.

The ore is developed by slopes varying from 12 to 45 degrees. The development of these mines up until the last decade was rather slow and crude. However, Birmingham in the last ten years has developed very rapidly as an iron and steel center, due to a recognition of its favorable conditions.

The red ore operations of the Tennessee Coal, Iron and Railway Company are divided into three groups, known as Muscoda, Wenonah and Ishkooda, and located on Red Mountain which runs in a general direction northeast and southwest, passing through the city limits of Birmingham. Although the operations of the mines of this company appeared to be on a comparitively economical basis, it was recognized that further improvements could be made and would be warranted.

The electrification of a portion of these ore mines was begun for the following reasons:

1. To reduce the cost per ton of ore mined.
2. To increase the output.
3. To provide additional protection during the wet season.

GENERAL

The coming of the Alabama Power Company into this district made the electrification of these mines even more favorable because of the large power capacity available for use direct on large hoists, and because the expenditure for a large generating station and transmission lines was conserved.

In the Muscoda group there are five slopes. Number 4 slope was completely electrified by installing motors on the hoist, air compressors, crusher and shops. The underground equipment for all slopes was completely electrified, excepting the drilling.

In the Wenonah group there are five slopes, of which the underground equipment only has so far been electrified.

The power is furnished by the Alabama Power Company, from a substation 5 to 10 miles distant from the points of delivery, at 44000 volts, three-phase, 60 cycles, and stepped down to 2300 volts for local use.

MUSCODA

At Muscoda there is an eight panel switchboard with remote control hand-operated oil switches located in the basement immediately below the board. The switchboard is equipped with the necessary indicating and graphic instruments and integrating meters. Provision was made in the design of the board for further electrification of this group of mines.

Surface Equipment

Electric Hoist: In point of capacity, the electric hoist is the largest item in the equipment (Fig. 1). The hoist was originally a Nordberg twin Corliss, steam driven, first motion hoist, with cylinders 30 by 60 inches, and a single drum 12 feet in diameter. The connecting rods were disconnected and an 1800-h.p. induction motor installed on one side of the hoist; the motor driving the hoist through a herring bone gear having a reduction of 5.2 to 1 by means of a drag link connected to the crank pin on the drum shaft. The speed of the motor is 354 r.p.m. at full load, which gives a hoisting speed of 2570 feet per minute. The motor is of the wound rotor type, controlled by a liquid rheostat which is operated mechanically from the engineer's platform between the engine cylinders.

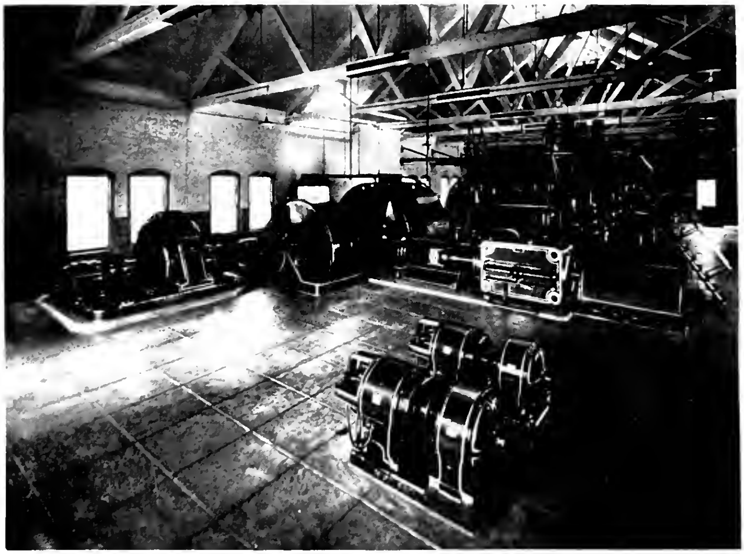

Fig. 1. View in Hoisting Engine House showing Steam Hoist Converted into Electric and Driven by 1800-h.p., 2200-volt, 3-phase, 60-cycle Induction Motor. In the foreground are the two induction motor driven exciters for the synchronous motors on the compressors shown in the far end of the room

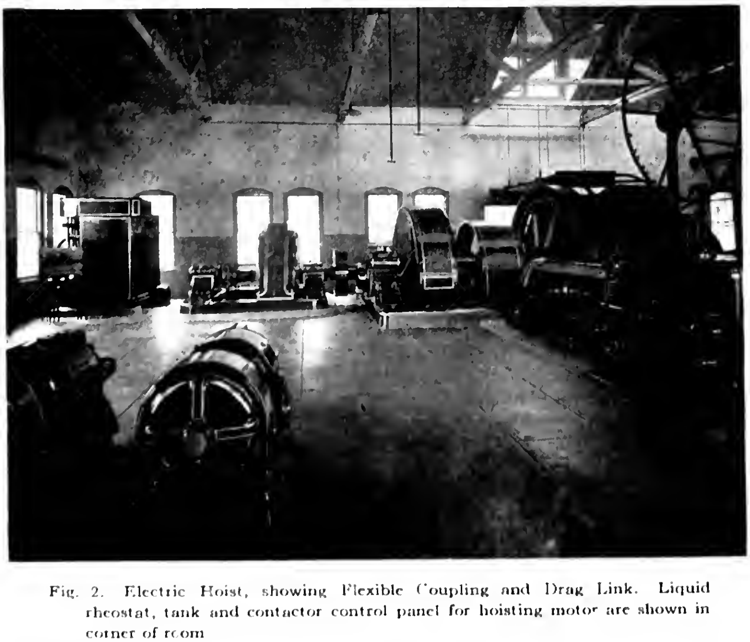

Fig. 2. Electric Hoist, showing Flexible Coupling and Drag Link. Liquid rheostat, tank and contactor control panel for hoisting motor are shown in corner of room

The rheostat (Fig. 2) has a range of resistance of 120 to 1, obtained by the use of two sets of electrodes. The motor operates very economically at full speed, as a contactor automatically short circuits the secondary motor leads at the rheostat as the motor approaches full speed. This control is provided with interlocks to prevent sudden reversal of the motor without first inserting all resistance. Furthermore, the rate of acceleration is fixed by the adjustment of the circulating pump on the rheostat and cannot be exceeded by the operator. The primary reversing control consists of a two panel marble switchboard, each panel having mounted upon it a three-pole 2300-volt air break electrically operated contactor. The contactors are provided with heavy arc deflectors and powerful magnetic blowouts. The board is in the basement in a fire proof location and is safeguarded against accidental contact. All the auxiliary control apparatus is actuated by alternating current.

The ore skip weighs 6 tons, and the ore hoisted per trip is 12 tons. Upon slowing down, the skip dumps automatically at the tipple. The maximum rate of hoisting is 150 tons per hour, and the average rate 100 tons per hour.

The cycle of hoisting is shown in the curve of Fig. 3. The lowering is done by means of friction brake. The hoisting cycle is approximately as follows:

Loading—30 seconds
Acceleration—15 seconds
Hoisting—106 seconds
Slow-down—8 seconds
Dumping—5 seconds
Lowering—115 seconds

The above cycle is an average, and varies with the heading from which ore is being hoisted. The maximum length of the slope at the present time is 3400 feet, and this slope will average 23 degrees incline.

Air Compressors: The two Nordberg twin two-stage, steam driven air compressors of 3700 cubic feet capacity each, with steam cylinders 24 by 48 inches, were each equipped with a 565-kv-a., 90-pole synchronous motor running at 80 r.p.m. The flywheel was removed and a motor with split stator and rotor was installed in place of the flywheel (Fig. 4). The motor frame is very narrow, making it unnecessary to widen the distance between the air cylinders. The rotors are provided with a squirrel cage winding for starting and for making the operation more stable under the operating conditions, which otherwise might result in hunting. These motors start very smoothly through the use of a compensator in connection with the usual starting and running oil switches incorporated in the main switchboard.

Two 50-kw. motor-generator exciters are shown in the foreground of Fig. 1. The motors are of the squirrel cage induction type, and are wound for 2200 volts. The generators are interpole machines, and deliver 125 volts for field excitation. One motor-generator set has sufficient capacity to excite the two synchronous motors.

The motor-driven air compressors operate in connection with the steam-driven air compressors of this group, feeding into the same air lines for supplying air for drilling in all the mines of this group. No provision has been made for regulating these motor driven air compressors, as the steam compressors now do the regulating. When all the compressors are electrically driven, provision will be made for some type of unloading device to avoid frequent starting and stopping under fluctuating demands for air.

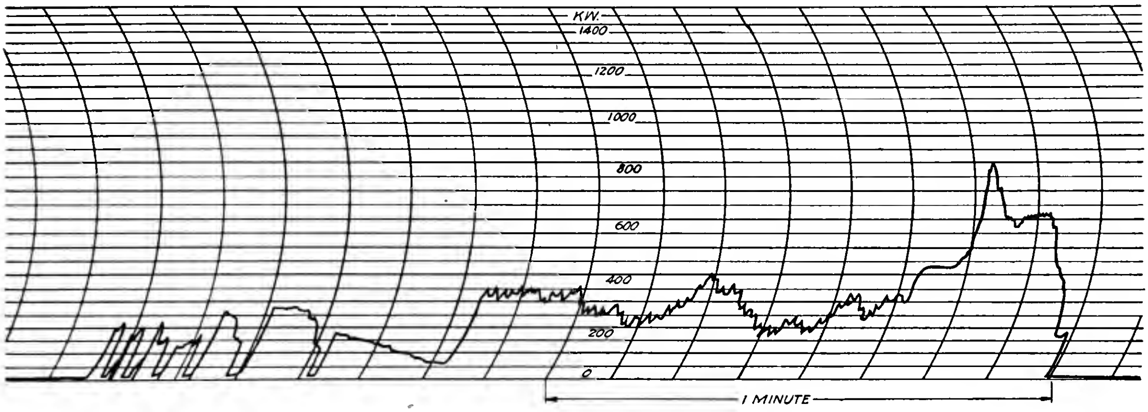

Fig. 3. Graphic Record of Typical Hoisting Operation

Crusher: The crusher located at the tipple is a Gates No. 8L, and is belt driven by a 125-h.p., 2200-volt, high-torque squirrel-cage induction motor of 570 r.p.m. The motor is provided with push button control and is operated from the crusher platform.

Shops: The shops of this group are the main manufacturing and repair plants of the ore and coal mines, and for this reason require a large variety of equipment but a relatively small amount of power. The power supplied to the shop is stepped down from 2300 volts to 220 volts by a group of pole-type transformers located near the shop. In the machine shop proper, the line shafts are driven by 25-h.p. and 10-h.p. motors of 865 r.p.m., the blacksmith shop by a 10-h.p., 860-r.p.m. motor, and the carpenter shop by a 25-h.p., 865-r.p.m. motor.

Miscellaneous: There are many small motors used elsewhere on the surface for driving small pumps and isolated machinery. The camps and buildings are amply lighted by 110-volt, 60-cycle supply circuits fed from a separate 2300-volt lighting circuit through 3 to 5-kv-a. transformers.

Fig. 4. Two Synchronous Motor-driven, Twin, Two-stage Air Compressors with Former Steam Ends Removed

Underground Equipment

Feeders: The power for the underground operation is carried down the mine through the manway by a three conductor, lead enclosed, wire armored cable. This cable is clipped to a messenger supported from the roof by expansion bolts and terminates at the five panel distributing switchboard in the main pump room. At this point the power is distributed to the pumps and to each of the mines of the group through the slopes and main passageways. At points where the cable changes size or branches, automatic oil switches are installed to localize trouble and minimize delay.

Pumping: The pumping conditions have been very much improved lately in this group of mines by the construction of a large sump slightly above the main station pump, to which water from all the slopes of the group is delivered. A bottom pump (Fig. 5) in each slope raises the water to such a head as to allow it to flow into the main sump. These bottom pumps are Aldrich 5 by 7 triplex plunger machines having a capacity of 100 gallons per minute at 500 ft. head. They are each driven by a 15-h. p. type HI squirrel-cage induction motor, through one gear reduction, and are started by means of a standard compensator with overload and no-voltage release protection.

The main station pump is a Prescott duplex, double acting unit, driven at 585 r.p.m., by a 300-h.p., 2200-volt, wound rotor type induction motor (Figs. 6 and 7). The plungers are 8 in. by 36 in. and the pump runs at 47 r.p.m. It has a capacity of 1500 gallons per minute, against a head of 665 ft. The discharge line is connected to the discharge line from the old steam driven, direct acting, triple expansion pump, so that in case of emergency the steam pump can be put into service.

The domestic water supply is handled by a motor-driven centrifugal pump, located within short distance of the main station pump. This pump has a capacity of 400 gallons per minute, against a 602 ft. head, and is driven at 1750 r.p.m. by a 100-h.p., 2200-volt, squirrel-cage induction motor (Fig. 8).

Fig. 5. Typical Bottom Pump Installation showing 5 by 7 Aldrich Triplex Pump Driven by Fully Enclosed 15-h.p. Squirrel-cage Induction Motor through Flexible Coupling

These two pumps are under the control of one operator, and handle all the underground water. The small bottom pumps referred to run intermittently and are under the control of men sinking the slope.

Sinking Hoists: The 2300-volt, three-phase power is carried to a point within 250 to 500 feet of the bottom of each slope, where three 20-kw., single-phase transformers step it down to 220 volts. This voltage was adopted as being reasonably safe for use on the sinking hoists and the bottom pumps. It is also used to furnish light in this portion of the mine. The sinking hoists are of the single drum, double gear reduction type driven by 30-h.p., wound rotor induction motors, with drum controller and grid resistance. These hoists are portable and are moved down as the sinking of the slope warrants (Fig. 9).

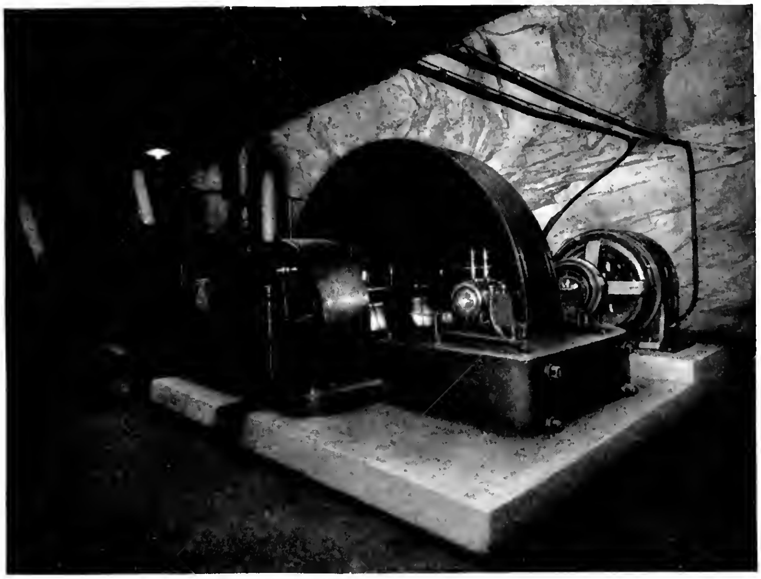

Fig. 6. Crank end of 1500-gallon Duplex Double-acting Prescott Station Pump showing enclosed Herring Bone Gear, Flexible Coupling and 300-h.p. Wound Rotor Induction Motor. Fossil Slope No. 8

WENONAH

The electrification of the five slopes of this group has been confined almost exclusively to the underground equipment. The conditions underground as regards the quantity of water and heads are so nearly the same as those in the Muscoda group that duplicate pumping equipment, sinking hoists, motors, transformers and switches were installed.

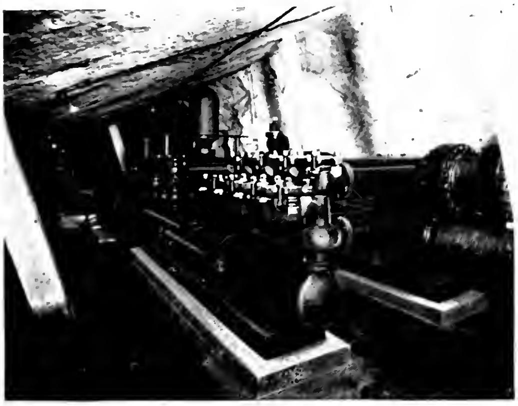

Fig. 7. Pump End of 1500-gallon Prescott Duplex Double-Acting Station Pump, Muscada Slope No. 4

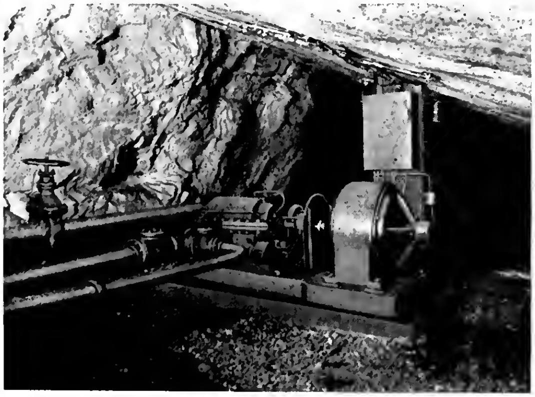

Fig. 8. 400-gallon 4-stage Centrifugal Pump, Driven by 100-h.p. Squirrel-cage Induction Motor for Furnishing Domestic Water Supply. Muscoda Slope No. 4

The surface electrification consists principally of two pumping stations for handling domestic and boiler water supply. The pumps are of the Aldrich triplex type, driven by 15-h.p. Type HI squirrel-cage induction motors, one being belted and the other geared. Light is also supplied to buildings and camps as at Muscoda.

A three panel switchboard is installed in the hoisting engine house at No. 8 slope and controls the incoming power, and the mine and surface feeders.

The mine feeder is carried through conduit from the hoisting house to the manway and is supported in the mine in the same manner as at Muscoda.

Fig. 9. Hoist, made by Connellsville Mfg. & Mine Supply Company, has 36-in. drum, double gear reduction, one reduction being obtained by back geared motor rated at 30 h.p. intermittent service, fully enclosed

In both of the above installations effort was made to reduce the number of sizes of motors, pumps, transformers and underground hoists to a minimum, so as to make the carrying of spare parts a very simple and inexpensive item. The conditions were particularly favorable for carrying this out.

On all of the geared motor drives, except the sinking hoists which are back geared, flexible couplings were placed between the motor and the pinion shaft, for the reason that such couplings permit of independent alinement of the herring bone gears, as well as more flexibility in mounting the motor and greater ease in replacing motors, particularly when underground.

Results: Previous to electrification, surface machinery was operated by means of steam, in most cases the steam lines being very long. Steam is also used in the main underground station pump in No. 4 mine, all other pumping underground being done by means of compressed air. The long steam and air lines, with their consequent losses and the low efficiency of pumping by air, made it possible to make a very large saving in power cost by superseding steam and air operation by electric power. The steam plant is shut down, but can be put into service should it be required. This alone gives additional protection against damage to the mine by water. The largest saving has been made in the pumping and least of all in the hoisting. The results have shown up so favorably in this initial installation that there is no doubt that the company will continue the application of electric power, especially as the cost of fuel is increasing.

All of the electric equipment, except the cable, was furnished by the General Electric Company, in accordance with the purchaser's specifications. These installations were completed in July, 1916, and have been in regular service since they were first put in operation.

Fig. 10. No. 4 Tipple, Red Ore Mines, Tennessee Coal, Iron and Railroad Company

THE OPPORTUNITY

By James J. Wood

Inventor of the "Wood" Systems and

Factory Manager, Fort Wayne Electric Works of General Electric Company

The following short address was read before the Electrotechnical Club, Fort Wayne. The author shows that opportunities for advancement are greater now than ever before and that success or failure is in the hands of the individual rather than being determined by his environment.—Editor.

There is an old adage—"Opportunity knocks but once at the door." If this is the case, it is every man's duty to be prepared and ready to take advantage of it. "Opportunity" is usually considered a chance, a favorable or advantageous circumstance, but in my opinion "Opportunity" consists of being prepared to a point, or degree, where you are able to take advantage of the improved conditions or environments by which you are surrounded, and can better your own condition thereby. This definition removes the element of chance or uncertainty and assumes that you are prepared to act with vigilance, tact and aggressiveness, which will carry your project to a successful issue. Therefore, other things being equal, they have the most opportunities who possess the most practical and useful knowledge.

The man who is really ambitious, and I hope you are all ambitious in the right way, is the man who is never satisfied. The truly ambitious man says—"No matter what I do, I shall simply try to do better. No matter how hard it may be, I will improve." To do this you must keep at it, work your very best just where you are. Don't waste time dreaming of what you might do if things were different. The only thing you can do is to develop yourself, and you can do that right where you are. Keep at your work. Don't shirk whatever you have undertaken. Don't think that idleness or shirking cheats an employer. It cheats the man who shirks. The man who is always watching the clock or whistle and thinks he is doing all he is being paid for, is not earning his pay, and he never advances very far.

To make a real success, you must have first of all—industry, stickto-itiveness and the faculty for hard work. That quality is greater than all others put together, and you can cultivate that quality in yourself. Map out what you are going to do each day, and do it. Never let yourself get into the habit of leaving a thing unfinished. It is hard—for some it is almost impossible—but if you will do this, you can make yourself a hard worker eventually. That is the first step to real success.

What I would most earnestly impress upon the young man of today is this: You must study your own character and find out your own weakness; you must make up your own mind what qualities are necessary to push you ahead and cultivate them, remembering that whatever you do has got to be done absolutely by the exercise of your own will power. If you deceive yourself, blaming others for your failure, you will never get ahead. You must be your own most severe judge, and remember that it is not sufficient to wish for success, or to admire the qualities that make success. You must develop those qualities and use them—bearing in mind that the favorable opportunities for the young man of today are greater than ever before in the history of the world, on account of the wonderful advance in the sciences, arts and application of electricity to the use of mankind, opening up vast possibilities and untried fields for research and improvement; thereby giving the young man of this twentieth century such opportunities for advancement as were never dreamed of before.

THE EFFECT OF X-RAYS ON THE LENGTH OF LIFE OF TRIBOLIUM CONFUSUM

By Wheeler P. Davey

Research Laboratory, General Electric Company

While various investigators have done considerable work upon the effect of X-rays on living organisms, practically all such work has been open to criticism in that the investigators have failed to record all the physical data necessary to enable their work to be correlated with the work of others. In addition, the work to date has been of a qualitative nature. It is believed that the following article is the first of its kind to give completely the physical data necessary to enable others to duplicate the results. By using an appropriate method of handling his data, the author is able to show quantitative results of considerable accuracy.—Editor.

Introduction

A great deal of work is reported in the literature on the effect of X-rays on various forms of animal life. A study of this literature shows that, interesting though the results may be, it is with few exceptions difficult to duplicate the experiments because the physical data relating to the dosage have been so incompletely given. Excluding work on human beings, the following work may be mentioned.

Hastings, Beckton and Wedd(1) found that the hatching of silkworm eggs was accelerated by X-rays (dose not given) and that the second generation was less fertile. Bordier(2) X-rayed six silkworms, giving them a dose of 7 to 8 H*, at some unknown penetration. He found an increased restlessness and smaller size. The cocoon was only half size, and the moth did not emerge. Hasebroeck(3) was able to kill caterpillers of Charaxes (dose not given), but those of Vanessa urticae, after being X-rayed an unknown amount, developed into butterflies which were unable to fly. Lopriori(4) found a destructive action on Vallisneria spiralis, Genista and Darlingtonia (dose not given).

Perthes (5) X-rayed the ova of Ascaris megalocephala, giving them a dose of 24 H at a voltage corresponding to 6.5 cm. spark gap. Cell-division was so much retarded that although the control specimens were in the 4-cell stage at the end of 36 hours, the rayed specimens were still in the 1-cell and 2-cell stage. Hastings(6) rayed eggs of the same species, using an unknown quantity of characteristic X-rays from copper. He found a retardation in growth. Runner (7)X-rayed the eggs of the cigarette beetle (Lasioderma serricorne) using a Coolidge tube and giving a dose of 150 milliampere-minutes at 65 kilovolts at a distance of 7.5 inches. He found that eggs less than 3 days old failed to hatch, and became shrunken in about 10 days. Eggs over 3 days old hatched but the larvae never reached the pupa stage. Larvae similarly rayed refused to eat, and although they lived a long time after raying, they never reached the pupa stage.

Gilmam and Baetjer(8) found that X-rays (amount not given) accelerated the development of eggs of Amblystoma for about 10 days, but produced monsters. They also rayed hen's eggs (dose not given) and found an accelerated development for 36 hours with the final production of monsters. Bordier and Galimard(9) gave incubating hen's eggs daily doses of X-rays of 15 H each (penetration not given) for 20 days. The eggs contained no embryos. In specimens which had been allowed to develop somewhat before raying, growth was arrested at the first dose. These results were confirmed by Gaskell(10), but he makes no record of the dose.

Lengfellner(11) X-rayed three pregnant guinea pigs, three days before term (dose not given). Two of the mothers were at once killed. Their young died in 10 minutes. The third mother had a miscarriage in 5 hours; the young were all dead. He also rayed one hind leg of an 8 days old puppy (dose not given). Seven and one-half months later, this leg was 8 cm. shorter than the other. Cohn(12) rayed the *heads* of pregnant rabbits (dose not given) enclosing the rest of the rabbit in a lead box. Pregnancy continued to full term. For 14 days after birth the young seemed normal, but afterward they became stunted so that after 7 weeks they

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* Holzknecht units are measured by means of the change in color produced by X-rays in a pastille of barium platino-cyanide. The reading of these pastilles varies considerably with the wave-length of X-rays used, so that X-ray measurements made by such pastilles are meaningless except when the voltage across the tube is given, or when the "penetration" of the rays is given in some other reliable way. A better method of measuring X-rays is given later in this article.

(1) Hastings, Beckton and Wedd, Arch. Middlesex Hosp. 11th Cancer Report, 1912.

(2) Bordier, Le Radium, II, p 410, 1905.

(3) Hasebroeck, Fortschr. a.d. Geb. der Roent. XI, p. 53.

(4) Lopriori, cit. Schaudin in Pfluegera Arch. 77, p. 31, 1899.

(5) Perthes, Deut. med. Woch. *30*, 1904.

(6) Hastings, Arch. Middlesex Hosp. 11th Cancer Report, 1912.

(7) Jour. of Agr. Research, June 12, 1916.

(8) Gilman and Baetjer, Am. Jour. Physiol. X, p. 222, 1904.

(9) Bordier and Galimard, Jour. d' Elect. Med. p. 491, 1905.

(10) Gaskell, Proc. Roy. Soc. B *83*, Feb. 28, 1911.

(11) Lengfellner, Munch. med. Woch. p 44, 1906.

(12) Cohn, Verh. d. deutch. Roent. Gesel. Bd 11, 0. 128.

were only one-third the size of the controls. Forsterling(13) found that if he rayed the heads of 40-hour old rabbits (dose not given) the whole animal was stunted, but if any other part of the animal were rayed, only that part was stunted. Krukenberg(14) found that if the pelvis of a young dog or goat is X-rayed (does not given) the growth of the hind legs is retarded. Raying the shoulders caused ataxia and nervousness, affected the eyesight and made the animal more irritable.

The work showing the possibility of a stimulating effect on eggs is confirmed in an interesting way by studies on single types of cells in animals. Menetrier and Mallet(15), and Rowntree(16) have shown by raying the ears and tails of rats that somewhere between zero dose and that dose necessary to produce dermatitis, there is a dose which stimulates the growth of epithelial tissue. Benjamin, Ruess, Sleuka and Schwartz(17), Aubertin and Beaujard(18) and Murphy and Norton(19) have shown that X-rays in the proper amount may increase the number of leukocytes.

All the above work may be summarized as follows: X-rays may act upon an organism (or on a single type of cell in that organism) in one of three ways: (1) to produce a stimulation; (2) to produce a destructive effect which takes place only after a certain latent interval; (3) to produce an instant destructive effect.

By analogy with the action of various drugs, one would expect that the rays could be made to act in any one of these three ways at will by merely varying the size of the dose. Not enough of the authors cited above have adequately recorded the dose to enable one to verify this analogy without further experimentation. It is the purpose of this article to record the results of experiments made toward this end.

About a year ago the writer was engaged in some preliminary work on the lethal effect of X-rays on tribolium confusum. These little beetles are ordinarily called "flour weevils" and are said by Chittenden (20) to be the most injurious enemy to prepared cereal foods. In two years from the time of their recognition as a distinct species, they had spread to nearly every state in the Union, and even as early as 1895 are said to have cost the millers of the United States over $100,000 in manufactured products alone. It was found possible to destroy the eggs of these beetles with X-rays, thus giving hope of a new technical use for X-rays, but the most interesting results from a scientific point of view were obtained from the beetles themselves.

It was found that these beetles could be killed with X-rays if a sufficiently large dose were given, but it was noticed that the beetles did not die for several days after they were rayed. Further experiments indicated that the length of this latent interval depended upon the amount of the X-ray dose, and there seemed to be some evidence that this relation was approximately logarithmic. It was therefore decided to repeat these experiments more carefully, first making sure that the effect was really due to X-rays and not some attendant circumstance, and then to investigate the relation between the latent-interval and the X-ray dosage. This required a large number of beetles and it was necessary to determine their life history and how best to propagate them. It was found that they grow and propagate best in oatmeal or whole-wheat flour, but they will live in corn meal, white flour or any of the prepared cereal products. Propagation takes place best at a temperature of 35–36 deg. C. and at high humidity. Temperatures of 45 deg. C. or over are fatal. The eggs are white and from 0.3 to 0.6 mm. in diameter. They are usually associated with pieces of grain. Larvae grow to a length of 5 or 6 mm. and shed their skins six times. Pupae are white. Young beetles are a light straw color which later darkens to a russet. The beetles are about 4 mm. long. They are especially adapted to such work as is reported here because they are small, harmless, easy to handle and count in large numbers; they propagate readily, cannot crawl out of glass breakers or small porcelain crucibles, and show little tendency to fly.

In the preliminary experiments mentioned above, the beetles were packed in small wooden pill boxes with some food. There were 25 beetles in each box. There was a possibility that death was not due to any action of X-rays on the beetles, but might have occured from any of the following causes,

1. Lack of air and food.
2. High temperature due to over crowding.
3. Injury due to over crowding.
4. NO_2 caused by the high voltage connections of the X-ray tube.
5. Ionized air.

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(13) Forsterling, Verh. d. deutsch. Roent. Gesel. Dd III, p. 126.

(14) Krukenberg, Verh. d. deutsch. Roent. Gesel. Bd V, p. 68.

(15) Menetrier and Mallet, Bull. de l'Ass. fran. pour l'etude du Cancer II, p. 150, 1907.

(16) Rowntree, Arch. Middlesex Hosp. Cancer Reports 1908–1909.

(17) Benjamin, Reuss, Sleuka, and Schwartz, Wien klin. Woch. *19*, p. 788, 1906.

(18) Aubertin and Beaujard, Arch. de Med. Exper. et d'Anat. Path. *2*, p. 273, 1908.

(19) Murphy and Norton, Science, Dec. 10, 1915.

(20) Chittenden, Bull. No. 4, New Series, Revised Ed. U.S. Dept. of Agr. p. 113, 1902.

6. Excessive humidity.
7. Effect of X-rays on the food in the boxes or even on the boxes alone.

The following seven experiments were therefore made.

EXPERIMENT I.

To Show that the Beetles were not Killed by Lack of Air and Food Rather than by X-rays

A. 10 beetles were sealed up in a glass tube with a rubber stopper, without food, in a space 0.05 cubic inch. They were all alive at the end of 76 hours.

B. 20 beetles were sealed up, without food, in a space 0.05 cubic inch. They were all alive at the end of 3 weeks, but some of them seemed to be stuck together by a film of moisture. At the end of 4 weeks, 8 were still alive.

C. 10 beetles were sealed up in a space 0.05 cubic inch together with a pinch of white flour. They were all alive at the end of 8 weeks. Evidently the flour had taken care of the body moisture noted in B.

Therefore, Tribolium Confusum are not easily killed by lack of air, provided they are kept dry and have food.

EXPERIMENT II.

To Show that the Beetles were not Killed by some Effect of Temperature, Rather than by X-rays

20 beetles were placed in a round-bottom test tube, ⅜ of an inch in diameter, well heat-insulated. Temperature was measured from time to time by means of a delicate thermocouple. The highest temperature reached was 27¼ deg. C.

Therefore, the beetles cannot by over-crowding in a heat-insulated space raise their temperature high enough to produce death.

EXPERIMENT III.

To Show that the Beetles were not Killed by Mechanical Injury Rather than by X-rays

A. 5 beetles were placed in a tapered test tube. Diameter of test tube was ⅜ inch. Length of taper was 1⅛ inch. A small hole in the bottom gave ventilation. The beetles were therefore crowded together, and repeatedly crawled over one another in their efforts to escape. All were alive at the end of 97 hours.

B. 5 beetles were shaken violently in a glass breaker 50 times a day. At the end of two days, 4 were still alive. At the end of a week, 3 were still alive.

C. In addition, it may be stated that beetles used as "controls" in the main body of this work do not seem to be at all affected by being dropped through a funnel several times daily during the process of counting.

Therefore, the beetles are not easily given fatal injuries.

EXPERIMENT IV.

To Show that the Beetles were not Killed by NO_2 Rather than by X-rays

A. 20 beetles were put in a test tube ⅜ inch in diameter with a little corn meal. The test tube was connected to a source of NO_2. All beetles were alive after having been in an atmosphere of NO_2 for 25 hours. At the end of 64 hours, 5 were alive.

B. 25 beetles were put in a vial and exposed to dilute NO_2 for 5 minutes. The concentration of NO_2 was such as to distinctly color starch-KI paper in 1½ minutes. 23 beetles were found alive after the 20th day. But there is not enough ozone and NO_2 together in the lead box where the beetles are X-rayed to color starch-KI paper during an exposure of 14,000 $\frac{MAM}{25^2}$ at 50 kv.

Therefore, there is not enough NO_2 produced while the beetles are being X-rayed to affect them.

EXPERIMENT V.

To Show that the Beetles were not Killed by Ionized Air Rather than by X-rays

25 beetles were carefully shielded from X-rays. Ionized air, together with what little ozone and NO_2 might be present was drawn past the beetles during an exposure of 19,600 $\frac{MAM}{25^2}$ at 50 kv. Even if only 10 per cent of the ions remained uncombined when they reached the beetles, still this would be equal to that caused directly by 1960 $\frac{MAM}{25^2}$ at 50 kv. This dose of X-rays, acting directly on the beetles, would have killed them all in less than 2 weeks if death were produced by ionized air rather than by X-rays directly. But at the end of 21 days, only 1 beetle was dead.

Therefore, the beetles are not killed by ionized air.

EXPERIMENT VI.

To Show that the Beetles were not Killed by too High Humidity Rather than by X-rays

A. 10 beetles were put, without food, in a flat bottomed test tube ⅜ inch in diameter, which was kept dry by a side tube filled with P_2O_5. All but one were alive after 6 days.

B. 60 beetles were gathered in such a way that each beetle was slightly moistened on the back. They were all put, without food, in a test tube 1 inch in diameter. As they crawled over each other, the moisture was spread over their whole bodies. In 6 hours most of the beetles were dead. Those alive were so weak that they could not turn over, even when lying on their sides. 60 other beetles put in a similar test tube with a cloth bottom lived. The cloth bottom could only have acted as a ventilator and an absorber of water.

C. Beetles are grown in an almost water-saturated atmosphere in the brooders and seem to thrive well.

Therefore, the beetles are not harmed by either extreme dryness or by high humidity, but may be killed by strangulation when water is condensed on them.

EXPERIMENT VII.

To Find Effect of X-rays on the Food of the Beetles

> A box similar to those used in the preliminary experiments was filled with corn meal and X-rayed 15,000 milliampere-minutes at 25 cm. distance at 50 kilovolts. 25 beetles were then put in this box with the corn-meal. They lived lives of normal length. But beetles rayed this amount die almost instantly.
>
> *Therefore*, X-raying the boxes and the food has no effect upon the length of life of the beetles.

In the light of the above experiments, it seems safe to conclude that the death of the beetles recorded below was due to X-rays, rather than to some accidental circumstance.

APPARATUS

X-rays were produced by a water-cooled Coolidge tube (tungsten target) operating directly from a high-tension 60 cycle transformer. Such tubes will rectify their own current up to 50–100 milliamperes, at 50 kilovolts (r.m.s.). Oscillograph tests showed that the transformer was of such a type that when operated under the above conditions the wave-form of the secondary (high voltage) resembled that of the primary (low voltage), and the inverse voltage did not exceed the direct voltage (i.e. operating voltage of the tube) by 5 per cent. Further tests with the oscillograph showed that the r.m.s. voltage of the secondary differed from that shown by a voltmeter coil by not more than 3 per cent. Tube voltage was therefore measured in terms of r.m.s. kilovolts, as shown by the meter.

The voltage impressed upon the primary was controlled by means of an auto-transformer of such size as to cause no appreciable change in wave-form. The wave-form used was very nearly sinusoidal.

The filament of the X-ray tube was heated by current from a small transformer. This was connected through a ballast transformer to the terminals of the circuit supplying the auto-transformer. Connections are shown in Fig. 1.

Tube current was measured with a direct-current milliammeter. Since this current was pulsating (half of every wave being suppressed by the rectifying action of the X-ray tube), oscillograph records were taken to compare the meter-reading with the instantaneous value of the current. It was found in all cases that the value of the mean current as shown on the meter was almost exactly half the value of the peak of the wave. The current through the tube was therefore read in mean milliamperes on the meter. The wave form of this current was similar in every way to that of other Coolidge tubes.

The X-ray tube was in a lead box whose walls were ¼ inch thick. This provided a safe protection from X-rays at the voltages used. The tube was connected to the transformer by ½ inch rods, to prevent corona.

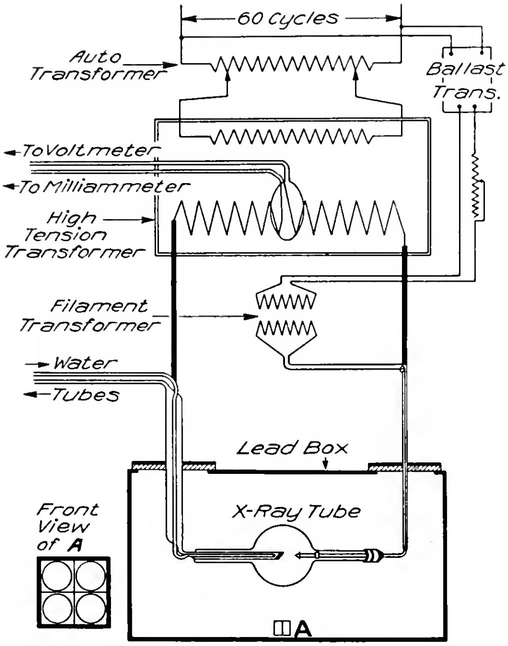

Fig. 1. Diagram of Connections of X-ray Outfit

Where these rods entered the lead box, the lead was replaced by lead glass 1 inch thick, which acted both as insulation and as X-ray protection.

A chamber of lead (see *A*, Fig. 1) 7 cm. square and 5 cm. long was placed in the wall of this lead box, directly opposite the focal spot of the X-ray tube. A sheet of aluminum 0.025 mm. thick was fastened across the end of the chamber nearest the X-ray tube. This protected the interior of the chamber from electrostatic effects, and prevented any NO_2, ozone, etc. from the interior of the lead box, and any radiant heat from the X-ray tube from entering the chamber. The lead sides of the chamber protected the interior from any secondary X-rays which might be produced on the walls of the lead box. The only rays which could enter the chamber were those sent out directly from the X-ray tube itself.

Into this chamber were placed, four at a time, the boxes of beetles to be rayed. These boxes were of wood, cylindrical in shape, 1⅛ inches in diameter and ⅝ of an inch high The wood was ⅛ of an inch thick. Each box contained 25 beetles and a little cornmeal, and was kept closed during the raying. The X-rays, therefore, after leaving the X-ray tube, passed through 0.025 mm. of *Al* and 3 mm. of wood before reaching the beetles and cornmeal. At the voltage employed in this work (50 k.v.r.m.s.), the error due to absorption of X-rays by the small thickness of *Al* and wood was very small.

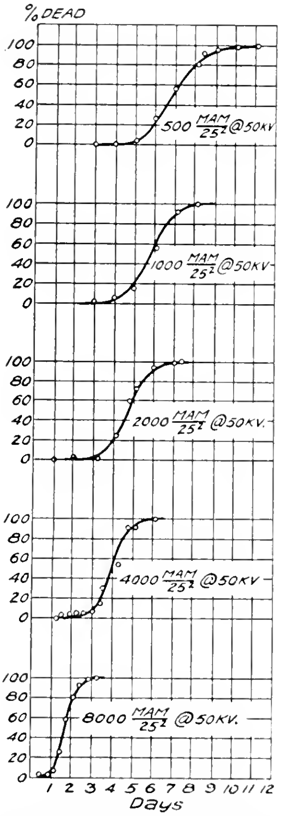

Fig. 2-A. Curves Showing Per Cent Beetles Dead at Different Intervals after Raying. Doses Vary from 500 to 8000 $\frac{MAM}{25^2}$ at 50 Kv.

Experimental

Two or three thousand beetles were gathered from the same brooder on the same day and put into a large granite-ware pail. The next morning they were packed with a little sterile cornmeal in the wooden boxes mentioned above, 25 in each box. In this way the distribution of age, susceptibility to X-rays, etc., was as nearly uniform as possible. From this time on the tightly closed boxes were kept in incubators at 35–36 deg. C. and at saturated humidity, except while being X-rayed or while being counted. Every box was opened daily, the beetles separated from the cornmeal and a record made of the number of live and dead beetles. The assistants who did this counting had no way of knowing the dose of X-rays which had been given.

After all the beetles in a given group of boxes were dead, the data sheets were collected and the data combined as shown in Table I. From 4 to 8 control boxes were used with each experiment to make sure that the beetles were in every way normal. The normal death rate at the end of the first 15 days was never more than 4 per cent. Beetles rayed 500 $\frac{MAM}{25^2}$ at 50 kv. were practically all dead in 15 days. Beetles rayed larger doses were all dead in less than 15 days. Therefore no correction for normal death rate of the X-rayed beetles was considered necessary.

It was found that, while all the beetles in a given box did not die at the same moment, there was a very narrow range of time during which most of them died, thus suggesting that we were dealing with a quantitative effect which could be studied to some good. For example, the results given more in detail

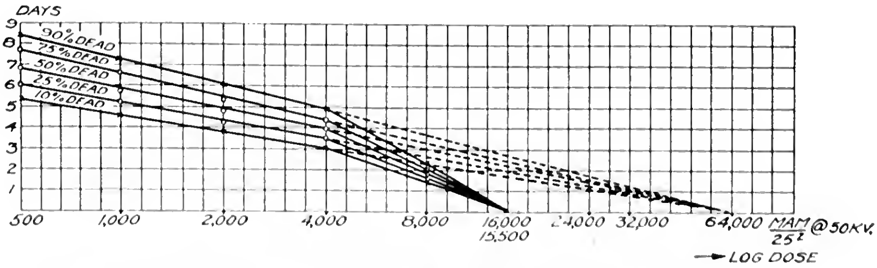

Fig. 2-B. Curves Showing Length of Life, after Raying, of 10, 25, 50, 75 and 90 Per Cent of Beetles. "Days Life" is Plotted against the X-Ray Dose.

in Tables I and II and in Fig. 2-A, show that if the dose was 15,000 $\frac{MAM}{25^2}$ at 50 kv., all the beetles were dead at the end of the raying; if the dose was 2000 $\frac{MAM}{25^2}$ at 50 kv. practically all the beetles died between the 3rd and the 6th days after raying, while half of them died between the 4th and 5th days; if the dose was 500 $\frac{MAM}{25^2}$ at 50 kv., death took place between the 4th and the 9th days, while half of them died between the 6th and 8th days. Doses less than 500 $\frac{MAM}{25^2}$ at 50 kv. were not fatal to all the beetles.

Now if the percentage of dead beetles is plotted against the time which has elapsed since they were X-rayed, it is evident that the points follow a smooth curve, which is the integral of a probability curve. If now the slope of this curve is plotted against its abscissae, a probability curve may be obtained. If the beetles represented by two such curves have been gathered from the same brooder at the same time, the corresponding points on the two curves may be compared, for they represent beetles of corresponding resistance to the action of the X-rays. It will be noticed that the curve approaches the zero and the 100 per cent lines asymptotically. This is in agreement with the well-known fact in toxicology that some individuals are especially susceptible to a given harmful agent, so that a very small dose causes death, while other individuals are especially resistant to the same agent so that they continue to live for a comparatively long time, even when given large doses. The steepness of the curves as plotted in Fig. 2-A is a measure of the idiosyncrasy.

This gives a method of handling the data which not only eliminated errors due to idiosyncrasy, but which even gives a measure of idiosyncrasy which is accurate enough between the limits of " 25 per cent dead" and "75 per cent dead." Fig. 2-A shows a series of results obtained in this way in which even the 10 per cent and 90 per cent points could be used. Before discussing Fig. 2-B, it will be necessary to explain the methods of recording X-ray dosage.

In order to define the quantity of X-rays and the bundle of wave-lengths used in a given experiment, it is necessary to record explicitly,

1. The material used as a target in the X-ray tube.
2. The thickness and kind of filters (if any).
3. The form of the voltage wave.
4. The form of the current wave.

TABLE I

BEETLES RAYED 500 $\frac{\text{MAM}}{25^2}$ @50 KV_{RMS}

Box Days	0	1	2	3.2	4.2	4.8	5.2	6	7	7.2
36	0	0	1	1	5	14	17	22	24	25
37	0	0	0	0	6	15	19	24	25	25
38	0	0	0	0	5	16	18	24	25	25
39	0	0	1	1	9	15	18	24	25	25
Total dead	0	0	2	2	25	60	72	94	99	100
Per cent dead	0	0	2	2	25	60	72	94	99	100

TABLE II

BEETLES RAYED 500 $\frac{\text{MAM}}{25^2}$ @ 50 KV_{RMS}

Box Day	0	1	2	3	4	5	6	7	8	8.3	9	10	11
23	0	0	1	1	1	2	11	18	24	24	24	25	25
24	0	0	0	0	0	1	5	9	17	20	23	24	25
25	0	0	0	0	1	3	6	19	22	24	25	25	25
26	0	0	1	1	1	1	6	11	20	23	25	25	25
Total Dead	0	0	2	2	3	7	28	57	83	91	97	99	100
Per cent dead	0	0	2	2	3	7	28	57	83	91	97	99	100

The following must be recorded either explicitly or implicitly,

5. Voltage across the X-ray tube.
6. Current through the tube.
7. The length of time the X-rays were employed.
8. The distance from the focal spot of the X-ray tube to the point to be rayed.

If 1, 2, 3, 4 are kept constant throughout the experiment, they may be stated once for all (as was done in this report under the head of "apparatus"), and the dose of X-rays may then be defined by either of two methods:

a. The voltage may be expressed directly, or an approximation may be given in terms of the readings of a Benoist penetrometer or in terms of the Christen "half value layer." The other factors may be given in terms of the reading of a Kienböck strip or a Holzknecht pastille, etc., or better,

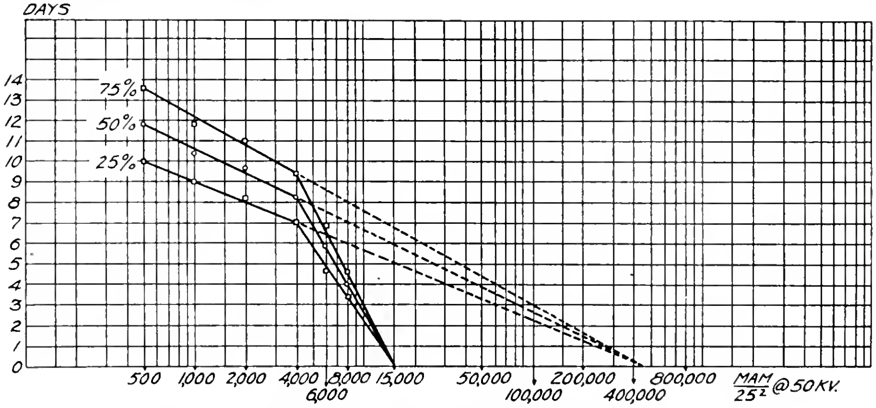

Fig. 3. Curves Similar to those of Fig. 2-B. "Days Life" is Plotted against the Logarithm of the X-Ray Dose

b. The voltage and distance are given directly and the product of the current and time is given, thus, "100 milliampere-minutes at 25 cm. distance at 50 kilovolts." This is usually contracted to read

$$100\ \frac{MAM}{25^2} \text{ at 50 kv.}$$

It will be noticed that the distance is expressed in terms of its square. This is because the intensity of X-rays varies inversely as the square of the distance. Too much stress cannot be laid upon the necessity for recording the voltage, and for keeping the voltage reading constant; for not only does the penetrating power of the X-rays depend upon the voltage, but even the quantity of rays given off by the tube per milliampere depends very largely upon the voltage.

In Fig. 2-B, *days life* is plotted against the *logarithm* of the X-ray dose. The 10, 25, 50, 75 and 90 per cent points of the curves for 500, 1000, 2000 and 4000 kv. lie on a family of straight lines. $Y = A - B \log X$, where X is the X-ray dose and Y is the number of days life after raying. All these lines meet the zero line at the point 64,000. The points for 8,000 and 15,500 $\frac{MAM}{25^2}$ at 58 kv. do not lie on these lines, but when taken along with the points for 4000 $\frac{MAM}{25^2}$ at 50 kv., they are found to form a new family of curves of the same type as the first, but with a steeper slope. The interpretation of this is given later. It should be noted here, however, that beetles rayed more than 4000 $\frac{MAM}{25^2}$ at 50 kv. were unable to move their legs and antennae easily, but that this effect was not noticed in beetles rayed less than this amount. For this reason it was difficult at the higher dosages to obtain data as accurate as that obtained at the lower dosages.

Curves like Fig. 2 have been obtained time after time, the only difference being in the height of the ordinates and the slope of the family of curves. Fig. 3 shows a typical curve of this sort. It will be noticed that in spite of the difference in the ordinates, the sharp break in the curve occurs at the same dosage.

At 50 kilovolts the lowest dose of X-rays which is fatal to all the beetles is 500 $\frac{MAM.}{25^2}$ In order to explore the field below this dose, 1100 beetles were gathered from the same brooder at the same time and packed into boxes of 25 each with sterile cornmeal, and these boxes were divided into 7 groups of 8 boxes each, and one group of 4 boxes.

One group of 8 was kept as a control. The others were rayed 100, 200, 250, 300 $\frac{MAM}{25^2}$ at 50 kv. respectively. The group of 4 was rayed 500 $\frac{MAM}{25^2}$ at 50 kv. The results are plotted in Fig. 4, curves A, B, C, D, E, F, G.

It will be noticed that there is no essential difference between curves A and B. Except for a small hump between 0 and 10 days, there is no essential difference between curves A and C. This is brought out in curve G, which is the same as curve C, except that the calculations are based on the supposition that there were no beetles dead on the tenth day. This similarity is still more marked between curves B and G. Except for a similar hump between 0 and 12 days, curve D resembles curves A and B. The hump is, however, much higher than in C. In curve E the hump is still of the same shape as in curves C and D (it is the integral of a probability curve) and covers a period of 12 days, but is considerably higher. In curve F the "hump" is the whole curve, except for a very flat portion which represents a *single* very resistant beetle.

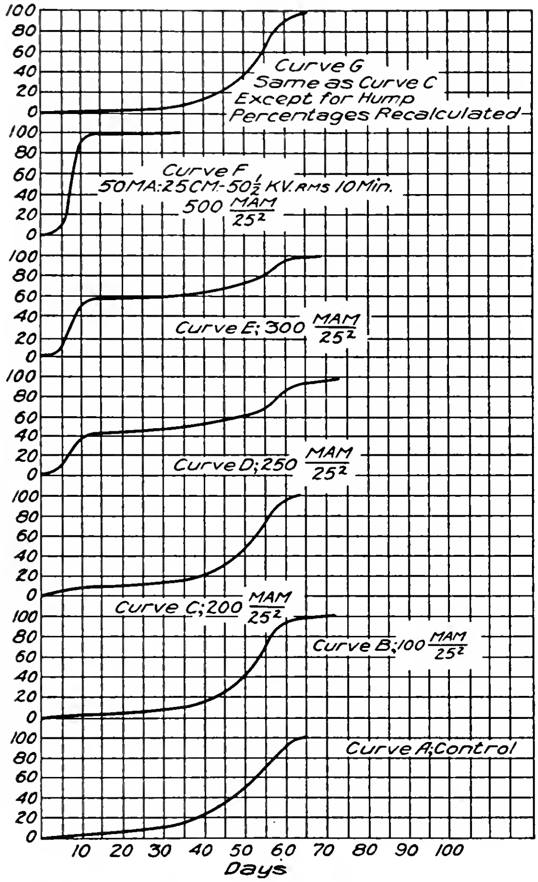

Fig. 4. Curves showing per cent beetles dead at different intervals after raying. Doses vary from 0 to 500 $\frac{MAM}{25^2}$ at 50 kv.

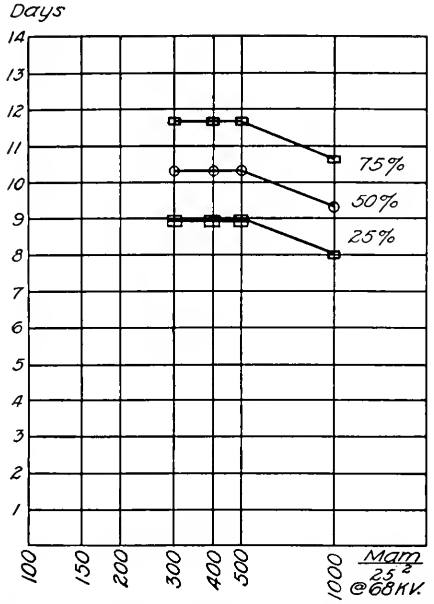

Fig. 5. Curves giving fragmentary data of "Days life" plotted against the logarithm of the X-ray dose at 68 kv.

These curves have been duplicated several times, and although beetles gathered from different brooders at different times give curves of slightly different shape, still all the curves agree very closely with the typical ones shown in Fig. 4, especially with regard to the "hump."

This would make it seem that at 50 kilovolts, 200 $\frac{MAM}{25^2}$ is the minimum lethal dose of X-rays for the least resistant beetles, and that 500 $\frac{MAM}{25^2}$ is the minimum lethal dose for the most resistant beetles. The fact that the "hump" is always of the same form suggests that these beetles which would live 9 days with a dose of 200 $\frac{MAM}{25^2}$ at 50 kv. would live a shorter time if rayed 250 $\frac{MAM}{25^2}$ at 50 kv. and that some more slightly resistant beetles which would be unaffected by a dose of 200 are killed off at the end of 9 days by a dose of 250. But when a dose of 500 $\frac{MAM}{25^2}$ at 50 kv. is reached, the most resistant beetles are also affected by the rays, so that the whole graph then approximates the probability integral.

Due to a breakdown of the transformer, the data to date at any other voltage than 50 kv. is fragmentary. Fig 5 shows the data obtained at 68 KV_{RMS} just before the transformer broke down. The beetles were gathered at the same time as those of Fig. 3 and the raying was done within 3 days of that of Fig. 3. The two graphs may therefore be compared for what they are worth. It is hoped later to determine more accurately the effect of voltage.

THEORETICAL

It has been shown above that if the dosage of X-rays is sufficiently large, the experimental relation between length of life (Y) and X-ray dosage (X) is of the form

$$Y = A - B \log X$$

This formula may be easily derived from an extension of the Psycho-physic Law, which states that a change in response to an external stimulus is directly proportional to the change in the stimulus, but inversely proportional to the amount of the stimulus. Thus the flicker-sensation caused by suddenly dimming a light is directly proportional to the amount of dimming, but inversely proportional to the total intensity of the light. Now let us suppose that the same principle applies to the action of X-rays on living cells.

Let Y = the number of days a beetle will live after being X-rayed.

Let X = the amount of the X-ray dose.

Then dY is directly proportional to dX and inversely proportional to X. Moreover, an increase in X produces a decrease in Y.

Therefore,

$$dY = -B\frac{dX}{X}$$

Integrating, $Y = A - B\ (\log X)$ which is the same as the equation of the experimental graph.

The constant of integration A has at present only a theoretical meaning, for it represents the number of days a beetle would live if it were X-rayed only 1 $\frac{MAM}{25^2}$ at 50 kv. and if no process of repair went on inside the beetle, and if there were no other cause of death present.

It will be noticed that this formula takes no account of any cause of death other than X-rays, nor of any process of repair which may go on inside the beetle. It therefore applies only when the X-ray dose has been large enough to completely destroy the protective mechanism of the beetle, and when the damage caused by the X-rays is large enough so that all other causes of death may be neglected.

It should be noted that length of life after raying is a measure of the *resistance* of an organism to X-rays, not of its *susceptibility*. If X-rays are able to kill the organism in two different ways, as by attacking two different kinds of cells, or two different organs, then the experimental graph should be the resultant of two straight lines, but in such a case it must be remembered that *susceptibilities* not *resistances* are to be added.

The graphs shown above seem to indicate that Tribolium Confusum are affected in two ways by the X-rays; the threshold dose being, for the first way, 500 $\frac{MAM}{25^2}$ at 50 kv. and for the second way about 4000 $\frac{MAM}{25^2}$ at 50 kv. These graphs would also seem to indicate that the cause of death for dosages between 500 and 4000 is negligible in the presence of that for dosages above 4000 $\frac{MAM}{25^2}$ at 50 kv.

Summary

I. It has been shown that the lethal effect noticed on tribolium confusum beetles after X-raying is really due to X-rays and not to some accidental circumstance.

II. A method has been developed which eliminates the error due to idiosyncrasy, thus making it possible to obtain bio-physical data of a considerable degree of precision.

III. It has been shown that the lethal effect of X-rays on tribolium confusum bears a definite mathematical relation to the logarithm of the total X-ray dose.

IV. An extension of the Psycho-physic Law gives a theoretical explanation of the experimental data, if the *resistance* rather than the *susceptibility* of the organism to the X-rays is considered.

The effects produced by changes in voltage, and by dividing the dose of X-rays into small parts, will be taken up in a later article.

A full bibliography of work done up to 1912 may be found in Fortschr. a.d. Gebiete der Roent. XIX, p. 123, 1912, in an article by Walter.

A complete bibliography of all X-ray work since 1912 has been published by Gocht.

GENERAL ELECTRIC REVIEW

A MONTHLY MAGAZINE FOR ENGINEERS

Manager, M. P. RICE
Editor, JOHN R. HEWETT
Associate Editor, B. M. EOFF
Assistant Editor, E. C. SANDERS

Subscription Rates: United States and Mexico, $2.00 per year; Canada, $2.25 per year; Foreign, $2.50 per year; payable in advance. Remit by post-office or express money orders, bank checks or drafts, made payable to the *General Electric Review*, Schenectady, N. Y.

Entered as second-class matter, March 26, 1912, at the post-office at Schenectady, N. Y., under the Act of March, 1879.

VOL. XX., No. 3

MARCH, 1917

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(For description of the hydroelectric development at this point, see page 226)

GENERAL ELECTRIC REVIEW

THE ENGINEER AND HIS PART IN NATIONAL PREPAREDNESS

In our issue of December, 1916, we printed an address by E. W. Rice, Jr., in which he emphasized the obligation resting on the engineer, as a citizen, to give thoughtful consideration to our national problems and to exert his influence for our national welfare.

Of certain of these problems the engineer is peculiarly qualified, by training and experience, to recognize the importance and difficulty. This is especially true of problems in connection with our national defense. War today is largely engineering. The time has long past when a merchant ship could in a few days be converted into an effective ship-of-the-line, and when a supply of flint-lock muskets and a few small cannon constituted an adequate equipment for an army. The battle ship or cruiser of today is a monstrous power plant, the construction and equipment of which entails years of labor and the highly specialized skill of many branches of engineering—marine, mechanical, metallurgical, steam, electrical, chemical, and radio. The engineer knows this, and he knows that the proper maintenance of such a huge and complicated machine requires multifarious auxiliaries, including adequate naval yards with dry docks and repair shops on land, and colliers, oil ships, supply ships and tenders of many kinds at sea. He further realizes how completely the effective operation of such ships with their complex mechanisms depends on a skilled personel, working with the high efficiency which comes only from long training in disciplined, intelligent co-operation.

In short, if deficiencies exist in our naval defenses, no one can perceive more clearly than the engineer the importance of a prompt beginning to supply them. It is therefore peculiarly incumbent on engineers to inform themselves in regard to our national defenses, their strength and their weakness, and to reach an intelligent decision on the steps, if any, which should be taken better to prepare our country to meet the dangers that threaten.

The navy is our first line of defense. Any hostile first class power that had gained control of the sea could, in a few weeks, according to our military experts, land on our shores an army many times the size of ours; but until our navy is destroyed invasion by any trans-oceanic power is impossible.

The navy, even more than the modern army, is dependent on engineering. We are therefore glad of the opportunity of presenting to engineers the thoughtful article by Prof. Cathcart, which appears in this issue of the Review, on our navy and its needs.

We believe that this presentation of the state of our naval preparedness is timely. The war clouds that have long been threatening have now drawn very near, and before these words reach our readers war may actually be upon us. Then, in one sense, it may seem too late to discuss deficiencies which would take many years to supply; it will be necessary to make the best of what we have. But, in another sense, now is the time of all others for taking stock. War, if it comes, will doubtless thrust into prominence weaknesses which the mass of the people have hitherto ignored. Then will ensue the indiscriminate criticism, usual in such cases, of those in authority, and the desire to find a scape-goat for the popular indignation.

Now, in anticipation of such developments, a study of Prof. Cathcart's dispassionate presentation of facts is very salutary. He points to faults of omission which have extended over years, and which have long been plain to any who cared to see. It is because the people have not cared to see that those faults have been suffered to exist uncorrected. If weaknesses there are, it is we, the people, who are to blame. Congress, in general, tries to give the people what they want. If the people make it clear that they are more keenly interested in a dry dock imperatively needed by our navy than in a dozen unnecessary post-offices, we shall get the dry dock. Therefore, if it is reserved for war to reveal our deficiencies so glaringly that we can no more overlook them, the remedy lies, not in captious criticism, but in the high resolve on the part of each citizen that henceforth and forever he will look beyond private and sectional interests to the nation's welfare, will study and try to understand the nation's needs, and will strive, by word and deed, and, if need be, at personal inconvenience, to insure the satisfaction of those needs and to safeguard the national welfare.

On no other class is such a resolution more obligatory than upon engineers, "for the reason"—to quote Rear Admiral Fiske—"that the engineers of any country have so much power to exert for the safeguarding of their country, and because men are always responsible for the power committed to their keeping."

STRUCTURE OF THE ATOM

PART I

By Dr. Saul Dushman

Research Laboratory, General Electric Company

In the following paper, which will consist of two parts, the writer discusses the theories of the structure of the atom in the light of the most recent discoveries in physics. Part I deals with the experimental observations on which these theories are based.—Editor.

Introduction

The progress achieved during the past twenty years in the study of the structure of matter has made this period one of the most wonderful epochs in the history of science. There was a time, not so long ago either, when in a number of universities it was considered "unscientific" to speak of atoms and molecules, much less to believe in their existence. The doctrine of "energetics," with its blind worship of the two fundamental laws of thermodynamics, was taught as the only logical and true viewpoint from which to regard chemical and physical phenomena. However, just about the time when these ideas seemed to have achieved the widest popularity and it appeared as if atomic and molecular theories were doomed to complete oblivion, there were discovered a number of new phenomena which could be interpreted only in terms of these theories.

Evidence for Atomic and Molecular Theories

First came the investigations of J. J. Thomson on the conduction of electricity in gases. Continuing the experiments of Crookes on cathode rays, he showed that these rays consist of negatively charged corpuscles whose mass is less than one thousandth that of a hydrogen atom. Then Rutherford and Soddy took up the study of radioactive elements which had been recently discovered by Bequerel and the Curies. These investigations led them to the conclusion that the atoms of some elements are not at all stable, but disintegrate spontaneously and form atoms of other elements. During this disintegration the atoms emit not only small negatively charged corpuscles or electrons (beta particles) such as constitute the cathode rays, but also positively charged particles (alpha particles) of the same mass as helium atoms, and a radiation (designated as γ-rays) whose nature was unknown until a couple of years ago when they were shown to be extremely short waved X-rays.

C. T. R. Wilson has actually been able recently to photograph the paths of these alpha and beta particles through gases, and the spinthariscope of Crookes enables us to observe the effects produced on a fluorescent screen by the bombardment of the alpha particles from a small mass of radioactive matter.

While these observations alone would be sufficiently convincing evidence for the atomic theory of the constitution of matter, we have a mass of even more direct evidence on this point. The kinetic theory of gases, in spite of its splendid correlation of a large number of facts, was comparatively speaking neglected by the majority of physicists, until it received such signal confirmation in the observations on Brownian movements. The particles in a suspension of gum arabic or other colloidal solution are occasionally big enough to be actually visible in a powerful microscope; the smaller particles can be made visible by means of the ultra-microscope. But, whatever their size, they all obey the same laws as the hypothetical molecules of a gas. It is surely no great stretch of the imagination to realize that we can have particles so small as to be invisible by even the ultramiscrope and yet possessing the same average kinetic energy and general motions as those larger colloidal particles which we can study individually under high magnifying powers.*

The investigations of Perrin, Svedberg and Millikan have furthermore led to methods by which we can actually count the number of molecules in a cubic centimeter of a gas under standard conditions. As a matter of fact, there are no less than a dozen totally different methods of arriving at this number; some of them are based on the study of radioactive phenomena, others on the study of Brownian movements, and some, on the determination of the value of the unit electric charge, while

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*A more complete account of these phenomena and of the investigations mentioned in the next paragraph will be found in the writer's paper on "The Kinetic Theory of Gases," General Electric Review, Vol. XVIII (1915).

one is based on the accurate determination of the laws of distribution of energy in the radiation from a black body. Yet, and here is the significant coincidence, all these methods lead to the same result.

But even if these facts were not enough, we have an equally striking proof in the results obtained by W. H. Bragg and W. L. Bragg in their study of the structure of crystals. When X-rays are reflected from the cleavage surface of a crystal they form interference patterns whose intensity reaches a maximum when the angle at which the beams strike the surface bears a definite relation to the wave-length of the rays and the distance between successive layers of atoms which are situated parallel to the reflecting surface. Hence, it is possible by using rays of known wave-length to determine the positions of the individual atoms in the crystal structure, and the Braggs have been able in this manner to determine the structure of a large number of crystals of different metals and chemical compounds.

Another series of investigations in which the application of the concepts of atoms and molecules has been found to be of great assistance is concerned with the study of chemical reactions in gases at low pressures, as carried on by Dr. I. Langmuir. By the application of the kinetic theory of gases it is possible to calaculate for instance, the number of oxygen molecules which strike the surface of a tungsten filament. What fraction of these molecules react with the tungsten? How does the magnitude of this fraction vary with the temperature; how is it affected by the presence of other gases in slight amounts? Not only is it possible, as Langmuir has shown, to answer these questions definitely, but also from the results obtained it is possible to show that the tungsten atoms at the surface can become covered with a layer of gas one atom or one molecule in thickness which inhibits the reaction between tungsten and another gas with which it would normally react. We thus obtain a much clearer insight into the actual mechanism by which surfaces may be "poisoned," as regards certain reaction, and, on the other hand, made to act as catalysts for other reactions.

Very recently, Dr. Langmuir has also been making a study of surface tension phenomena and he has been able to deduce from these measurements a number of interesting conclusions as to the shapes and mode of arrangement of the molecules in the surface layer of liquids.

The atom of the chemist must therefore be considered as a reality. The evidence in favor of the existence of atoms and molecules may in fact be regarded as being almost as conclusive as can be desired.

But now there must arise the further question: What is there about the inner structure of atoms and molecules which makes them possess these properties by which we have learnt to differentiate and detect them? What is it that causes an atom of sodium and an atom of chlorine to unite so readily, while an atom of argon will remain perfectly inert towards all other atoms? Why is a solution of sodium chloride a good electrical conductor, while liquid methane is almost an absolute non-conductor? These questions might, of course, be increased ad infinitum, and we are far from being able to say that all the possible questions regarding atomic structure can be answered at present. Nevertheless some sort of beginning has been made during the past few years towards answering these questions at least partly, and in the following paragraphs we shall attempt to describe some of the answers which have been suggested as a solution of this most important problem of atomic structure.

And firstly, it is probably well that we should consider briefly some of the fact which must be considered as having an important bearing on the problem under consideration and then we shall be able to test the value of any suggested theory by the success attained in applying it to these observations.

The Periodic Law

During the last decade of the seventeenth century, an Englishman, Robert Boyle, defined as the chief problem of the "chymists," the discovery of the different elements of which substances are compounded. "I mean by elements," "he wrote," certain primitive and simple, or perfectly unmingled bodies; which not being made of other bodies, or of one another, are the ingredients of which all those called perfectly mixed bodies are immediately compounded, and into which they are ultimately resolved." At the time, these words were written, it was still considered proper to believe in the existence of only four foundamental principles or elements (air, water, earth and fire) as taught by the followers of Aristolle. Guided by the principles so clearly laid down by Boyle, the chemists have succeeded in isolating one element after another, and at the present time we know of some ninety odd elements which are the "ingredients of all perfectly mixt (compound) bodies."

MENDELEJEFF'S PERIODIC SYSTEM OF THE ELEMENTS

Containing Atomic Weights, Atomic Numbers and Isotopic Radioactive Elements

Group 0	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6	Group 7	Group 8
- - - -	E_2O - -	EO - -	E_2O_3 - -	EO_2 EH_4	E_2O_5 EH_3	EO_3 EH_2	E_2O_7 EH	EO_4
He **3.99** *(2)*	H **1.008** *(1)* Li **6.94** *(3)*	Be* **9.1** *(4)*	B **11.00** *(5)*	C **12.00** *(6)*	N **14.01** *(7)*	O **16.00** *(8)*	F **19.0** *(9)*	
Ne_I **20.2** Ne_{II} **22** *(10)* Ar **39.88** *(18)*	Na **23.00** *(11)* K **39.10** *(19)*	Mg **24.32** *(12)* Ca **40.07** *(20)*	Al **27.1** *(13)* Sc **44.1** *(21)*	Si **28.3** *(14)* Ti **48.1** *(22)*	P **31.04** *(15)* V **51.0** *(23)*	S **32.07** *(16)* Cr **52.0** *(24)*	Cl **35.46** *(17)* Mn **54.93** *(25)*	Fe **55.84** *(26)* Co **58.97** *(27)* Ni **58.68** *(28)*
Kr **82.92** *(36)*	Cu **63.57** *(29)* Rb **85.45** *(37)*	Zn **65.37** *(30)* Sr **87.63** *(38)*	Ga **69.9** *(31)* Yt **89.0** *(39)*	Ge **72.5** *(32)* Zr **90.6** *(40)*	As **74.96** *(33)* Cb† **93.5** *(41)*	Se **79.2** *(34)* Mo **96.0** *(42)*	Br **79.92** *(35)* - *(43)*	Ru **101.7** *(44)* Rh **102.9** *(45)* Pd **106.7** *(46)*
Xe **130.2** *(54)*	Ag **107.88** *(47)* Cs **132.81** *(55)*	Cd **112.40** *(48)* Ba **137.37** *(56)*	In **114.8** *(49)* La **139.0** *(57)*	Sn **119.0** *(50)* Ce **140.25** *(58)*	Sb **120.2** *(51)*	Te **127.5** *(52)*	I **126.92** *(53)*	
			Pr **140.9** *(59)* Nd **144.3** *(60)* - - *(61)* Sa **150.4** *(62)* Eu **152.0** *(63)* Gd **157.3** *(64)* Tb **159.2** *(65)* Ho **163.5** *(66)* Ds **162.5** *(67)* Er **167.7** *(68)* Tm_I Tm_{II} **168.5** *(69)* *(70)* Yb‡ **173.5** *(71)* Lu **175.0** *(72)*		Ta **181.5** *(73)*	W **184.0** *(74)*	- *(75)*	Os **190.9** *(76)* Ir **193.1** *(77)* Pt **195.2** *(78)*
	Au **197.2** *(79)*	Hg **200.6** *(80)*	Tl **204.0** Ac D **207.2** Th D **208.2** Ra C_2 **210.2** *(81)*	Pb **207.20** Ra D **210.2** Ac B **211.2** Th B **212.2** Th D_2 **208.2** Ra B **214.2** Ra D_2 **210.2** *(82)*	Bi **208.0** Ra E **210.2** Ac C **211.2** Th C_1 **212.2** Ra C **214.2** *(83)*	Ra F **210.2** Ac C_1 **211.2** Ac A **215.2** Th C_2 **212.2** Th A **216.2** Ra C_1 **214.2** Ra A **218.2** *(84)*	- *(85)*	
Ac Em **219.2** Th Em **220.2** Ra Em **222.2** *(86)*	- *(87)*	Ac X **222.2** Th X **224.2** Ra **226.2** $MesTh_1$ **228.2** *(88)*	Ac **227.2** $MesTh_2$ **228.2** *(89)*	Rd Ac **227.2** Rd Th **228.2** Io **230.2** Th **232.2** Ux_1 **234.2** *(90)*	Ux_2 **234.2** *(91)*	U_{II} **234.2** U_I **238.2** *(92)*		

* Be = Gl
† Cb = Nb
‡ Neoytterbium = 173.5

Atomic Weights listed in **Bold figures.**
Atomic Numbers listed in *Italics* in parentheses

Fig. 1

Now a most significant fact about all these elements is that it is possible to arrange them in groups so that the members of any one group are much more alike in physical and chemical properties than any two members from two different groups. The *periodic law* enunciated by Mendeljeff in 1871 states *that the properties* of the *elements, and the properties and compositions of compounds, vary periodically with the atomic weights of the elements.* The arrangement of the elements, based on this law, and including those which have been discovered since the above date, is shown in Fig. 1.*

There is probably no series of observations bearing on the question of atomic structure that is of greater importance than those which are embodied in the periodic table of the elements.

When the elements are arranged in order of increasing atomic weight, it is observed that among the first twenty elements, there is a repetition to a large extent of physical and chemical properties at every eighth element. Thus sodium resembles lithium; phosphorus, nitrogen and chlorine, fluorine. Beginning with argon, we have to pass over eighteen elements before we come to an element similar to it, and then we have another group of eighteen before we reach xenon which is the next homologue to kryton and argon. Thus, leaving hydrogen out of consideration for the present, we have two series of seven elements and then two series of eighteen. In the series beginning with xenon, however, there occurs a sort of pleiadic system between cerium and tantalum. All these elements comprised in the heavy lines are known as the "rare earths." Most of them are so nearly alike chemically and physically that their separation is a matter of extreme difficulty. Evidently there is some fact connected with the structure of the atom which makes the existence of such a group possible when we get to elements whose atoms are heavier than those of cerium. As the atoms increase in mass, the structure becomes more and more complex and finally we obtain a series of elements whose atoms are capable of spontaneous disintegration and thus form the group of radioactive elements.

When Mendeljeff arranged his elements in order of increasing atomic weight, he found that tellurium and iodine apparently did not follow in the order which they should follow according to their chemical and physical properties. Thus, while iodine is very similar to chlorine and fluorine, and tellurium is similar to oxygen and sulphur, the latter has an atomic weight greater than that of iodine. The same discrepancy occurs in the case of argon and potassium. For a long time it was thought that the discrepancies were due to wrong atomic weight determinations, but innumerable investigations have shown that the values as given in Fig. 1 are accurate to less than one-tenth per cent.

However, a study of the properties of the radioactive elements and observations on the X-ray spectra of the different elements has led to the view that the atomic weight is not the real determining factor as to the place which an element occupies in the periodic table, but rather the *atomic number*, which is a number indicating the place in the table beginning with hydrogen 1, helium as 2, lithium as 3, and so on. These numbers are indicated in italics in brackets in the table of Fig. 1.

Mendeljeff's arrangement is not the only one which has been suggested in order to exhibit the periodical recurrence of elements possessing fairly analogous properties. W. D. Harkins† has proposed a space form which is shown in Fig. 2. This form may be easily converted into a plane diagram by plotting the atomic numbers radially from a point in a plane, and we thus obtain a spiral form.‡ Similar elements are thus made to occur along the vertical lines in Fig. 2, and along radial lines in the spiral arrangement.

The most significant fact brought out by Mendeljeff's arrangement is the gradual change in valency as we pass in each series from the elements of low atomic number to those of higher numbers. The elements of group 0 are chemically inert; they cannot be made to react with any other elements. They are therefore assigned the valency 0. Elements of Group 1 are monovalent (forming compounds of the general type E_2O; those of group 2 are divalent, and so on. The elements of the fifth, sixth and seventh groups possess two kinds of valencies. With H they form compounds of the types EH_3, EH_2 and EH respectively, while with oxygen and more electronegative elements they are able to form compounds of the types E_2O_5, EO_3 and E_2O_7 respectively.

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* The subject of the Periodic Law and the reasons for arranging the different elements in the manner shown in Fig. 1 have been discussed by the writer in a special article in the General Electric Review, July, 1915, Vol. XVIII, p. 614. The remarks in the present paper are therefore more in the nature of a summary of the much more complete discussion given in the above paper.

† J. Am. Chem. Soc. *38*, 169 (1916)

‡ This form is shown in the writer's articles on "Theories of Magnetism," General Electric Review.

Not only do the elements exhibit this periodical recurrence of chemical properties, but they exhibit the same periodic recurrence in most of their physical properties. Fig. 4[*] illustrates this in the case of the cohesional properties. Those elements which belong to the same group in the periodic table occupy corresponding positions on each of the curves.

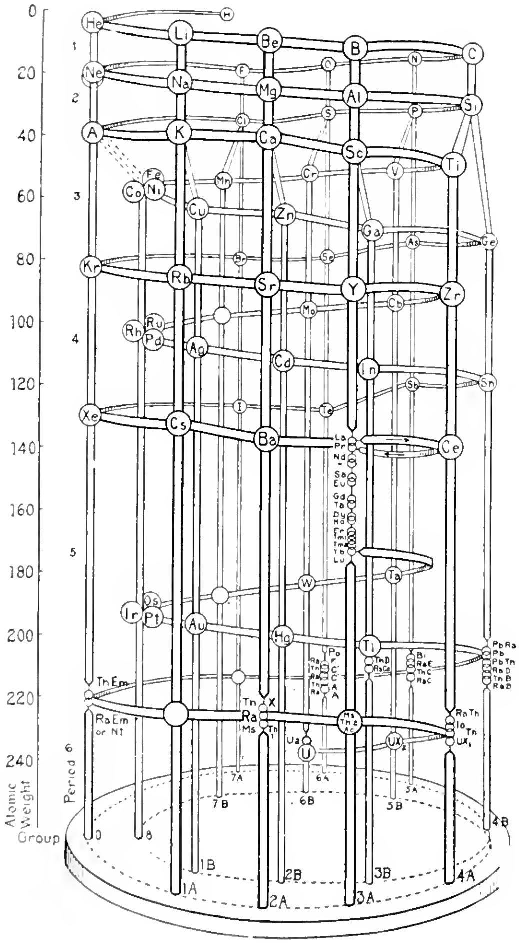

Fig. 2

Electro-positive and Electro-negative Elements

When a solution of copper chloride is electrolyzed, copper is deposited at the cathode, that is, the electrode which receives negative electricity, while chlorine is liberated at the anode. Copper is therefore said to be electro-positive, while chlorine is electro-negative. In a Daniel cell, when the plates are joined by a wire, the zinc goes into solution and the copper becomes plated with more copper from the solution. Since the current flows in the wire from the copper to the zinc, we say that the copper is electro-positive with respect to the zinc.

Now it is extremely significant that the most electro-positive elements occur in Group 1, while the most electro-negative ones occur in Group 7; furthermore, in each group the electro-positive property increases with increase in atomic number, so that *Cs* is much more electro-positive than *Li*, while *I* is much less electro-negative than F. Also, the elements of Group 1 combine readily with those of Group 7, the reaction being often quite energetic. The compounds so produced are extremely good electrolytes in aqueous solution and react readily when in solution with other salts. As we proceed from Group 1 to Group 7, the electro-positivity decreases, and in Group 5 we find more or less pronounced electro-negative elements, the electro-negativity finally reaching a maximum in Group 7.

The electron theory of J. J. Thomson immediately suggests that there ought to be a relation between this property of the elements and their tendency to give up electrons, and indeed, as Dr. I. Langmuir has shown in a recent paper[†], such a relation does exist.

In order to explain this relation it is necessary to refer to a number of observations on electron emission from heated metals and also from metals exposed to ultra-violet and visible light.

It has been known for a long time that a heated carbon filament gives off negative electricity. J. J. Thomson showed that this negative electricity is given off in the form of free electrons which are similar in charge and mass to those which had been previously discovered by him as constituting cathode rays. Richardson showed that platinum and other metals when heated are also capable of emitting electrons, and that the number of electrons emitted increases rapidly with the temperature according to a law which is similar to that obeyed by the molecules emitted from a heated liquid. In other words, the electrons are "evaporated" from a heated metal, and for every metal there exists a "heat of vaporization" (*w*) which represents the amount of work required to separate an electron from the metal.

The value of *w* has been obtained for a number of metals by Richardson, Langmuir

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[*] W. D. Harkins, loc. cit.

[†] Trans. Am. Electrochem Soc. (1916.)

and others, and in confirmation of the latter's suggestion, it is found that, in general, the more electro-positive the metal, the smaller is the value of the quantity, w.

The relation is also confirmed by two other lines of investigation. It has been shown that for every metal there exists a minimum value of the frequency of monochromatic light (ν_o) which is able to cause emission of electrons from that metal. According to Einstein this represents the minimum amount of energy ($h\nu_o$)* which is just able to cause an electron to escape from the illuminated surface, and thus corresponds to the quantity w mentioned in the previous section. As a matter of fact, the value of $h\nu_o$ is found to be practically equal to that of w for any metal.

The second line of investigations which is in accord with this idea that the electro-positive or electro-negative property of an element is intimately related with the electron affinity (as measured by $h\nu_o$ or w) is connected with the study of ionizing potentials and single spectra.

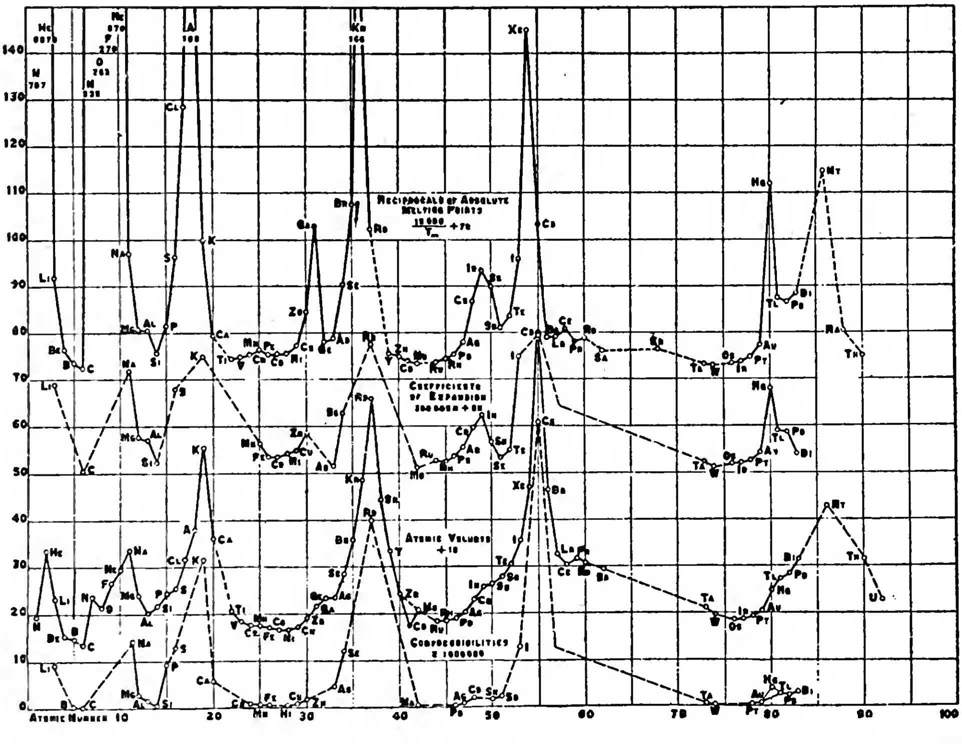

Fig. 3

"Franck and Hertz have found that the ionizing potential† of mercury vapor is 4.9 volts. Furthermore, when electrons with a velocity only slightly more than 4.9 volts were allowed to collide with mercury atoms, they observed that the mercury vapor emitted a spectrum consisting of a single line of wavelength 253.7$\mu\mu$. Franck and Hertz pointed out that the energy of an electron which has fallen through a potential difference of 4.9 volts is almost exactly equal to a quantum of energy, $h\nu$, where ν is the frequency corresponding to the observed spectrum line."‡

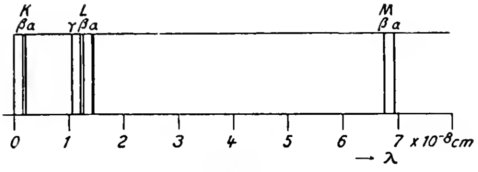

Fig. 4

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* h is a universal constant, known as the quantum constant. According to the quantum theory (See GENERAL ELECTRIC REVIEW, March, 1914.) radiant energy is emitted and absorbed in multiples of the unit quantum $h\nu_o$.

† The ionizing potential is defined as the work required to remove an electron from a neutral gas molecule.

‡ The relation between volts (V) and frequency (ν) is $V\epsilon = h\nu$ where ϵ is the charge on an electron.

Now, "McLennan and Henderson* have shown that by using very low voltages, various other metal vapors may be made to emit single-line spectra. The lines obtained in this way may also be observed as absorption lines under certain conditions. McLennan assumes that these single lines correspond to ionizing potentials." In those cases where single-line spectra have not as yet been obtained, McLennan calculates what the frequency of the single line would be, by an indirect method. By means of these two methods he arrives at the following ionizing potentials:

TABLE I
IONIZING POTENTIALS ACCORDING TO McLENNAN

	Volts
Mercury	4.89
Zinc	4.04
Cadmium	3.81
Calcium	2.94
Strontium	2.69
Barium	2.24
Lithium	1.85
Sodium	2.11
Potassium	1.61
Rubidium	1.56
Caesium	1.39

It is again interesting to note how similar the above order is to that in which the elements are arranged in the periodic table, and how, on the whole, this order agrees with the known electro-positive characters of the different elements. Caesium, the most electro-positive element, has the lowest ionizing potential, and next in order come rudidium, potassium and sodium. Lithium and mercury are apparently not in their expected order, but there may be some additional reason which further investigation will discover for this anomaly.

There are at least two conclusions regarding the structure of atom which can readily be drawn from these observations. Firstly, it is evident that the electron is a universal constitutent of all atoms. Secondly, some atoms have a greater affinity for electrons than others. The atoms with lowest electron affinity belong to those elements which we characterize chemically as most electro-positive. In a subsequent section we shall show that there are other relations between the electron affinity and different properties of the elements. At present we shall pass on to discuss other observations which enable us to determine the actual number of electrons in the atoms of the different elements.

High-frequency Spectra of the Elements

When cathode rays of low velocity strike the surface of any metal, the latter emits a continuous spectrum of X-rays with wave-lengths ranging around 1×10^{-8} cms. In the region of low frequencies, the spectrum is apparently unlimited, the only limit being that set by the crystals which are available for measuring the wave-lengths according to the method of Bragg described above. On the other hand, the spectrum is cut off very sharply at an upper limit of frequency (ν_m) which is connected with the maximum voltage over the X-ray tube by the relation

Fig. 5

$$V\epsilon = h\nu_m$$

where h is the quantum constant, and ϵ is the unit charge of negative electricity. That is, in order to emit X-rays of frequency ν_m, the cathode rays must possess at least that amount of kinetic energy which corresponds to the quantity $V\epsilon$. The relation is thus quite analogous to that already mentioned in discussing photo-electric emission

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* See Miss H. Hosmer, GENERAL ELECTRIC REVIEW, April, 1916, for discussion of these experiments.

As the voltage over the X-ray tube is raised above a certain definite value, the anti-cathode material is observed to emit a characteristic X-radiation which has an intensity much greater than that of the continuous radiation.* For each element it is thus possible to obtain a series of monochromatic X-radiations which are characteristic of that element. These rays as shown in Fig. 4 (which is a typical spectrum) are classified according to their wave-lengths into three groups, K, L and M, the latter having the longest wave-lengths.

In 1913, N. G. J. Moseley carried out an investigation in which he measured the wave-lengths of the lines in the K and L series for most of the elements. He found that the spectra of the different elements, beginning with that of aluminum and ending with that of gold, could be arranged in the same order as in the Periodic Table, and that under these conditions the wave-length of any one characteristic line of the K or L series decreased regularly with increase in atomic weight. Furthermore, Moseley found that if he assigned to each element a number (N) corresponding to its place in the Periodic Table ($Al = 13$, $Si = 14$, etc. as far as $Au = 79$), there exists for each series of radiations a simple relation between this number and the frequency of the characteristic radiation for that element. This relation has the general form

$$\sqrt{\nu} = a\,[N - N_o]$$

where a and N_o are constants.

These measurements have been repeated and extended more recently by de Broglie; A. W. Hull, and M. Siegbahn. Fig. 5 shows the K series for some of the elements between As and Rh as photographed by the latter. The dark line on the extreme left-hand end corresponds to a wave-length zero. The first line in each spectrum is found on closer examination to consist of two lines very close together. These are known as the α_2 and α_1 lines of the K series. The darker lines to the right also consist of two lines, which are not very easily separated. These are known as the β_1 and β_2 lines of the K series. Now the significance of Moseley's law is this: If we plot the square root of the frequency, or (what amounts to the same thing) the values of $\sqrt{1/\lambda}$ (for the α_1, α_2, β_2, or β_1 lines of the different elements) as ordinates with the atomic numbers (N) as abscissae, we obtain a straight line for each of these series, such as shown in Fig. 6.

Fig. 7 shows the L radiations for the elements Au, Tl, Pb and Bi†. For each of the series (γ, β_2, β_1, α_1 and α_2) an equation similar to that given above is found to hold.

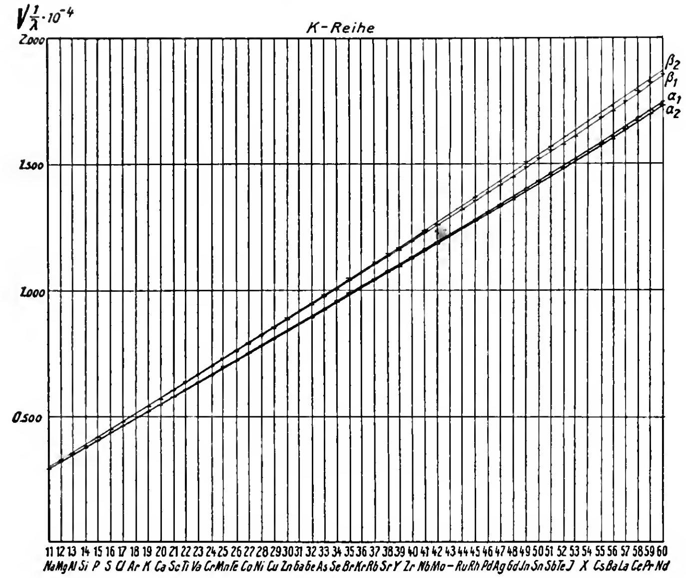

Fig. 6

The fact that such a relation exists which enables us to determine the atomic number, N, for each element and that this atomic number coincides in all cases with the order in which the element must be placed in the periodic table in accordance with its physical and chemical properties, this fact must be regarded as one of the most important discoveries in recent years. Not only does it add a new significance to the Periodic Table, but it also throws much light upon the whole problem of atomic structure. For, according to Rutherford the atomic number signifies nothing more or less than the magnitude of the positive charge on the nucleus of the atom, and hence N corresponds also to the actual number of electrons in the atom, since the number of negative charges in a neutral atom must be equal to the total positive charge.

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* For illustrations, see the paper by Dr. A. W. Hull, "The X-ray Spectrum of Tungsten," in the GENERAL ELECTRIC REVIEW, July, 1916; also the paper on X-rays by Dr. W. P. Davey in the GENERAL ELECTRIC REVIEW, Vol. 18, (1915).

† See also the paper by the Dr. A. W. Hull in the GENERAL ELECTRIC REVIEW, July, 1916, for photographs of the K and L radiations from Tungsten.

The observations of C. G. Barkla on the scattering of X-rays are also in accord with this conclusion. Barkla finds that when X-rays strike an atom of any element, secondary X-rays are produced. Furthermore the amount of this "scattering" increases regularly with increase in atomic number. On the assumption that X-rays are electromagnetic pulses (which Bragg's work as mentioned above has confirmed), Barkla also arrives at the conclusion that the number of electrons in the atom of any element cannot be greater than half the atomic weight.

Fig. 7

Scattering of Alpha and Beta Particles by Matter and the Nuclear Theory of the Atoms

We have already mentioned that Moseley's results are in accord with a nuclear theory of the structure of the atom postulated by Rutherford. It is, however, necessary to describe more fully the experimental observations on which Rutherford has based this theory.

Geiger and Marsden observed in 1909 that when alpha rays are allowed to strike a piece of thin gold foil, some of the alpha particles, one out of 20,000 or so, suffer a deflection of more than a right angle at a single encounter.

Now remembering that an alpha particle has the same mass as an atom of helium, but differs from the latter in carrying two positive charges, it would seem a reasonable guess that the alpha particle suffers the deflection because it comes close to another positive charge which is of much greater magnitude. Rutherford assumes, therefore, that the scattering is due to a positive charge of magnitude $N\epsilon$ (where N is the atomic number) situated at the center of the atom; and that this nucleus is surrounded by N electrons uniformly distributed within a sphere of atomic radius. Furthermore, he assumes that this positively charged "nucleus" repels the alpha particle with a force which varies inversely as the square of the distance. On these assumptions it is possible to calculate the relative distribution of the alpha particles for the different angles at which they are deflected and also the minimum distance, b, to which the nucleus is approached by the alpha particle. As the law of distribution calculated on this basis is found to agree splendidly with the results actually observed by Geiger and Marsden, it is reasonable to conclude that the original assumptions are probably quite justifiable, and that therefore the distance b, which represents the maximum value of the sum of the radii of the two nuclei, has a real significance.

Now it is extremely interesting to note that Rutherford finds in this manner that the alpha particle approaches the nucleus of the atom of gold within a distance of 1.7×10^{-13} *cm.* Also, in the case of the scattering of alpha particles by hydrogen, where the mass of the nucleus is only one-fourth that of the alpha particle, we would expect to find, from ordinary dynamical considerations, that some of the hydrogen atoms would actually be made to recoil four times as far as the penetrating distance of the alpha particle. Marsden has shown that this is actually the case, and from the observations it can also be concluded that the sum of the radii of the atoms of hydrogen and helium is less than 1.2×10^{-13} *cms.* On the other hand, considerations based on the kinetic theory of gases and the known atomic volumes, lead to the conclusion that on the average the diameter of an atom is around 2×10^{-8} *cms.* It therefore follows that not only is the diameter of the positive nucleus less than one hundred thousandth of that of the atom, but, what seems contradicatory, that the nucleus contains practically the whole mass of the atom, since the mass of the negatively charged particles which surround the nucleus must be negligible in comparison with that of the atom itself.*

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* Thus, in the case of the atom of uranium, the heaviest of all the atoms, $N = 92$ and the mass of the atom is $238.2 \times 1.663 \times 10^{-24}$ *gm.* $= 393.1 \times 10^{-24}$ *gm.*, while the total mass of the electrons is $92 \times 9.01 \times 10^{-28}$ *gm.* $= .0829 \times 10^{-24}$ *gm.*

Radioactive Phenomena

So far we have dealt with two sets of observations which are of extreme significance for gaining an idea of the structure of the atom. The periodic table indicates that as the atom becomes more and more massive, there is a periodic recurrence of the same arrangement of the outermost electrons in the atom. The observations on high frequency spectra and scattering of alpha particles lead to the conclusion that the atom consists of a positively charged nucleus of extremely small dimensions compared with those of the atom itself ,and furthermore, that the chemical properties of the elements depend only upon the magnitude of the positive charge on the nucleus.

We now pass on to the discussion of a number of observations which show us that not only is the atomic weight of but secondary significance in determining the position of an element in the periodic table and that we may have several atomic weights for the same element, but that the structure of the nucleus itself is quite complicated.

It has already been mentioned that in the radioactive elements discovered by Becquerel and Mme. Curie, we have unstable atoms which disintegrate spontaneously, as has been shown conclusively by Rutherford and Soddy. After a certain average period of existence, which may range from over a thousand years, as in the case of uranium (U_1), to a millionth of a second, as in the case of $Ra\ C_1$, the atom undergoes a sudden explosion and yields an atom which possesses totally distinct properties. Further investigation has shown that the rate at which these atoms disintegrate is absolutely uninfluenced by any of the factors, such as temperature, pressure, illumination with ultra-violet or X-rays, etc., which are used in controlling the rate of ordinary chemical and physical reactions.

Since the disintegration of any atom always yields an atom occupying a different place in the periodic table we must conclude that the change actually occurs in the nucleus itself. Furthermore, as electrons and alpha particles are emitted during the disintegration, it follows that the nucleus, small as it is, consists of negatively changed corpuscles and helium nuclei, packed close together. How is it possible for positive and negative charges to remain in equilibrium under such conditions? Probably Coulomb's law fails completely for distances as small as those which exist inside the nucleus. It may indeed become reversed; that is, positive and negative charges repel each other at distances which are less than 10^{-13} cm.

It has been found that each of the radioactive products belongs to one of three well-defined distintegration series whose starting points are uranium, thorium, and actinium respectively.* The most noteworthy feature about these products is the fact that individual members of each series appear to be chemically indistinguishable from certain members of the other series. Hence, according to Boyle's definition, they belong to the *same element*. Owing, however, to the difference in previous history of these atoms, they *possess different atomic weights* and also differ in period of existence. Soddy, who has drawn attention to these cases, has named these products *isotopes*, since they occupy the same place in the periodic table. As shown in the table in Fig. I, there are three other isotopes of thallium, and no less than six isotopes of lead. These results are thus in accord with the conclusion already advanced above, that *the most characteristic property of any element is its atomic number*, and not the atomic weight. The different isotopes of any element may therefore be regarded as consisting of atoms which are all alike as far as the number of electrons, their arrangement, and the charge on the nucleus; but the arrangement of electrons and alpha particles in the nucleus of each of these atoms is evidently not the same. Hence arise the differences in mass and average life.

General Conclusions Regarding the Structure of Atoms

It is obvious that any theory of the structure of the atom which we can form at present must be regarded as only a first approximation. But there are some conclusions which can be drawn with a certain degree of assurance from the above observations.

Firstly, the atom must be constituted of a positive nucleus of extremely small dimensions, (but approximately equal in mass to the atom itself), and a number of electrons distributed presumably in one or more rings or spherical shells outside the nucleus, the total number of electrons being equal to the positive charge on the latter. Secondly, all the physical and chemical properties of the atom (excepting radioactive and gravitational) are governed solely by the magnitude of this charge on the nucleus (or atomic number).

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* See "The Periodic Law," GENERAL ELECTRIC REVIEW, July, 1915, for the diagram representing the disintegration products in each series.

Thirdly, in order to explain chemical combination and periodic properties, we must assume that there are two classes of electrons, an inner and outer set. The outer ones are the electrons which are active in chemical combination and conduction of electricity thru metals. They are the so-called valency electrons. The number of electrons in this outer set undergoes periodic changes in value as the atomic charge increases, and the maximum number of electrons which are stable on the outer surface of the atom is eight, thus accounting for the periodicity of eight in Mendeljeff's table.

The outer electrons are also those which are active in the production of ordinary emission spectra. If Lorentz's explanation of the Zeeman effect is right, and it is the only one that explains the phenomenon quantitatively, then we must conclude that the lines visible in ordinary emission spectra are due to the vibration of electrons with frequencies ranging around 10^{15} per second. The fact that these emission spectra are modified by method of excitation and also differ with different compounds, shows that the electrons producing these phenomena are near the surface of the atom and therefore probably the same as the valency electrons.

On the other hand, the inner electrons are unaffected by ordinary methods, but high velocity electrons may stimulate them and thus produce the high-frequency spectra observed by Moseley and others. As pointed out by Kossel* the continuity of the K-line spectra for the different elements from the lowest atomic number to the highest, shows that the periodicity observed in the outer electrons does not extend to the innermost.

C. A. Kraus has stated the reasons for drawing the same conclusions from a chemical standpoint.† "The outer electrons," he writes, are held loosely and are able to move from atom to atom. These electrons are very sensitive to changes in condition, such as temperature, pressure, the presence of other atoms, etc. So weak is the bond emitting the electron to an atom, that more electro-negative atoms may remove it from the original atom in question. The electrons *to which conduction is due in metals are the same electrons which are involved in the common chemical combinations of metals with other elements.*

"*The less tendency the metal has to retain its electron, the more electro-positive it becomes and the more readily does it in general react.* Ordinarily, the positive and negative constituents of a compound are held together through the medium of the electron. Under certain conditions, however, (for example in solution in a dielectric medium) the electrostatic force acting between the metallic atom and its electron becomes weakened to such an extent that the negative constituent escapes, carrying the electron with it. The same result may be obtained at high temperatures with the fused salt or even with the solid compound."

That is, when sodium and chlorine combine, the sodium atom gives up an electron to the atom of chlorine (which is the electronegative element), and the atoms are thus held together by the electrostatic forces between the positively charged residue of the sodium atom and the negatively charged atom of chlorine. In a solution of high dielectric constant such as water, these electrostatic forces are weakened to such an extent that we have the phenomenon known as "dissociation" and the formation of Na (sodium ion) and Cl (chlorine ion). Naturally the properties of those ions are radically different from those of metallic Na and gaseous Cl_2 as we know them.

The electrolytic conductivity of metallic lithium dissolved in liquid ammonia is explained in a similar manner. Here we actually have a separation of the lithium atom into Li and an electron, and in the electrolysis, the lithium is deposited at the cathode while electrons are carried to the anode.

Similar ideas have been expressed by Sir Wm. Ramsay; G. N. Lewis; W. Kossel and others. All are agreed upon this conclusion that chemical combination between different atoms consists in the transference of one of the outer electrons from one atom to the other. But as to the actual distribution of the electrons in the different atoms and the nature of the forces between the electrons and the positive nucleus—regarding these and allied questions there is quite a variation of opinion. The discussion of this part of our subject must, however, be deferred to a subsequent issue.

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* Ann. d. Physik, *49*, 229 (1916).

† Journ. Am. Chem. Soc., *35*, 1732 (1913).

INDUSTRIAL CONTROL

Part VIII

CONTROLLERS FOR STEEL-MILL DIRECT-CURRENT AUXILIARY MOTORS

By G. E. Stack

Industrial Control Department, General Electric Company

Previous installments of this series on " Industrial Control " have described the " Applications of magnetic control to alternating-current motors in steel mills " (September 1916) and the " Applications of magnetic control to speed-regulating sets in steel mills " (October 1916). The present installment completes the section on " Magnetic control for steel mills " and describes the applications of magnetic control to steel-mill direct-current auxiliary motor drives. In the latter portion of the article considerable valuable information is given relative to the use of standard cast-grid resistors and the advantages secured from their employment. The concluding installment of this series on " Industrial Control " will appear in a later issue and will treat of the " Design of magnetic control appliances."—Editor.

The majority of machines classed as auxiliaries in steel mills require motors of less than 100 h.p. capacity. The applications of these motors and the controls required are somewhat varied but the drives are generally of a reversing character and in only a few instances do they require speed control. The duty cycle varies from that of an approach table as one extreme, in which a starting and running period of not more than ten seconds is required every two or three minutes with rarely a reversal, to that of a screw-down as the other extreme, in which starting, reversing, and " plugging " occurs continuously in rapid succession as many as twenty to thirty times a minute.

Ingot Buggy

The requirements of an ingot buggy comprise one of the exceptions in which speed control is desirable and at the same time automatic slow down and stop by dynamic brake is very often required. Fig. 1 shows the wiring diagram of a control equipment which meets nearly all the demands of this type of drive.

No-voltage protection is obtained by means of the circuit-breaker contactor, which is closed only at the " off " position of the drum-type master switch and remains closed except in case of overload or failure of voltage. When the master switch is returned to the " off " position the circuit-breaker contactor will close, providing voltage has returned to the line. Inasmuch as it normally remains closed and is called upon to rupture current only in case of overload, it offers the advantage of inserting in the circuit a contactor which has been used but few times and, therefore, should be in first-class condition for opening the circuit, even though the remaining contactors on the panel have been allowed to deteriorate to such an extent as to impair their arc rupturing capacity for heavy current. Speed control is obtained from a six-point hand-operated master switch and shunt contactors provided with current-limit interlocks for limiting the current to a predetermined value during acceleration.

Shunt current-limit interlocks are provided on two of the line contactors, one for each direction. In the forward direction contactor *1* closes (see Fig. 1). A circuit is thereby established from *L2* through the overload relay coil, contactor *1*, motor armature, shunt current-limit coil on contactor *4*, part of starting resistor, series field, circuit-breaker contactor, overload relay coil, and back to *L1*, thus putting full line voltage across the shunt current-limit coil. The interlock on contactor *1* then energizes and closes contactor *4* which completes the motor circuit through all of the starting resistor, this automatically throwing the shunt current-limit interlock coil of contactor *4* in parallel with the section of the starting resistor between *R2* and *R5*. From this sequence it is evident that the interlock coil is first subjected to the line voltage which prevents the contact from closing while contactor *4* is closing, an operation which would otherwise take place because the contact is held open mechanically by the contactor itself only in the open position. The voltage drop across the resistor is proportional to the current flowing through the resistor and the contact can therefore be adjusted to close on any desired current value. The series current-limit interlocks operate in much the same manner as those of the shunt type except that the full line current passes through the series coils. The contacts of the interlock are held open mechanically as long as the contactor to which it is connected is open, and are allowed to close by gravity when the contactor closes, providing there is insuf-

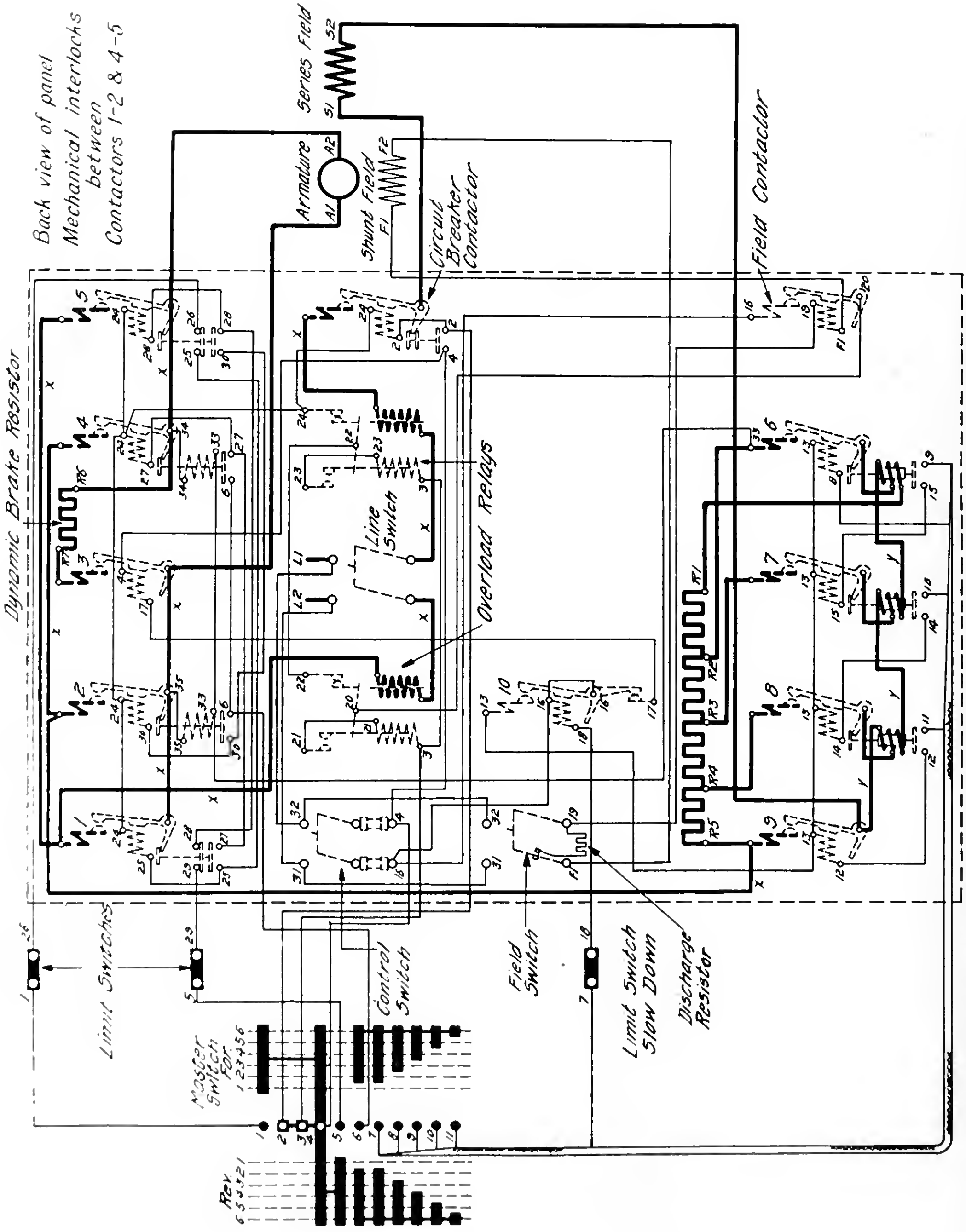


Fig. 1. Wiring Diagram of an Equipment Furnishing Speed Control, and Automatic Slow Down and Stop by Dynamic Brake

ficient current in the coil to hold them open. Each coil is wound with a tap brought out from the center of the winding. The current passing through the entire coil is always more than sufficient to hold the contacts open while the contactor is closing, because the contact is adjusted to close after the contactor has closed when the current is passing through only the upper half of the coil because this is the shortest path or the path of least resistance.

A slow down near the dumping point is obtained by a limit switch which opens the double-throw contactor *10*, the upper contact of which opens the circuit and drops out the accelerating contactors *6*, *7*, *8* and *9* which, in turn, inserts the starting resistor in series with the motor. The lower contact of contactor *10* also closes contactor *3* which puts the resistor marked *R6* to *R7* in parallel with the armature. This results in a very effective slow down. Contactor *10* is also controlled from the master switch and thus allows the operator to obtain this feature independent of the limit switch when desired, as well as a creeping speed during starting.

An automatic stop is provided at the dumping point, and also at the other end of the track by two limit switches which are wired to open their respective line contactors. At the dumping point the motor is already slowed down and it only remains for the stop limit switch to open the line contactors for the resistor in parallel with the armature will provide the necessary dynamic braking for a quick stop. At the other end of the track a slow-down limit switch is not provided and the stop limit switch, in this case, opens both the line and the accelerating contactors and closes contactor *3* thereby applying a dynamic brake immediately.

The other incorporated features such as overload protection, shunt field protection, etc., are so generally used that they will not be discussed here.

Transfer Table

Approach tables, live tables, and run-out tables all require practically the same type of control, differing only in capacity and duty cycle. The general requirements call for a reversible equipment with a master switch giving one-point hand control in each direction and sufficient contactors to give automatic acceleration. Fig. 2 shows the wiring of an equipment which provides the operating characteristics usually required for tables. In this equipment the automatic acceleration is obtained by means of series contactors.

Screw Down

Two types of screw-down equipments are being used. Both of them seem to be equally successful from the manufacturers' viewpoint but there appears to be an unsettled question among the mill operators as to whether a quicker and more accurate stop can be made with a control in which the motor is plugged for stopping or with one in which dynamic braking is provided at the "off" position. A simple reversing equipment as shown in Fig. 2 for table control is sufficient for the former but for the latter a complicated control is required because series motors are preferable for this class of work and for these it becomes necessary to reverse either the field or armature to obtain the dynamic braking feature. The use of compound-wound motors has been suggested and tried, dynamic braking being done with the shunt field only, but it was found that the stop was not sufficiently quick. By employing the series field, either of a straight series motor or that of a compound-wound motor, the stop is effected much more quickly because the series characteristics of the motor are then used to the best advantage.

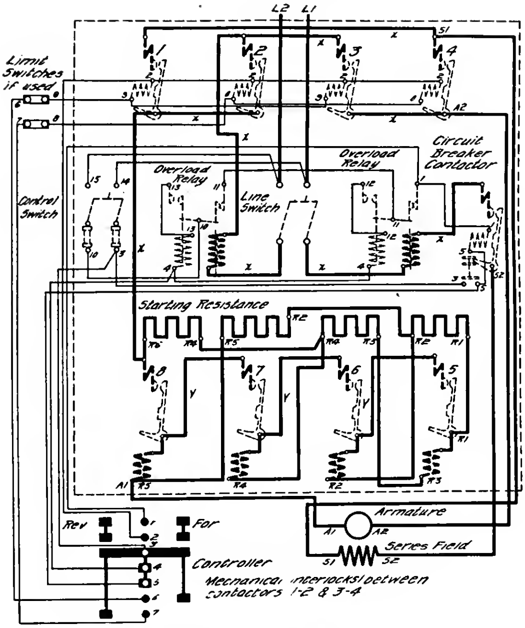


Fig. 2. Wiring Diagram of a Simple Reversing Equipment for a Table Control

Fig. 4 shows the wiring of an equipment using a compound-wound motor the series field of which is used during the dynamic braking period. The two mechanically interlocked relays *12* and *13* serve to energize the proper contactors for the brake. In the direction marked " forward " contactors *1*, *2* and *4* are closed, also relay *12* which by means of a mechanical interlock prevents *13* from closing until *12* is opened. The series accelerating contactors also close, bringing the motor up to speed. When the controller is returned to the " off " position, a circuit is completed from finger *6* on the master switch through relay *12* to contactors *3* and *5*, which close. A circuit is also completed through the coil of relay *13*, which however, cannot close because of the mechanical interlock between it and *12*. Together with contactors *3* and *5*, contactor *10* is also closed at the " off " position. This connection allows the dynamic-brake current generated by the armature to flow in the same direction through the series field as when running in the forward direction, and a very quick stop is the result. When operating in the reverse direction relay *13* and contactors *1*, *3*, and *5* close and at the " off " position *2* and *4* close. Thus contactors *2*, *4*, and *10* establish the dynamic-brake circuit providing the motor is running in the reverse direction and contactors *3*, *5*, and *10* if running in the forward direction. Contactor *1* simply serves to clear the equipment from the line during the braking period.

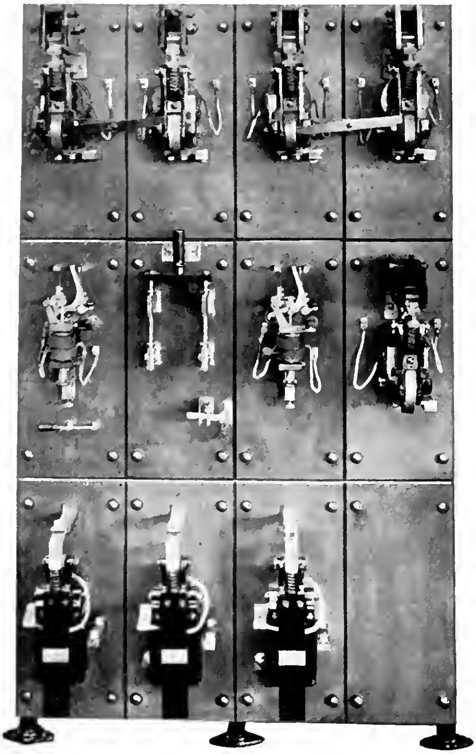


Fig. 3. Contactor Panel for Direct-current Auxiliary Steel Mill Motor, showing Individual Base Construction and General Arrangement

Manipulator Side Guards

The control for side guards is similar to the control for screw-downs in that frequent reversals with short runs are required. In addition, the control must permit of almost instantly stopping the motors when the guards come together or come against the ingot. A slip clutch is generally used to connect the motor to the drive proper for the purpose of absorbing these excessive shocks, but they require careful attention to keep them in proper adjustment. It might be remarked that " proper adjustment " is somewhat a matter of opinion and has resulted in arguments between the electrical and the mechanical departments of mills, with the result that the electrical engineer operated the motor with a permanent resistance in series to act as a buffer and allow the motor to come to a stalled condition more gradually. In some cases where the slip clutch is set at a very high torque, the motor will come to rest without the clutch slipping. This is especially true when only a moderate speed has been attained before the shock occurs. Before permanent resistance was used in this connection, torque-limit relays were employed to insert the starting resistor when the guards came together, but the arrangement met with questionable results. The same contentions, regarding the advisability of using plugging versus dynamic braking for stopping, exist here as mentioned under screw-down equipment. Limit switches are provided to prevent the guards from damaging the sides of the mill.

Manipulator Fingers

A wiring diagram of a very simple type of control now in use for manipulator fingers is shown in Fig. 5. This control gives one complete up and down motion of the fingers for each operation of the controller. The operation must necessarily be very quick; and in order to prevent over travel the limit switch is used to stop the motor at the proper

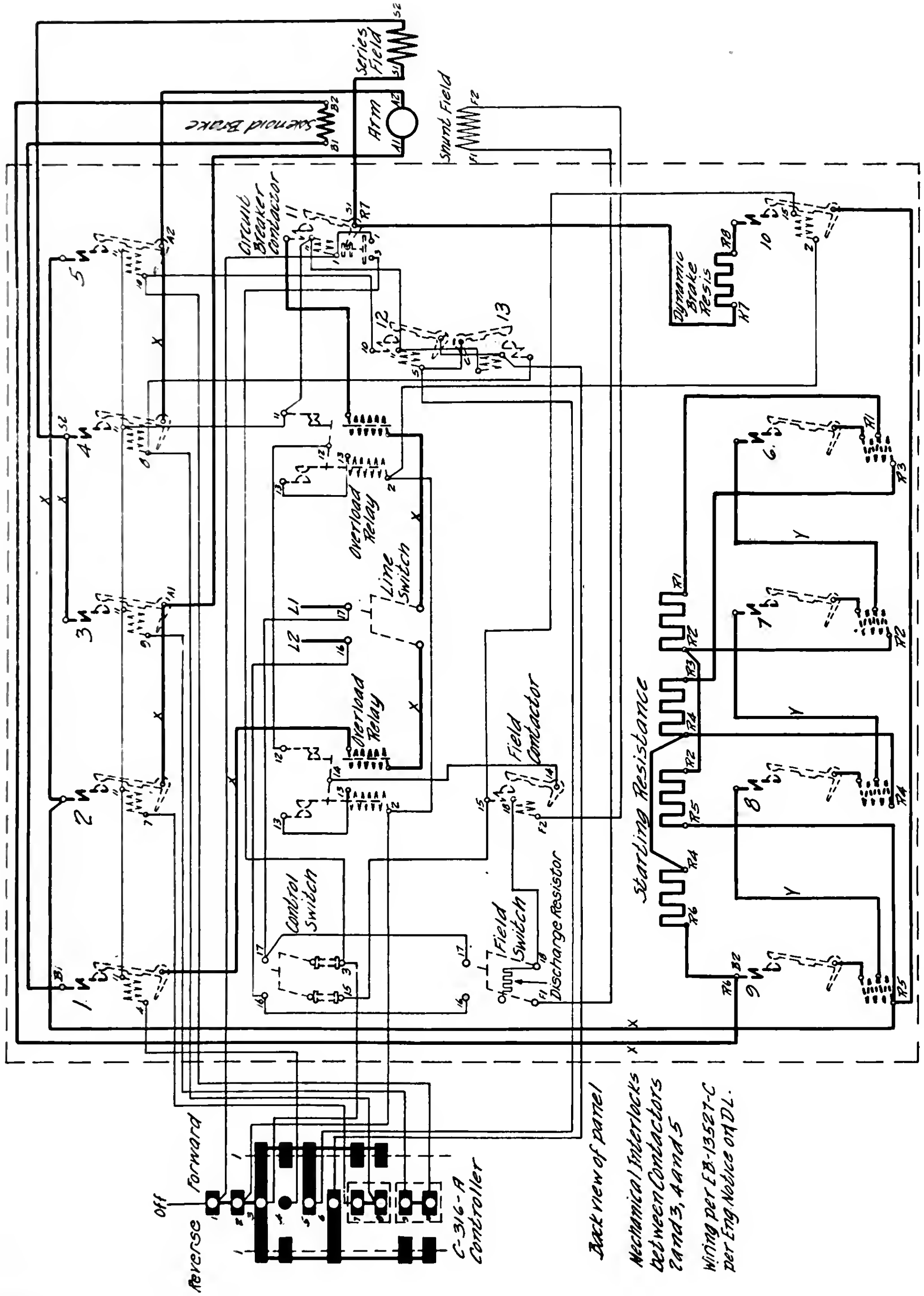
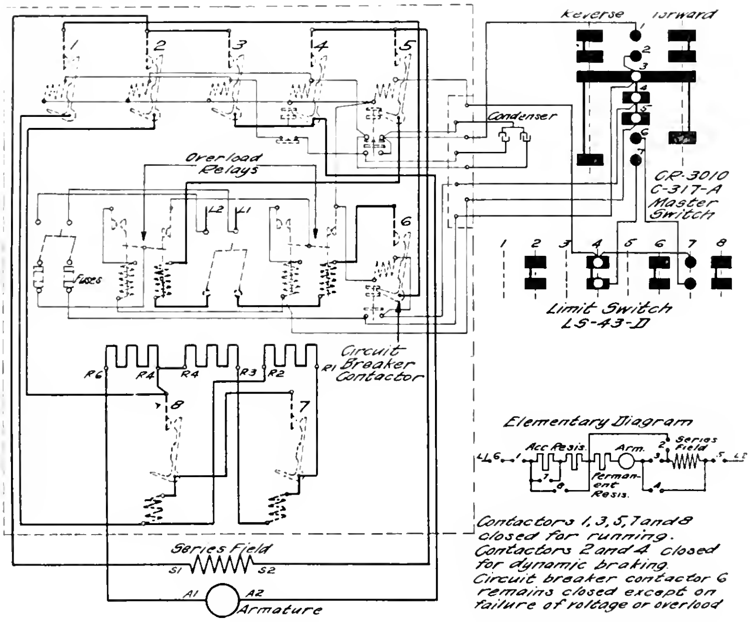


Fig. 4. Wiring Diagram of Compound Wound Motor with Series Field Used During Dynamic Braking Period

position during normal operation, and from the master switch when desired. When the master switch is thrown in the reverse position contactors *1*, *3*, *5*, *7*, and *8* close in proper sequence and the motor runs until the limit switch is tripped, which breaks circuit *7*, drops out the above mentioned contactors, and closes contactors *2* and *4*, thus establishing a dynamic-brake circuit on the generated voltage of the armature which forces current through the series field in the same direction as when running as a motor, resulting in a very abrupt stop. The change from the running to the dynamic braking connection is effected so quickly that the residual magnetism of the field is sufficient to start braking current immediately, its value being limited by the resistance in circuit. For the next operation the master switch is moved from the reverse to the forward position, when the above cycle will be repeated. The limit switch alternately makes and breaks circuits *7* and *6* at each operation.



Contactors 1, 3, 5, 7 and 8 closed for running.
Contactors 2 and 4 closed for dynamic braking.
Circuit breaker contactor 6 remains closed except on failure of voltage or overload

Fig. 5. Wiring Diagram of a Simple Control for Manipulator Fingers

The equipment has also been applied to certain types of pushers and other cam operated devices with very satisfactory results.

General Remarks

Only a few of the more important and complex types of control have been covered in this article, as the field for d-c. control of steel mill apparatus is very large.

When going through steel mills it is not uncommon to find the last one or two accelerating contactors on a control equipment blocked out or the adjustment set so that they will never close. Again, the operation of other equipments is of such short duration that these last accelerating contactors do not have time to close. This has suggested the possibility of using a control having a reduced number of accelerating contactors and operating with a permanent resistor. When selecting motors for steel-mill operation, their rating is based upon the maximum load to which they will probably be subjected. This load is often encountered when starting the mill after a long shut-down. After the mill is limbered up, however, the operating loads are often well within the capacity of the motor, or in other words the machine is over-motored for normal operation. This condition permits the use of the permanent resistor without affecting production.

The number of accelerating contactors and the amount of permanent resistance to use on different machines depends upon the speed characteristics desired and the length of time the motor is allowed to run continuously. A large number of intermittent cycles will permit the use of as few as two accelerating switches, one for cutting out the plug resistor, more commonly known as the plugging contactor, and one for cutting out the accelerating resistor. The remaining resistor is left permanently in circuit. This type of control is very well suited to equipments which are operated by series motors and run only intermittently, such as screw downs, side guards, kick ups, and tables.

The equipment described reduces the initial cost, lessens the maintenance cost, and has the additional advantage of providing a certain degree of protection to the motor. The permanent resistor serves as a bumper to absorb severe shocks, such as occur when the side guards or the rolls of a screw down come together or when the motor is accidentally subjected to abnormal conditions due to improper switching.

Steel mill operators appreciate the ruggedness of cast-grid resistors; new steps toward standardization have been developed recently and are meeting with the general approval of steel mill engineers. However it is not uncommon at the present time to find a motor with resistors made up of several boxes, each box containing from one to three different sizes of grids. When it is considered that a line of grids consists of 10 to 15 different sizes, the combinations which might be obtained when arranged in series and multiple connection are evident. This point has been called very forcibly to the attention of several engineers recently as they have placed their orders for future equipments to cover resistors in which standard boxes are used. One of these installations, consisting of upwards of several hundred motors ranging in size from 5 to 175 horse-power, uses less than 20 standard boxes. The total number of equipments involved and the range in capacities will determine the number of standard boxes for any complete installation.

The standard boxes are made up with only one size of grid, each connected all in series or two in multiple, or three in multiple. This allows a possibility of three standard boxes for each size of grid or a total of 27, but in Table II only 19 appear because 8 proved to be practically duplicates of those listed.

When connecting these boxes in the equipment, one complete box is always used for a division of the resistor. If the necessary capacity cannot be obtained in one box, two complete boxes are put in. This eliminates any taps in the box, and in case one of the boxes becomes damaged it is only necessary to disconnect the two end terminals, pull the box out, and replace it with a box from the stock room. When the number of different boxes is small, the cost of keeping several boxes in stock would be small compared to the convenience afforded.

This method of using standard resistor boxes is not particularly advantageous from the initial cost standpoint, but it works in very well for the larger sized motors where the standard control provides for cutting out all of the resistor and also works in very much better for all sizes of motors where the permanent resistor method is adopted. The maintenance cost of resistors when using grids and standard boxes is very low, because the unsatisfactory "freak" boxes having a variety of grids connected in a variety of ways are entirely eliminated. But a very small amount of engineering and no drafting is required to design a resistor for repairing old equipments or building new ones.

Table I gives the resistance and current capacity of various sizes of grids; and Table II describes a set of standard boxes which will be found very applicable to motors ranging from 5 to 200 h.p.

TABLE I
INDIVIDUAL GRID RESISTANCES AND CAPACITIES

Grid Number	Ohms Per Grid	Amps. Capacity
1	0.01	140
2	0.02	100
3	0.03	85
4	0.04	70
6	0.06	60
8	0.08	50
12	0.12	35
18	0.18	30
22	0.22	22

Table II lists standard boxes made from grids in Table I and suitable for a wide variation in motor capacity. One or more complete boxes are used for each division or step of the resistor.

TABLE II

Ohms Per Box	Amp. Capacity	Connection and Grid Number	No. of Grids Per Box
0.02	420	No. 1—3 in parallel	18
0.04	300	No. 2—3 in parallel	18
0.045	280	No. 1—2 in parallel	18
0.06	255	No. 3—3 in parallel	18
0.09	200	No. 2—2 in parallel	18
0.135	170	No. 3—2 in parallel	18
0.18	140	No. 1—series	18
0.27	120	No. 6—2 in parallel	18
0.36	100	No. 2—series	18
0.54	85	No. 3—series	18
0.72	70	No. 4—series	18
0.84	70	No. 12—2 in parallel	28
1.08	60	No. 6—series	18
1.26	60	No. 18—2 in parallel	28
1.44	50	No. 8—series	18
2.64	44	No. 22—2 in parallel	18
3.36	35	No. 12—series	28
5.04	30	No. 18—series	28
10.56	22	No. 22—series	48

In keeping with the use of standard boxes, the question of mounting is of great importance. The best arrangement so far seems to be one in which the boxes are placed on shelf-like supports made of angle iron. With the boxes all of the same size, the shelves or racks can easily be constructed to permit the boxes being mounted in tiers. Any individual box can very easily be removed without disturbing the others, which is not the case when the boxes are stacked on top of each other and bolted together.

In the steel mill and other industries, where a shut down for a comparatively short time at a critical period causes the loss of hundreds of dollars, it pays to be prepared for all emergencies. This is especially true of control apparatus. To meet these emergencies spare control panels are installed and the switches and wiring are so arranged that in case any panel fails the motor to which this panel is connected can instantly be connected to the spare panel. Economy will dictate the number of spare panels necessary. One noteworthy instance is a case having only one spare panel for the auxiliary of a blooming mill, in which a total of less than one hour of shut-down of the mill was chargeable to the control during the period of one year. In this installation the change-over switches were hand operated and necessitated an attendant, but more recent developments have called for automatic throw-over devices under the control of the operator.

KNOCKING DOWN A 120-TON ELECTRIC LOCOMOTIVE FOR EXPORT

By W. D. Bearce

Railway and Traction Engineering Department, General Electric Company

The electrification of heavy steam railroads is rapidly becoming of world-wide interest. A current installation is taking place in South America where a Chilian ore hauling road is being equipped for electrical operation. The transportation difficulties likely to be encountered in the export shipment of heavy electrification material are well illustrated in the following article which describes the procedure followed in tearing down and shipping a 120-ton electric locomotive to facilitate handling by the existing crane equipment. A brief description of the road upon which these locomotives are to operate is also included.—Editor.

The export of electric locomotives up to the present time has largely been limited to small units of such size that they could be transported completely assembled and ready for service. In the case of the Panama Canal equipment, locomotives weighing 41 tons each were shipped to New York City and loaded completely assembled on the decks of the ocean-going freighters which carried them to the canal locks. Several other complete locomotives have been shipped on the decks of the large liners which are accustomed to handling heavy packages.

Pair of Driving Wheels, showing Method of Protecting Axle

Method of Packing Contactors

In the case of the 120-ton electric locomotives which were recently shipped to the Bethlehem-Chile Iron Mines Company at Tofo, Chile, there were no cranes of sufficient capacity either on the vessel or on the docks at the destination to lift the complete locomotives to and from the deck of the vessel. The capacity of the unloading crane at Cruz Grande is approximately 35 tons and the capacity of the ordinary deck hoists on the freighter S. S. "Celia" is approximately 5 tons each. It was therefore necessary to disassemble these locomotives in somewhat the same manner as "knock-down" furniture, before shipment.

The locomotives were first assembled and tested at the Erie Works of the General Electric Company operating under the various conditions of service expected in actual operation. These tests included operation under load on 2400-volt direct-current trolley, operation of regenerative braking equipment and numerous other tests to determine the reliability of the various parts of the equipment. Other 2400-volt locomotives which were being tested at the same time for the Butte, Anaconda & Pacific and the Canadian Northern electrifications were utilized to fully test out the regenerative braking feature.

In general, the Bethlehem-Chile locomotives were constructed along the lines of a half unit of the Chicago, Milwaukee & St. Paul locomotive without the guiding trucks and without the provision for the heating of passenger trains. The complete unit weighs 120 tons and is equipped with four GE-253, 1500/3000-volt motors having a normal one hour rating of 240 h.p. on 2400 volts. The locomotives are geared for a speed at rated load of 12.2 m.p.h. and are capable of exerting a tractive effort of 42,000 lb. at the hourly rating. Each locomotive is equipped with Sprague General Electric Type "M" multiple unit control and regenerative electric braking apparatus similar to that used on the Chicago, Milwaukee & St. Paul main line locomotives.

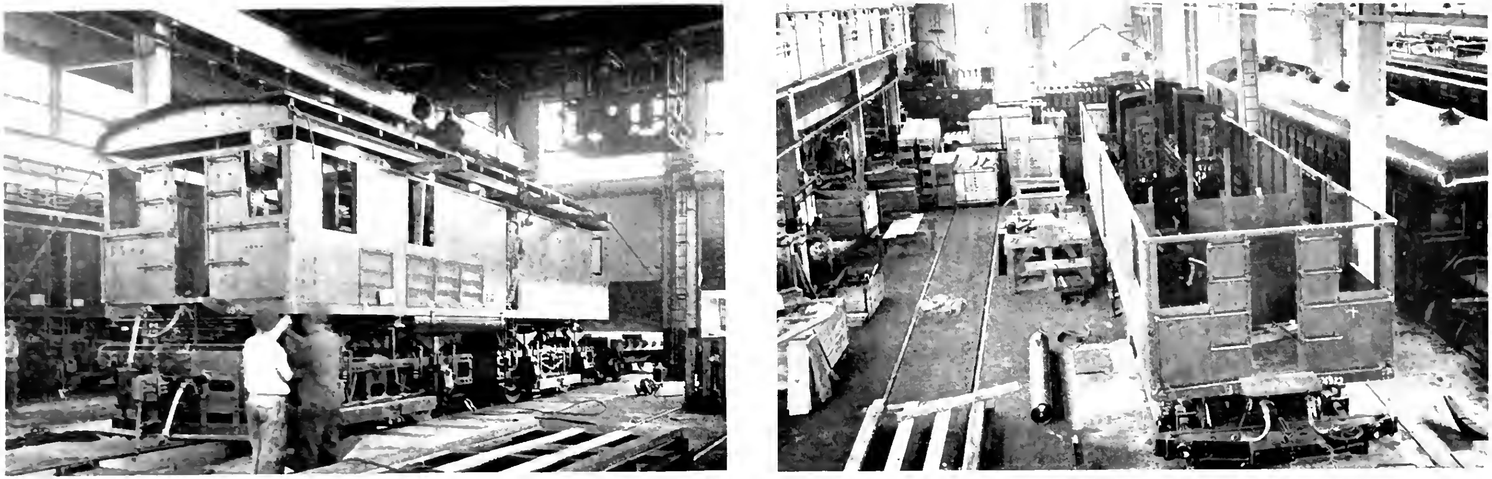
After tests were completed the locomotive was disassembled, care being taken to mark all parts so that the locomotive could be reassembled exactly as it stood in test. The process of knocking down this locomotive began with the removal of the pantograph trolleys followed by taking off the hatch covers of the roof, thus exposing the control and regenerative braking equipment. Through these openings the various smaller parts of the equipment were removed, including the motor-generator set, the air compressor and control equipment supports with contactors.

While these parts were being boxed for shipment, the roof was removed in one piece, weighing about 5 tons. In the building of the locomotive cab the roof and sides were assembled by the use of bolts and nuts with suitable inside flanges to facilitate disassembling. The usual construction of a cab of this kind would be by the use of solid rivets.

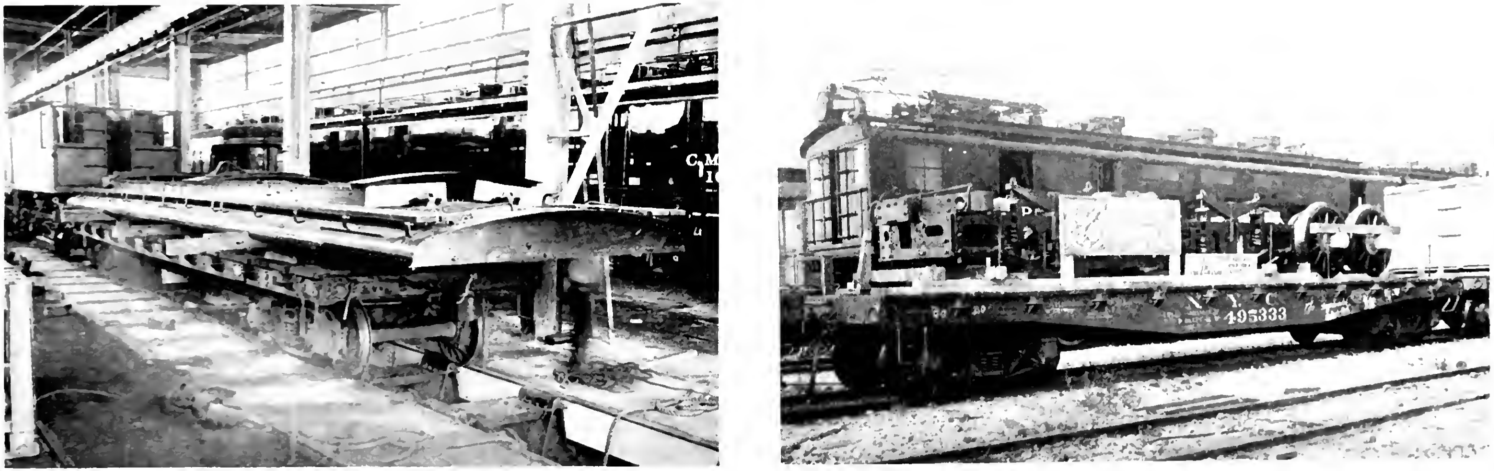
Locomotive Loaded on Flat Cars

On account of the flexibility of the roof caused by its extreme length (about 45 ft.) this was packed for shipment upon the platform of the locomotive after all equipment had been removed. After the removal of the roof, all electrical connections were opened up, the various panels, contactor compartments and other apparatus was removed and the sides and end framing taken down. The platform proper was the heaviest portion of the shipment weighing about 16½ tons. Together with the roof and the necessary boxing for shipment, this package weighed nearly 23 tons, the heaviest single article in the shipment.

The motors were then removed from the trucks, brake rigging and other accessory apparatus was also disassembled, the trucks separated and the axles removed. The



Different Stages in Knocking Down a 2400-Volt Locomotive for Export. This Locomotive was Shipped to the Bethlehem-Chile Iron Mines Company, Tofo, Chile



larger parts of the shipment for a single locomotive, together with weights and dimensions, are given below.

Weights of Principal Packages

Platform and roof (boxed)	45,800 lb.
Truck frame (unboxed)	24,000 lb.
Motor-generator set (boxed)	14,000 lb.
Traction motors (boxed, each)	12,000 lb.
Sides of cab (boxed)	10,000 lb.
Wheel and axle (unboxed, each)	8,000 lb.
Air compressor (boxed)	8,000 lb

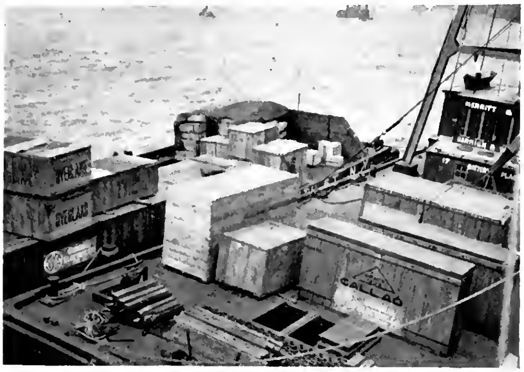
Dimensions of Most Bulky Packages

	Length	Width	Height
Platform and roof	46 ft. 3 in.	10 ft. 6 in.	5 ft. 7 in.
Sides	21 ft. 4 in.	6 ft. 10 in.	4 ft. 2 in.
Contactor compartment	16 ft. 2 in.	9 ft. 3 in.	6 ft. 10 in.
Truck frame	24 ft. 5 in.	10 ft.	4 ft. 7 in.

When completely prepared for rail shipment, the 120-ton locomotive occupied eight cars, including three box cars for the small package shipment and five flat cars for the heavier packages and the unboxed parts. Upon reaching the Harlem River, these cars were unloaded onto one of the harbor lighters and transferred to Pier No. 33 in Brooklyn alongside one of the W.R. Grace & Company's South American freighters. The second locomotive was shipped on a typical boat, the S. S. "Celia," an all-steel vessel 414 ft. in length and 50 ft. beam having a displacement of 8350 tons with a cubic capacity of 10,000 tons. The speed of this vessel is approximately 10 knots requiring about forty days for the trip from New York to Cruz Grande. With the exception of the one 23-ton package, the entire shipment was stowed in the hold of the S. S. "Celia." This package was lashed to the deck and for this purpose the boxing had been so constructed as to make it weather-proof.

A brief description of the railway upon which these 2400-volt direct-current locomotives will be operated may be of interest since there are several features which are not ordinarily met with in railway operation. This road is 15 miles in length extending from the port of Cruz Grande (about 300 miles north of Valparaiso, Chile) to the mining village located about 4 miles inland at Tofo. The iron mine at this point is located about 2200 feet above sea level and consists of two hills of iron ore which is removed somewhat after the manner of trap rock quarrying.

The railroad is standard guage with a uniform grade of 3 per cent for 14 miles and about one mile near the mines with 1 per cent grade. The trains will consist of an electric locomotive and from 12 to 20 fifty-ton ore cars. On account of the elevation of the line all the loaded cars come down grade. The motive power consists of three 120-ton, 2400-volt direct-current locomotives operating from a catenary trolley supported on concrete poles on the main line and from a 1200-volt third rail at the docks. It will be noted that while the mines are only four miles inland the railroad is 15 miles long. This circuitous route was necessary in order to limit the grades and the railroad is constructed in four loops, thus restricting the grade to a maximum of 3 per cent.


Parts of Locomotives on Lighter, Ready for Transfer to Steamship

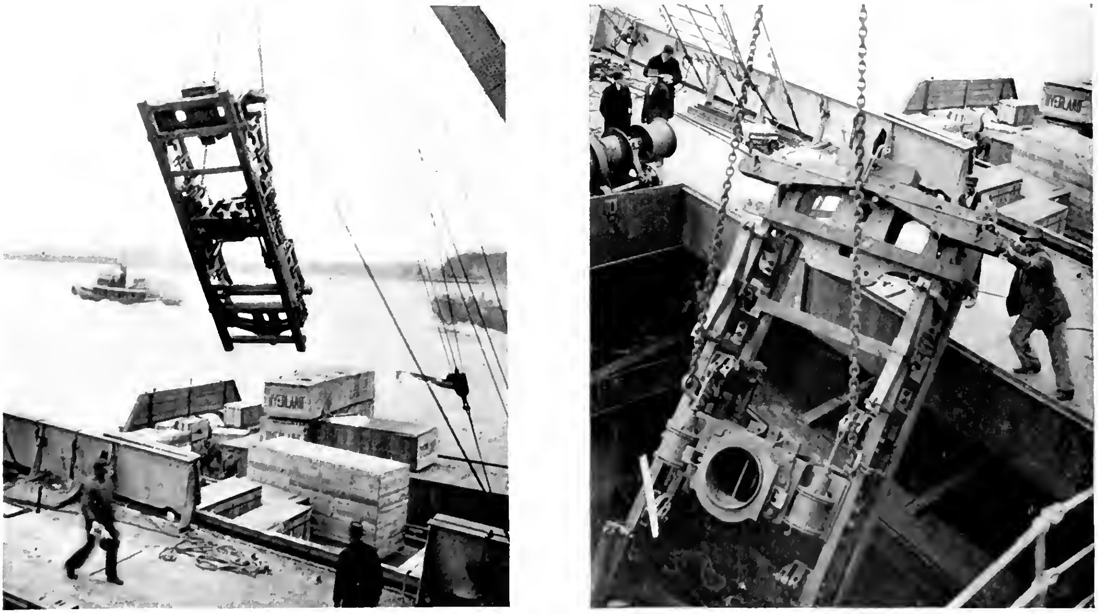
A power plant has been installed capable of furnishing sufficient power for mining and transporting 5000 tons of ore per day with provision for additional equipment to double the capacity. The present equipment consists of two 3500-kw. Curtis steam turbines generating 3-phase 60-cycle alternating-current and one 300-kw. 60-cycle turbine for lighting and small power service.

The railway substation equipment is located in the power house and consists of two 1000-kw. 2400-volt direct-current units operating directly from the 2300-volt alternating-current busses. On account of the circuitous route, there is considerable saving in feeder copper since a portion of the feeder takes a direct route from the mines to the docks.

In order to provide for suitable control on heavy down grades, these locomotives are provided with regenerative braking equipment similar to that supplied the Chicago, Milwaukee & St. Paul Railway for use on its main line electrification. The regenerative braking control will permit the locomotives to descend the grades with ordinary loads without the use of air brakes, thus returning power to the system and also appreciably saving wear on brake shoes, wheels and rails.

The air brake equipment on these locomotives is also of interest since it contains several new features which will enable the locomotive to descend with a greater load than can be held back by the regenerative braking equipment alone. This outfit provides for either straight or automatic operation either on the train alone, the locomotive alone or both together. In addition to this the cars are provided with an empty and loaded-brake to secure maximum braking power on each car whether empty or loaded. The trains will descend at about 12 m.p.h. at which speed with a trailing load of 1500 tons the locomotive will return approximately 1000 kw. to the line. The schedule will be so arranged that the empty train going up will take power from a loaded train coming down the hill. Excess power will be absorbed by switching operations at the mines and docks.

At Cruz Grande is a steamer dock equipped with three tracks for delivering the ore to the boats and to the steel bins. On account of the travelling gantry crane which extends over these tracks, it was considered advisable to feed the locomotives on this section of the road from a 1200-volt third rail. Power is supplied from either of the 1200-volt generators of the 2400-volt motor-generator set.



Loading Truck Frame on Steamship Celia

In addition to the railway equipment, a substation is located at Tofo which receives power from a 22000-volt transmission line and supplies the crusher motors, pumps, lighting, large air compressors and 600-volt direct-current motor-generators for operating electric shovels and mine locomotives.

THE TUNGAR RECTIFIER

By R. E. Russell

Supply Department, General Electric Company

This article is a description of the hot cathode argon gas filled rectifiers as at present developed commercially. These convenient rectifying units are now available in three sizes, the smallest having a capacity of two amperes when charging three cells of lead battery, and the largest a capacity of six amperes when charging from one to thirty cells. Some of the less obvious applications of a rectifier of this kind are also pointed out.—Editor.

The name "Tungar" applies to the hot cathode argon gas filled rectifier developed by the Research Laboratory of the General Electric Company as described by G. Stanley Meikle in the General Electric Review for April, 1916. A brief review of Mr. Meikle's article and the theory of the Tungar rectifier will be of assistance in describing some of the commercial types of rectifiers employing the Tungar principle.

Fig. 1. Two- and Six-ampere Tungar Rectifier Bulbs

It has been known for a number of years that a vacuum tube containing a hot and a cold electrode acts as a rectifier. Rectifiers of this principle were not practical for many reasons. More recently this principle has been utilized in the Kenotron, a rectifier of very high voltages, and also in the Coolidge X-ray tube. These two devices depend for operation upon the emission of electrons (small particles of negative electricity) from an incandescent filament. In the Kenotron and Coolidge tubes there is the highest possible vacuum, so that the electrons themselves are the only current carriers, and the tubes operate at low current and high voltage. When it is considered that the drop in voltage between the anode and cathode of the Kenotron is in the neighborhood of from 100 to 500 volts, it is quite evident that it would be impractical to try to operate it on the usual commercial secondary voltages.

In the Tungar rectifier bulb there is an inert gas, at low pressure, which is ionized by the electrons emitted from the incandescent filament. This ionized gas acts as the principal current carrier, with the result that the bulb operates with a very much lower voltage drop (5 to 10 volts) and is capable of passing a current of several amperes, the current limit depending on the design and size of the bulb.

Fig. 1 shows a simple 2-ampere, half-wave bulb, in which the cathode consists of a filament of small tungsten wire coiled into a closely-wound spiral, and the anode of a piece of graphite of relatively large cross-section.

The bulb rectifies for the reason that on the half cycle when the incandescent tungsten filament is negative the emitted electrons from it are being pulled toward the anode by the voltage across the bulb, these electrons colliding with the gas molecules and ionizing them, that is, making them conductive in the direction of anode to cathode; while on the other half of the cycle, when the filament is positive, any electrons that are emitted are driven back to the filament, so that the gas in the bulb is nonconductive during that half cycle.

All bulbs, whatever the material of which they are constructed, are carefully exhausted to the highest possible vacuum and then filled with argon in a high state of purity; but as certain impurities, even though present in very small quantities, produce a more or less rapid disintegration of the cathode and also have quite a marked effect on the voltage characteristics of the rectifier, means must be used to insure absolute freedom of the argon from these gases. To accomplish this, certain substances are introduced into the bulb at the time of manufacture, which chemically react with such impurities as may be present in the bulb. This reaction keeps the gas in a pure state practically throughout the life of the bulb. This purifying agent is shown in Fig. 1 in the form of a wire ring on the anode. As soon as the tube is started the purifier is volatilized and absorbs any foreign gases, and also (unfortunately for the appearance of the bulb) somewhat discolors the interior of the bulb. This is particularly true of the lower voltage bulbs in which a larger amount of purifying agent is used.

The general principles thus briefly discussed apply equally well to the half-wave and full-wave types of rectifiers. The half-wave rectifiers are particularly applicable to low current, low wattage designs on account of the much lower cost of manufacture and lower cost of bulb renewals. On larger sizes the lower power-factor makes them objectionable from the central station viewpoint, although it should be remembered that two half-wave rectifiers may be so connected to central station lines as to rectify both waves.

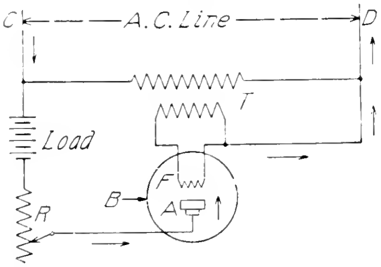


Fig. 2. Connections of Half-wave Rectifier

Fig. 2 shows the connections of a half-wave rectifier in its simplest form. The equipment in this case consists of the bulb *B*, with filament (cathode) *F* and anode *A*, transformer *T* for exciting the filament, rheostat *R*, and the load which is shown as a storage battery.

Assuming an instant when the side *C* of the alternating-current supply is positive, the current follows the direction of the arrows through the load, rheostat, bulb, and back to the opposite side of the alternating-current line. A certain amount of the alternating current of course, goes through the transformer *T* to excite the filament, the amount depending on the capacity of the bulb. When the alternating-current supply reverses and the side *D* becomes positive, the current is prevented from flowing for the reason already mentioned. In other words, the current is permitted to flow from the anode to the cathode, or against the flow of emitted electrons from the cathode, but it cannot flow from the cathode to the anode with the flow of electrons.

Fig. 3 shows the general method of connecting two half-wave bulbs with a single load and one compensator In this case both waves are used and the resultant direct current is a pulsating uni-directional current which may be smoothed out as much as necessary by means of direct-current reactance in series. This is unnecessary, however, in ordinary battery charging. In actually designing the rectifier outfits the rheostat is omitted and the regulation obtained entirely by means of a compensator, with which is combined the filament transformer and reactance.

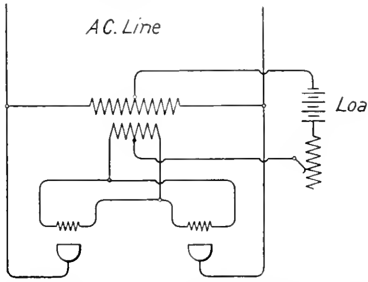


Fig. 3. Method of Connecting Two Half-wave Rectifiers to Rectify the full wave of Alternating Current

At present only small sizes (less than 500 watts) are being sold, and these are all of the half-wave type. Work is rapidly progressing on full-wave rectifiers for larger capacities and for services in which the half-wave rectifier cannot be used for reasons which will be mentioned later.

Commercial Types

At the present time there are three styles of Tungar rectifiers, all of the half-wave type with different ampere and voltage capacities as follows:

1. The 2-ampere unit, which when operated on 115 volts, 60 cycles alternating-current, will charge three cells at 2 amperes, six cells at about 1 ampere, and eight cells at about 0.75 ampere.
2. The 6-ampere, 7.5/15-volt unit, for charging either three or six cells of lead battery at 6 amperes when operated on 115-volt, 60-cycle circuit.

3. The 6-ampere, 7.5/75-volt unit, for charging from three to thirty cells of lead plate battery at from 1 to 6 amperes.

The 2-ampere Rectifier

This rectifier is shown in Figs. 4 and 5 The black japan sheet metal casing with perforated metal cover encloses the various parts of the rectifier, which are:

- Rectifier bulb and receptacle
- Compensator and reactance on one core
- Three ampere fuse and receptacle

The 2-ampere Tungar bulb is about 2 in. in diameter and between 5 in. and 6 in. long. This bulb is shown in Fig. 1.

The compensator is designed for stepping down the primary voltage of 115 to that required to deliver the proper direct-current voltage to the rectifier.

The connections of the compensator and the rectifier complete are shown in Fig. 6.

The dimensions of the rectifier casing complete are: 8½ in. high, 5⅞ in. deep, and 6¼ in. wide. It weighs 8 pounds.

The 6-ampere, 7.5/15-volt Rectifier

Fig. 4. Two-ampere Rectifier Complete

This rectifier is in general similar to the 2-ampere unit, with the exception that it has taps for charging three or six cells. These taps are connected to a fuse block on the top of the rectifier within the case, so that to charge six cells the fuse is screwed into the receptacle as shown in Fig. 7, and into the receptacle which is empty for charging three cells. With the exception of the tap the connections of the 6-ampere rectifier are very similar to the 2-ampere unit.

The 6-ampere bulb is about 3 in. in diameter and 7 to 8 in. long. It has a Mogul base on account of the higher current carried.

The dimensions of the 6-ampere rectifier are 10 in. high, 8 in. deep, and 6¼ in. wide. The weight is about 15 pounds.

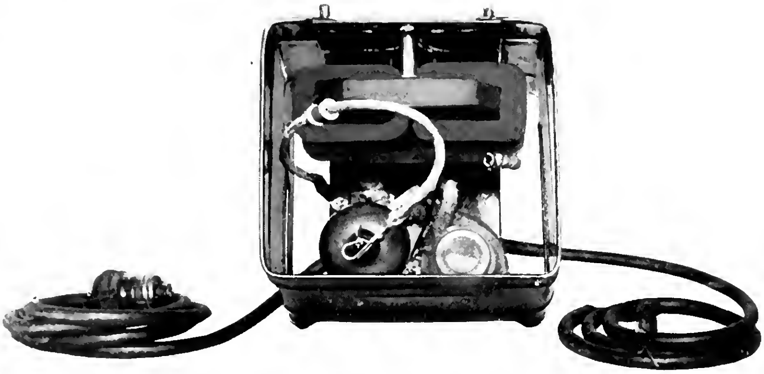


Fig. 5. Two-ampere Rectifier with Cover Removed

Operation of 2- and 6-ampere Rectifiers

To use either of these rectifiers after the proper connections are made to the battery (the red lead from the rectifier going to the positive lead of the battery, and the black lead going to the negative of the battery), simply connect the attaching plug to a convenient lamp socket and turn on the switch in the socket. This will cause the filament to light and the bulb will start charging immediately. The fact that the rectifier is charging is evidenced by a slight hum, which is due to the metallic case, and also on closer inspection it will be seen that there is a purplish glow between the cathode and the anode. This is not present when current is not flowing through the direct-current leads of the rectifier or through the bulb.

The 6-ampere, 75-volt Rectifier

This rectifier, as will be seen from Figs. 8 and 9, is somewhat more elaborate than the two smaller capacity sets just described. This set is designed for charging small batteries up to a total of thirty cells. It is equipped with a 6-ampere, 75-volt Tungar bulb with Mogul socket, a compensator with 15 taps, a dial switch, a reactance in series, a triple-pole fuse block (2 alternating-current fuses and 1 direct-current fuse), a steel panel and enclosure for these parts. On the front of the panel are a 10-ampere ammeter (in direct-current circuit), a handwheel for compensator switch, and a triple-pole snap switch (1 pole in the direct-current circuit and 2 poles in the alternating-current circuit).

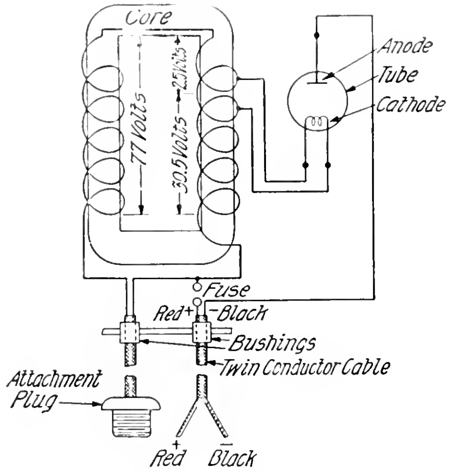


Fig. 6. Complete Connection of Two-ampere Rectifier

The dimensions of the panel are:

Height	11 in.
Width	10⅞ in.
Total depth of the complete outfit	12¼ in.

The 75-volt bulb is generally similar in appearance and size to the 15-volt bulb, but on account of the higher voltage output has not such a large amount of or so active an agent for absorbing the foreign gases in the bulb.

Efficiency

The efficiency of the present sizes compares favorably with other reliable devices of similar capacity. The smallest size takes from 60 to 80 watts from the line. The 6-ampere rectifier requires about 200 watts to deliver 90 watts output.

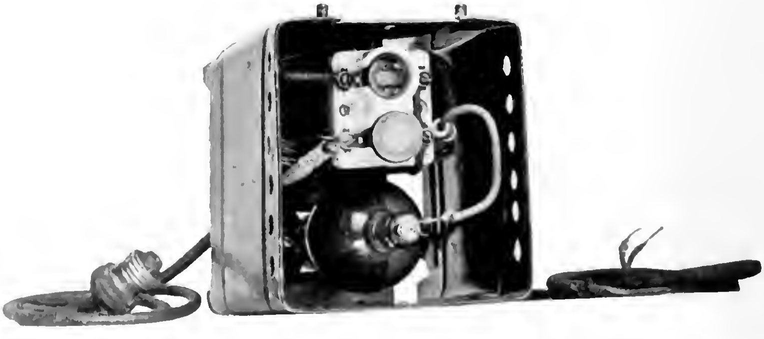


Fig. 7. Six-ampere, 15-volt Rectifier with Cover Removed

The efficiency of the 75-volt, 6-ampere rectifier is 75 per cent when delivering its full output of 450 watts. A curve of efficiency and cost of charging various numbers of three-cell batteries is shown in Fig. 11.

Uses

Probably most readers of this article will associate this rectifier with gasoline automobiles for charging starting and lighting batteries. There has already been a large demand for this purpose. The 6-ampere, 75-volt Tungar rectifier was designed primarily for charging ten of these three-cell batteries in public garages and battery service stations. The 6-ampere, 7.5/15-volt rectifier is for charging three to six cells in the home garage.

The 2-ampere unit has a similar field for charging smaller three-cell batteries for lighting and ignition; in fact, some service stations have made it a rule to charge all batteries at not over 2 amperes.

But there have been many other applications suggested which are not so obvious and probably for that reason seem to the writer more interesting. In rectifier work in the past, referring to rectifier loads, "amperes" was used; with the Tungar it is possible to speak in "milliamperes." In other words, a mercury arc rectifier requires at least one or two amperes to sustain the arc. In the Tungar the filament keeps the arc excited, thus permitting lower operating current. This has permitted the use of these rectifiers where others were impossible.

As an illustration of this feature: An electromagnet had been used for a certain purpose and operated from alternating current. This method required 55 watts for 24 hours, or 1320 watthours daily. It was found such a magnet could be operated from a 2-ampere Tungar bulb at .03 ampere and take only 18 watts alternating current, or 432 watthours daily—a saving of 67 per cent.

Another feature which will add to the usefulness of the Tungar is the fact that it is self-starting. The bulb starts and is ready to rectify as soon as current is supplied to the filament. Starting under normal conditions will take less than one second from the turning on of the alternating-current supply.

This makes the rectifier desirable for use with electric clocks, contact devices, motors and other small current devices where no storage battery is used.

In one instance a rectifier was desired for an electro-magnetic recording device in connection with timing job work in factories. A master clock was supplied with a contact device to make electrical contact every 15 minutes. The contact was connected in the primary, or alternating-current side of the rectifier. In using this scheme of connection the rectifier was run only a few seconds at each contact, or only a few minutes a day. With any converting device that must be continuously excited the wattage would be high during the entire working day. The same advantage would apply to the operation of fractional horse power motors used on adding machines, addressographs, electric pianos, etc., where frequent stopping and starting is the rule.

Fig. 8. Six-ampere, 75-volt Rectifier

Uniformity of bulb life will be found to play an important part in the popularity of the Tungar rectifier. There is every reason to believe that the bulb life will average at least 600 to 800 hours under normal conditions. In actual commercial use many of the standard bulbs have run as long as 1500 to 2000 hours, and the record for long life to date is 3440 hours on a 6-ampere, 75-volt bulb, which was operated at an average overload of 30 per cent. With the Tungar bulb it is possible and often desirable under certain conditions of service, where extra long life is essential and quick and frequent starting unnecessary, to operate the filament at reduced voltage and thus reduce evaporization and prolong the life. No definite information is at present available on the bulb life under such conditions. Some tests already under way indicate that the life will be considerably prolonged. This condition will prove of great advantage in the operation of rectifiers on storage batteries in connection with direct-current railway signals on electric interlocking systems.

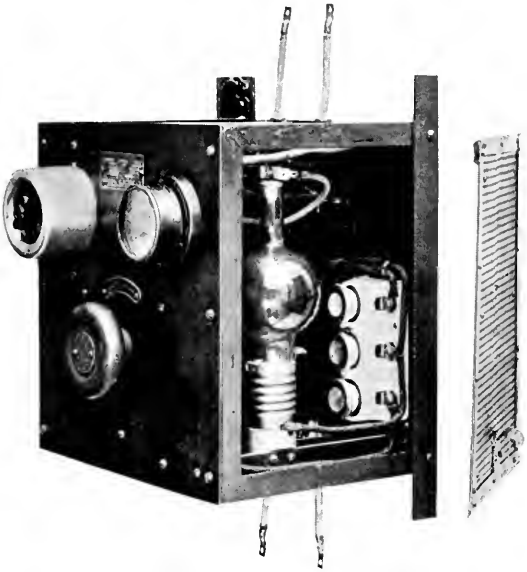


Fig. 9. Six-ampere, 75-volt Rectifier with side grating removed, showing Tungar Bulb and Fuse Block

Railway Signals

At the present time two Tungar rectifiers are being tried out by one of the large railroad companies for charging direct-current automatic signal batteries. The connections are shown in Fig. 10.

The track battery consists of three lead cells connected in multiple and through a resistance to each rail of track. The rectifier is connected to the battery and charges it continuously at about 0.75 amperes. In this rectifier an insulating transformer (separate primary and secondary) is used in place of the usual compensator. This is to prevent connection between the alternating-current line and the battery, both of which are grounded.

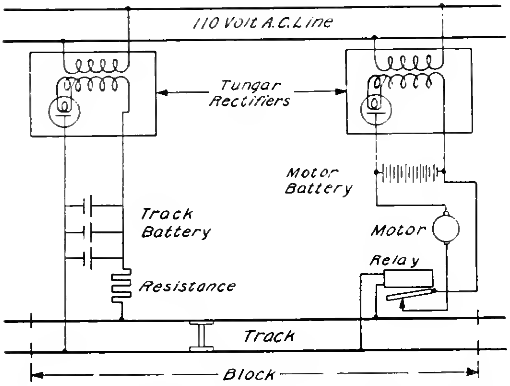


Fig. 10. Connection of Two Tungar Rectifiers for charging Storage Batteries operating Automatic Railway Signals

The motor battery used to operate the semaphore on the block consists of from five to eight cells. Here the rectifier is connected in much the same way as the track battery rectifier. The capacity of this rectifier is 0.13 to 0.2 amperes and 10 to 18 volts, depending on the number of cells used.

The rectified current output is designed to be just sufficient to keep the battery at a certain point of charge by supplying sufficient current to equal the average discharge plus the losses in the battery. It will take some months to determine the practicability of such a scheme, but if the device tests out to the satisfaction of railroad engineers, it will undoubtedly be a popular device for this service on account of its low cost and simplicity.

Fire Alarms

Another service to which the Tungar rectifier is applicable is the charging of storage batteries for use in operating bells and fire alarms in public schools and factories.

In the Schenectady schools, for example, several of these rectifiers have been installed for charging 7 to 9 small two-plate storage cells in series, having a normal charging rate of 0.75 ampere. In this particular installation duplicate batteries are used; one is connected to the discharging circuit or bells, etc., while the other battery is being charged. In this way the battery under charge is never connected to the bell system. In any case where there is a possibility of the alternating-current line becoming connected to a bell or other low-voltage circuit, an insulating transformer should be incorporated within the rectifier. This will add slightly to the cost of the rectifier set, but "safety first" makes such a design imperative. A similar rectifier charges 15 cells of a ¾-ampere battery, which runs the large tower clock in one of Schenectady's churches.

Telephone Batteries

Tungar rectifiers are also useful for charging storage batteries in private branch telephone exchanges. A one-half wave rectifier is useful on telephone systems only when two batteries are used; that is, the battery on charge must never be connected to the telephone line. The extreme pulsations of the half-wave rectified current would cause a very annoying hum in the telephone receiver. In small private exchanges using a battery having a 5-ampere charging rate or less it is usually cheaper to put in an extra battery than to install a more expensive charging device that is noiseless on the telephone line. A rectifier similar to the 6-ampere, 75-volt

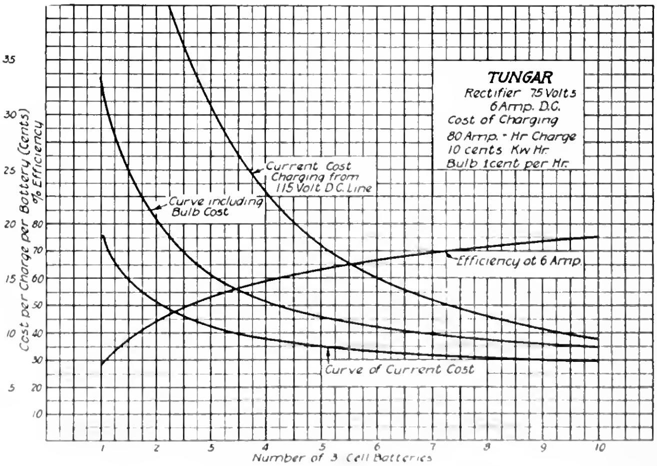


Fig. 11. Curve showing Efficiency and Cost of Charging Batteries with Tungar Rectifiers

type is being built for this service. The first sizes to be standardized will be 2.5-ampere and 5-ampere for charging the eleven or twelve cells generally used for telephone operation. These rectifiers will be equipped with insulating transformers.

For larger telephone systems it will be desirable to have a rectifier which can be used for charging the battery at the same time that it is discharging. This requires a full-wave rectifier having an exceptionally smooth wave, or in fact a nearly straight line direct current. At the present time such a rectifier has not been completely developed, but from present indications there is a possibility of such a device in capacities usually required.

Electric Vehicles

The possibility of using Tungar rectifiers for electric vehicle battery charging still seems rather remote. For this service at least 30 amperes and 110 volts are necessary—over 3 kilowatts—and commercially satisfactory bulbs have not yet been made.

Summary

Some of the many possibilities of the Tungar rectifiers in a variety of services are indicated in this article. There are many more which will undoubtedly become evident with the further development of the rectifier. The half-wave rectifier might be useful for operating electric toys. The writer found that it ran his youngster's miniature "N.Y.C. Locomotive" with perhaps more pull than alternating-current would give. There is a possibility of using these rectifiers for magnetic chucks on lathes, for small motors, for electro-therapeutic work, for electroplating small jewelry, etc., in fact, anywhere that not over 500 watts at low voltages is required for strictly direct-current uses and where only alternating-current is available.

Some of the features of the new Tungar rectifier may be briefly summarized as follows:

Low first cost
Good efficiency
Low installation cost
Adaptable to many special uses
Small size and light weight
Absence of adjustments, oil or grease
Self starting
Long bulb life
Simplicity of operation

With so many advantages, and so far as can be seen now, no real disadvantages, there is a big future for the little Tungar. Even though it has been on the market only three months, nearly one thousand have been sold, and there is a steadily growing demand for the device.

THE DEVELOPMENT OF OUR FLEET AND NAVAL STATIONS*

By Prof. W. L. Cathcart
University of Pennsylvania

One of the paramount problems confronting the United States today is preparedness. The gravity of the naval situation is brought out with remarkable clearness in the following article which analyzes the strategic conditions on our east, south, and west coasts, the inadequacy of our navy yards and naval strength in ships. In conclusion, Prof. Cathcart appeals directly to the Engineer who, by reason of his knowledge, is indispensable today.—Editor.

WHY WE NEED A GREAT NAVY

Why does the United States need a great Navy? Several conditions affect the answer: First, with unequalled wealth inviting spoliation, this Republic is the most vulnerable and ill-defended of all the great Powers. Second, our territory is immense, stretching from Eastport, Maine, to Manila, more than half around the world. Third, there is the factor of distance with regard to that territory, which factor has no parallel in Europe. Fourth, the fact that the United States Navy is really a "Disunited States" navy, since, like Russia with her Baltic and Black Sea littorals, we have two widely separated coasts, linked in our case by a canal which may fail us in a crisis either by slides, or by treacherous or direct attack with high explosives on its locks.

And these are not our only dangers; indeed, they may be the least of them. It is bad enough to be helpless. It is worse still, in one's helplessness, to provoke attack by a challenging attitude toward the world. And yet, for long years, that is just what this Republic has done. Militarily negligible, it has staggered diplomatically under the weight of some national policies which, while just, are as world-irritating and war-breeding as any that history has known. These policies are: The Monroe Doctrine, the Exclusion of Asiatic Races, the Neutralization of the Panama Canal and the "Open Door" in China.

Glance for a moment at but two of these policies. The Monroe Doctrine extends our "political suzerainty over two continents, comprising a fourth of the habitable earth and one-half of its unexploited wealth." Excluding Canada and the United States, this vital and yet war-inviting policy covers twenty republics, having a total area of nine million square miles, a population of eighty millions, and a foreign trade of nearly three billion dollars. And all this—these lands and peoples, their trade and wealth—are to be guarded from European seizure by the force behind a doctrine which is not international law, but simply a bluff declaration by the United States that Europe shall not enter in!

Our immunity from attack, thus far, because of this Doctrine, has been due chiefly to two conditions: the lack of means for the swift transfer of fleets and armies across the Atlantic, and the extreme delicacy of the balance of power in Europe. The progress of steam navigation has swept the first of these away, and as for the second, who dare predict political conditions in Europe when this war closes? Let me quote Elihu Root, sometime Secretary of State. He says:

"Our danger is not now, but later, when peace has been made and the great armies are free, when rulers and governments look about for ways to repair their losses, and when the great spaces and ill-defended wealth of the new world loom large on the horizon of their desires. * * * Then, must be determined whether the Monroe Doctrine has behind it the sincerity and courage of a great nation, or is to be surrendered as an idle boast."

Now, take the Panama Canal. By international law it is a part of the territory of the United States, and it is also, as a military and commercial highway, one of the world's greatest prizes. Therefore, we must defend it. Further, by the provisions of the Hay-Paunceforte Treaty of 1901, we guaranteed its neutralization. Either of these obligations necessitates a very powerful fleet, and neutralization presents as well most complex and dangerous problems for the future. David Jayne Hill, once Assistant Secretary of State, says:

"The time will possibly come when every right the United States possesses in the Panama Canal—the right to close the Canal, to defend it with ships within the three-mile limit, to re-victual its vessels within the Canal, and to subsidize its ocean-going vessels passing through it—will be called in question under this treaty."

We have glanced at the possible effects of but two of our national policies, and they alone hold menace enough for the future.

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* Abstracted from an address before the Schenectady Section A. I. E. E.

Trans-oceanic attack can be met primarily only by a fleet. Do you wonder, then, that statesmen and strategists fear that the time is drawing near when the mighty thunder of American guns will roll out in mid-Atlantic or on the sun-lit Caribbean, or perhaps along the coasts of Europe, or at the threshold of the Far East?

The surest way to delay the coming of that time is to have, behind the parleys of our diplomacy, a naval force stronger than those of our possible foes. All history shows that diplomacy, when backed by guns enough, can keep the peace. But notes without powder behind them are futile.

STRATEGIC SITUATION, EASTERN COAST

The elements of naval strength are: first, the fleet—its ships and men; and, second, the shore stations—navy yards at home and naval bases in our overseas possessions, which dock, repair and supply the ships, and from which the fleet may strike.

Of these two components of naval power, the shore factor is manifestly the more vital. For, when cut off by superior force from its bases in war, a modern fleet, with its many needs, becomes helpless—a homeless rover, whose food, fuel, and ammunition soon fail, and whose encrusted hulls move ever more slowly to their sure doom in battle. It is only the swift and isolated commerce destroyer, fattening on its prey, which can thus live at sea; and even so, its life there during this war has been brief indeed.

Let us glance briefly at the strategic situation of our eastern coast, with respect to our naval stations and the lines of approach of an attacking fleet.

When invasion by a European power is threatened, our Navy Department will know only that the enemy has set sail from some port across the Atlantic. His specific course and objective on our coast, or in the Caribbean Sea, will be unknown. Our fleet, if strong enough, would take the offensive-defensive, and attack the enemy a thousand miles or more at sea. To locate him, our admiral would send out a long line of scouts to scour the seas in a great arc from Cape Sable in Novia Scotia to Trinidad at the lower entrance of the Caribbean Sea.

There would be four principal points of departure for this enemy fleet, viz: from the Orkneys, the northern base of the British Grand Fleet; from the English Channel or the Straits of Gibraltar; or from some point on the African coast, as Agadir.

The steaming radius of a modern fleet in war is, for full efficiency, about two thousand miles; that is, it can steam that distance, fight a battle, and then return, if necessary, to its base. Now on these four lines of approach to our coast the distances range between 2800 and 4200 sea miles.

Hence, continuous operations against us from European bases are not practicable in the present state of naval science, and any enemy but Great Britain must, for such operations, seize a naval base on or near our coast. This does not apply, of course, to raiding expeditions—to a sudden dash, for example, in the summer by oil-burning battle cruisers, which could readily re-fuel at sea.

There are also other reasons why, for continuous operations, a fleet must seize an adjacent naval base. In the first place, a naval force, steaming far from its home bases, must be followed by a train of supply vessels—which train is huge when the force is large. Second, fleets can not invade. It takes an army to seize and hold territory. So if invasion is contemplated, the enemy fleet must be followed by troop transports. Finally, unless the enemy had previously gained command of the sea, these helpless fleets of transports and supply ships of his must be guarded always while en route throughout the whole period of his operations, and by a stronger force than we could bring against him.

From these considerations, several things are clear: First, for successful invasion any enemy but Great Britain must first seize a naval base on or near our coast. Second, to seize that base, he must first defeat decisively our fleet either destroying it, blockading it or forcing it to withdraw to a distance. Then, and then only, when the enemy has won command of the sea, will his convoys of troops and supplies be safe.

Naval bases suitable for hostile operations are fairly numerous on our coast. For example, Delaware Bay, Narragansett Bay, Provincetown, Mass., and several others, in their present defenseless state, could be seized with ease, if our fleet were first defeated.

As to our naval stations on this coast, a remarkable condition exists. Our chief navy yards there all lie within an air-line distance of five hundred miles, although our Atlantic and Gulf coasts are more than three thousand miles long. If an enemy should gain possession of these five hundred miles of coast, our dreadnaughts would be homeless, unless the fleet could flee to the Bay of Panama, since our southern yards are equipped for small craft only.

And this is not all. As the chart shows, Norfolk, which is the southernmost of these chief yards, is 875 miles from Key West and 1250 from Culebra, our most advanced West Indian base. And both Culebra and our other base at Guantanamo in Cuba are as yet wholly unequipped.

After the battle of Jutland, the British fleet had but four hundred miles to steam to its base for a swift refitting, which made it ready for action again within five hours of its arrival. As I will show shortly, our first sea battle of the future may be fought off Culebra, or twenty miles east of it, at St. Thomas.

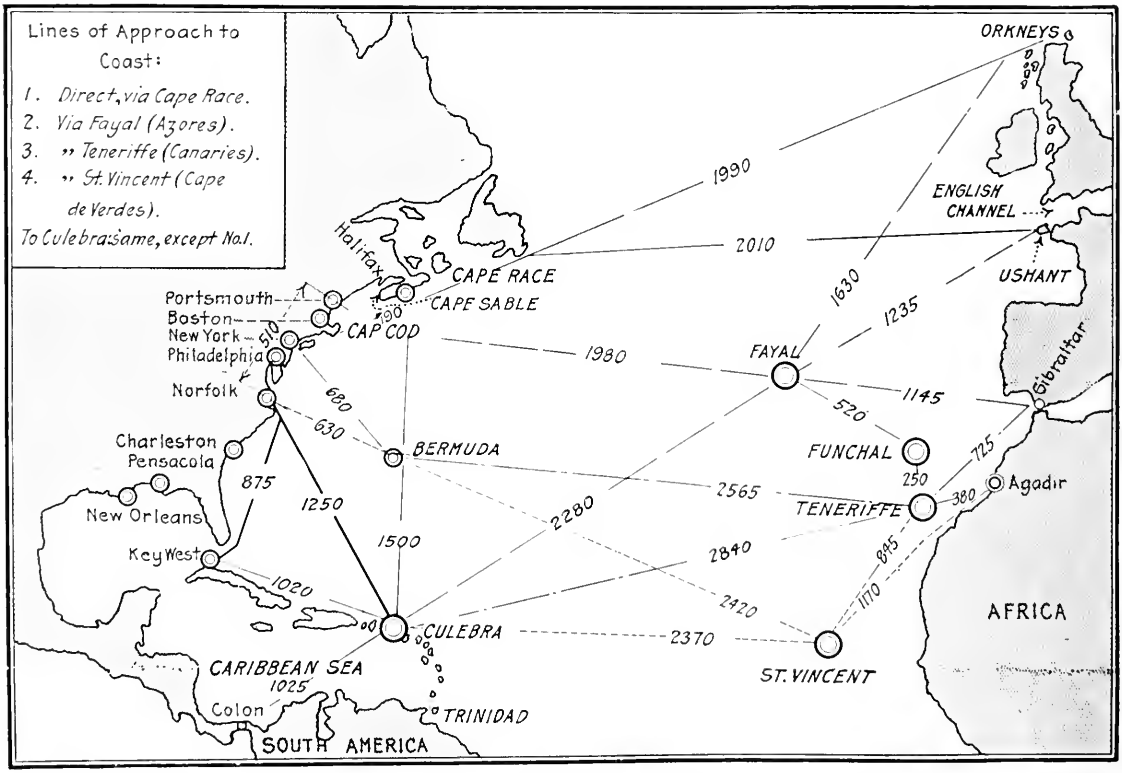


Fig. 1

So, after that possible battle, a battered dreadnaught may have to limp its slow way through 1250 miles to Norfolk, with imminent danger of foundering, of destruction or capture during that perilous run. Further, a damaged ship, which might be saved by quick docking after battle, will have to sink, as matters stand, unless she can be beached in some near-by harbor of refuge and coffer dams built.

Now, as to the probability of that battle off Culebra: As I have shown, no invasion of our eastern coast is possible, until our fleet has first been put out of the reckoning. If, then, the enemy must thus eliminate our fleet, it seems probable that he would endeavor to force action where our naval strength is most vulnerable; that is, off Culebra, where our ships would be more than twelve hundred miles from their home bases.

Again, for continuous operations against us, the enemy must have a naval base of his own, and the seizure of a small island, like Culebra or St. Thomas, or of a harbor in some larger island, would be much easier than the attempt to take some estuary on our coast, when opposed by the full strength of the mobile army of the United States.

Finally, if thus established in the Caribbean, with our fleet negligible for the time, the enemy could raid our South Atlantic and Gulf coasts at will; he could flank all our routes to the Caribbean and the Panama

Canal; and when (with full command of the sea) his convoys of troops had come, he could invade the Canal Zone, a thousand miles from St. Thomas.

Possession of the Canal would give him not only a powerful lever for bringing pressure on our Government, but would enable him to block the retreat of our defeated fleet to Gatun Lake or the Bay of Panama, and to prevent the coming of reinforcements from the Pacific.

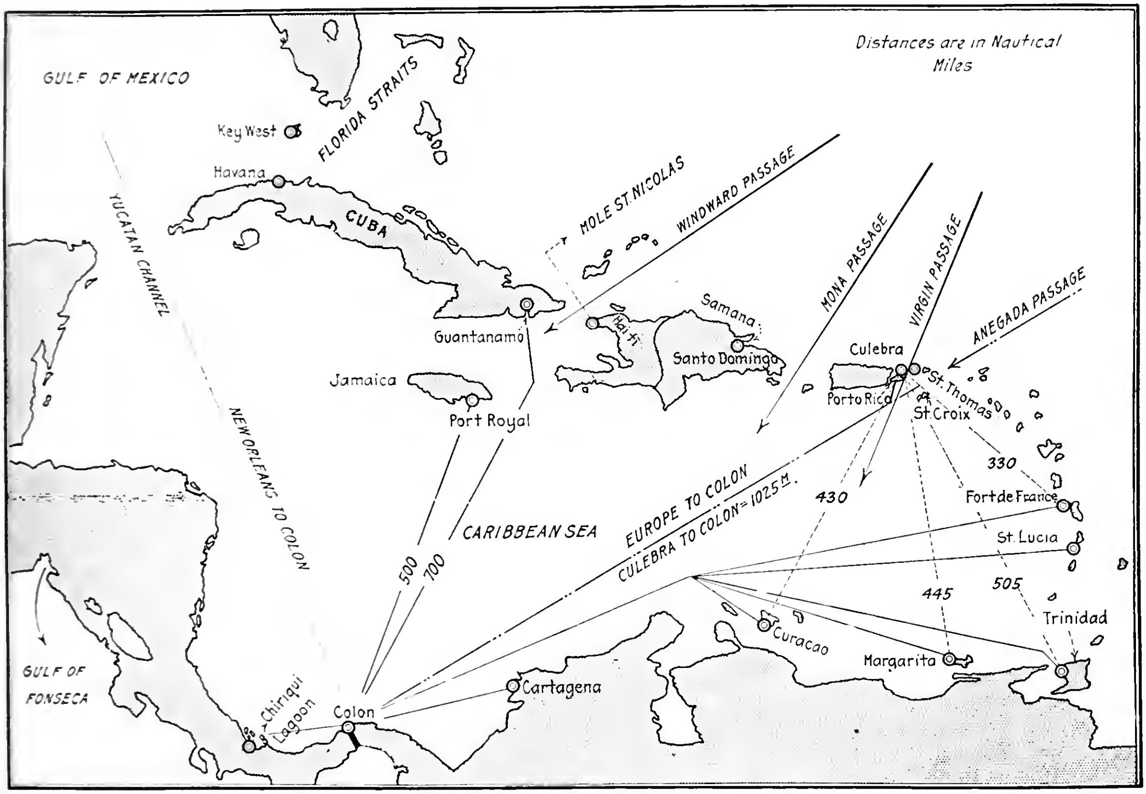


Fig. 2

These, then, are the considerations which make it seem probable that some point in the Caribbean Sea would be the primary objective of an enemy, since once established there he would find the second stage of his campaign much easier; viz: the invasion of continental United States.

STRATEGIC SITUATION, CARIBBEAN SEA

Now, consider our strategic situation in the Caribbean Sea. A glance at the chart will show that this sea is, as Admiral Mahan once wrote of it, "pre-eminently the domain of sea power." For its size it has more strategic positions than any other important expanse of sea on the globe. These potential naval bases cluster around Colon in a menacing ellipse, like hungry wolves lurking in the shadows about a camp fire. For the United States, the mastery of this sea in war is almost vital, since that mastery is the bulwark of our defense of the Monroe Doctrine and the Panama Canal.

Now, as to our two naval bases, Guantanamo and Culebra: Guantanamo is but seven hundred miles from the Canal, and, as it flanks all routes to Colon except that from Jamica, its location centrally is almost as good. Further, it has surpassing advantages in the fact that it is on a large island, which not only has great native resources, but also direct railway communication with manufacturing centers in the United States, except for the short sea link between Key West and Havana. Hence, supplies can reach Guantanamo by interior land lines immune from attack by sea, if the Florida Straits be guarded effectively.

As compared with Guantanamo, Culebra

is about six hundred miles farther to the eastward, and hence has a far better command of the eastern entrances to the sea—a fleet based on it flanking all routes through them by short runs of 350 to 500 miles. Further, it is but a few miles from Porto Rico, which is in itself difficult of defense. And finally, it is a salient thrust far to the eastward. If it were fortified and equipped, and an adequate fleet were based there, it would not only flank the main routes from Europe to our coast, but a hostile force endeavoring to enter the Caribbean would not dare to pass Culebra without first defeating our fleet there, since otherwise those ships of ours would be a constant menace to its communications with its home bases.

All of these advantages, and more, hold for St. Thomas, just across the Virgin Passage from Culebra. If we had let St. Thomas pass to the possession of a strong military power unfriendly to us, our base at Culebra would be confronted by a rival fortress on the further shore of that narrow pass. These conditions would be as if Gibraltar faced an equally formidable and alien "Rock," with but the Straits between.

The destiny of nations has given the United States full opportunity for holding the strategic mastery of the Caribbean Sea, through its present and prospective tenure of predominating positions there. But, strategic dominance on the sea means nothing, if the sites on which it depends are not fully equipped, fortified, and garrisoned, and have not adequate fleets based on them, since a more powerful enemy would simply wrest them from us. Therefore, these neglected West Indian bases of ours give cause for grave concern. With them, some day, the fate of this Republic may rest.

Their trouble is, as a prominent officer writes me, that the naval base in a distant sea has no constituency. Politics and Congressional "pork" are absent from its wave-washed shores. The votes do not lie thickest beneath its tossing palms. There are many able and patriotic men in our Congress, but there are not a few at Washington who are immersed in their own sordid schemes, to whom the flag of Valley Forge is but a strip of bunting, and who care little for its honor and security on these far-off waters.

So lacking naval bases in both the Caribbean and the Pacific our fleet is tied to our shores, and our naval arm is cramped and palsied. Under such conditions as these, the General Staffs of the strong military powers of Europe and Asia must smile sardonically at our guarantees of independence and our virtual protectorates of these weak West Indian lands. At this time the United States is too feeble to defend itself. Its declarations as to the protection of these southern republics are, in effect, but "scraps of paper."

STRATEGIC SITUATION, NORTH PACIFIC

Long ago, William H. Seward told the Senate of the United States that the commerce, politics, thought, and activities of Europe would "ultimately sink in importance, while the Pacific Ocean, its shores, its islands, and the vast regions beyond, will become the chief theater of events in the world's great hereafter."

Years later, that master-analyst of world-policies and strategy, Admiral Mahan, echoed these words, when he said:

"Men have not yet adjusted their thought to the new condition that the Pacific, rather than the Atlantic, holds the problem of the near future."

Let us now consider the military relations of our Pacific possessions. Napoleon said: "War is a business of positions," and positions of military value the United States has in plenty in this northern ocean. In the first place, we own, on the shores from Panama to Kiska in the Aleutian Islands, every important strategic point except three, viz., the Galapagos Islands, Magdalena Bay in Mexico, and Esquimault, the fortified port of British Columbia. Thus, geographically at least, our power over these shores is predominating for two-thirds the width of that great ocean.

Now, if you plot on a chart the principal strategic positions in a given war area and draw lines connecting them, the position lying nearest to the common intersection of these lines is predominating as the center of communications for that area.

On this basis, as the chart shows, Hawaii is the strategic focus of the eastern half of the North Pacific Ocean. This means that a fleet based there can strike with equal ease, in offense or defense, at all points on the great arc of coast line from Kiska to Panama. Hawaii thus dominates the whole strategic front formed by the shores of the eastern half of the North Pacific Ocean.

Similarly, the strategic lines of the western half of the North Pacific all intersect near our possessions, Guam in the Ladrone group, which is thus the strategic focus of that half of the ocean, and hence a menace in war to every position there, from Japan's northernmost one at Yetorofu and that of Russia at Vladivostok, down the Chinese coast to Singapore in the Straits Settlements. Well within the circle of Guam's protective area lie the Philippines, indefensible of themselves. And, also, well within its reach, stands that (now closing) "Open Door" in China.

Steaming at 12 knots an hour from Panama, it would take a fleet 16 days to reach Honolulu, 28 to Guam, and 33 to Manila. So, no fleet stationed on our western coast in war could protect the Philippines and that "Open Door." For their defense, and to some extent that of Alaska (2000 miles from San Francisco) we must rely on our island bases, Guam and Hawaii.

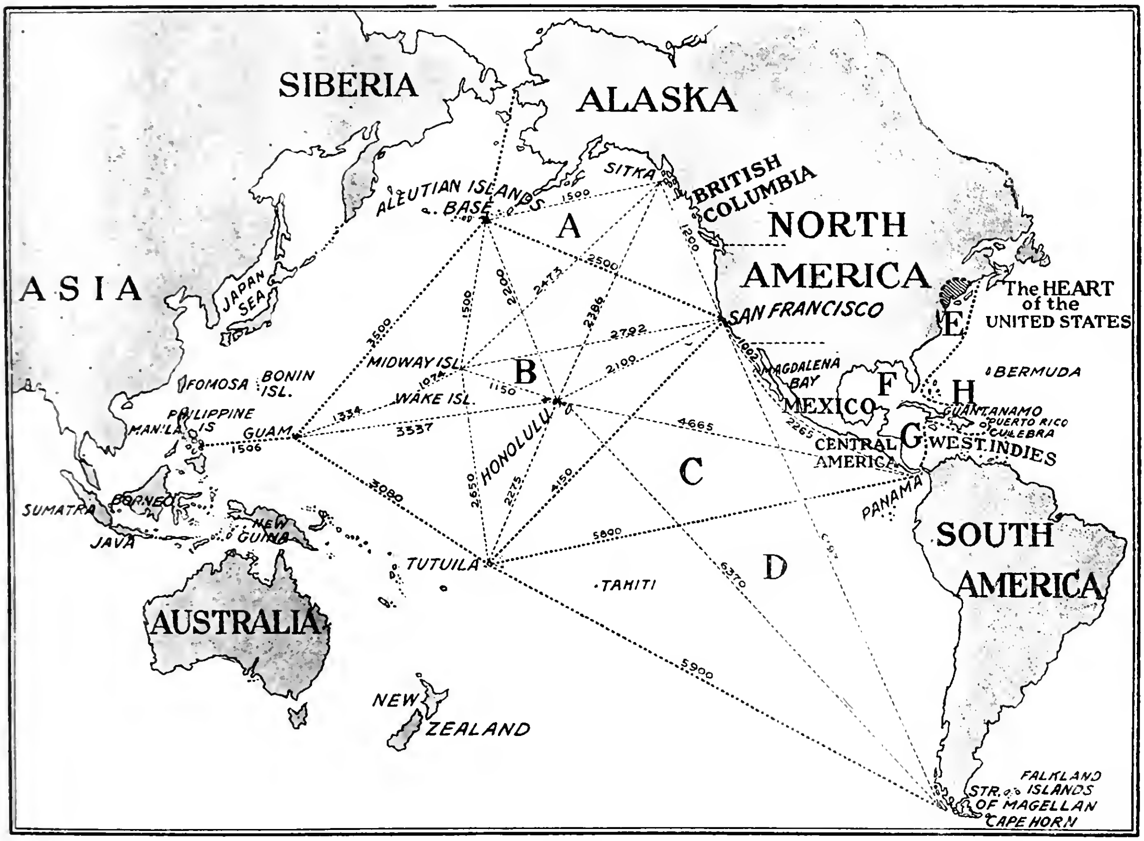


Fig. 3

Now, consider the relations of these bases to the defense of our western coast. For it, Gaum and Hawaii, if made ocean fortresses, would be our Malta and Gibraltar against aggression by any enemy sailing from the Far East. If, in war, we had strong fleets based there, no enemy from Asiatic waters would dare to pass Guam without masking or reducing it and destroying or dispersing its fleet. And, later, he would have a similar victory to win off Hawaii, before the Pacific coast would meet the shock of war.

And this is not all. From the southwestern extremity of Alaska stretches the long trail of the Aleutian Islands, the southern boundary of Bering Sea. These islands overlap the Alaska coast to some extent, their dangerous rocks guarding it like a fog-enshrouded barrier. Now, in Unalaska, one of these mist-veiled islands, there is an ice-free port, Dutch Harbor, which from its location and its great natural strength, seems to have been designed as Alaska's challenging outpost—a sub-Arctic Gibraltar, from which a watching fleet could guard with ease the main channels of approach to that territory.

And, further, this harbor, if developed, would be a most effective auxiliary to our chain of bases, stretching like the piers of a colossal bridge from Panama through Hawaii to Guam. The reason is that Dutch Harbor, Honolulu, and San Francisco are the vertices of an equilateral triangle, each of whose sides is two thousand miles long—which is about the radius of action of a fleet in war. This means that if either of the three were threatened, supporting forces from the other two could reach it simultaneously and make a united attack. And finally, with Dutch Harbor fortified and an adequate naval force there and at Honolulu, the Hawaii-Unalaska line would form an ocean-wall two thousand miles long, through which the enemy, flanked on both sides, would have to break before he could approach our coast.

There is another consideration which makes our strategical control of the North Pacific most important in war. It has been reported that German crops in the last harvest were reduced by thirty-five per cent, owing to the tremendous demand for nitrates for use in explosives.

The same conditions would exist in this country, in sudden war at this time. It is true that the Navy Department has taken steps to secure a very moderate reserve supply of Chilean nitrates, and that the construction, under government support, of a plant for the fixation of atmospheric nitrogen is contemplated. But, any nitrogen plant under government auspices is likely to be somewhat lingering in construction, so that the control of the North Pacific in war, to prevent cutting our communications with Chile, is of grave importance.

Guam is a little island—seven miles by twenty-nine—with no ships stationed there and garrisoned only by a small force of marines.

Guam, Samoa, and Dutch Harbor are wholly undeveloped, Hawaii is but partially fortified, and the garrison of Alaska is just five hundred men.

What this republic has to fear is, less the "yellow peril" than the "American peril"—the incomprehensible ignorance of, the careless indifference to the noble future which the God of Nations offers us in the Pacific Ocean. If national duty and national pride can not stir our Congress, it should be spurred to action by the huge loss of material advantages to this nation.

THE NEEDS OF OUR NAVY YARDS

In the upbuilding and maintenance of our navy, we shall need all the navy yards we have, and more. As a whole, these yards lack much, not only in the dredging of their channels of approach, but in modern equipment for building and repair, both as to hulls and machinery. The need of dry docks and of channels to these yards, which would be deep enough for our largest vessels at all stages of tide, is an amazing instance of naval unpreparedness.

For example, take the New York Yard: Owing to its strategic position and its unlimited resources, this yard should be our greatest naval station. Instead, it is, in its approaches, not only a nuisance to the navy in peace, but in war might readily prove a fatal trap for ships caught in it under certain conditions. The reasons are: First, its water front is congested, and it cannot receive even a moderate fleet. Second, its single approach, that from the Bay, has channels so shallow that large battleships can reach the yard only when wind and tide serve, and in war a damaged battleship, down by the head or stern, could not reach it at all. Third, when ships get there, they must stay after their repairs are completed, until wind and tide combine to let them out again. Fourth, when thus trapped, these ships might readily be sunk be gun fire in war, since a superior enemy fleet could easily get near enough to the coast to shell the yard.

The Kiel Canal has been of vital service to Germany during this war. Without it, she could not have held her Baltic coast against British dreadnaughts convoying troop transports. Every dollar of the ninety-four millions she spent on it has been repaid a thousand-fold in her defense. Now, we could have a largely similar waterway from Sandy Hook through Long Island Sound to the open sea between Montauk Point and Block Island, if the channels through New York harbor and at Hell Gate were deepened. This waterway would not only add incalculably to the effectiveness of our fleet in war, but would keep the New York yard from being a dreadnaught-trap under hostile fire. Our ships could at least flee from it up the Sound.

At Norfolk, our other great coast yard, the channel abreast the dry dock is but 525 feet wide. The 600-ft. *Pennsylvania* has been docked there, but only by canting her across the channel at an angle to the dock, and at imminent danger of serious damage to the ship. It is not pleasing to think of war conditions there, with half a dozen great ships, vitally needed outside the Capes, and yet all crowded in that narrow channel waiting their turn to twist into that dry dock.

As to the conditions south of Hatteras, Rear Admiral Edwards says:

"There is not a dry dock, owned by the Government or by anyone else, on the South Atlantic and Gulf coasts which will take any of our super-dreadnaughts. There is not a single stationary or floating crane on these coasts which will remove from, or install in, a battleship either a modern turret gun, a Scotch marine boiler, or an assembled low-pressure turbine of the kind now fitted in our large naval colliers, tankers, and battleships."

The situation as to dry docks is very grave. To date, we have a total of twenty-one dreadnaught battleships built, building, or authorized. Of this total, all but the four oldest are too large to be docked at any navy yards, except those at New York, Norfolk and Bremerton on Puget Sound, and that at Pearl Harbor in Hawaii when the dock now building there is completed. And, further, the Naval Act of 1917 also authorized four battle cruisers, and the pending Naval Bill will probably appropriate for two more battle cruisers and four battleships. Of these ten ships, the battle cruisers certainly, and the battleships probably, will be too big to enter any of our existing naval dry docks. At present, with our larger ships limited thus to but two naval docks on our eastern coast, the possibilities, after but one great battle there, seem appalling.

It is true that the dock at Balboa, which is large enough for any ship that can pass through the Canal, is now available, and that two naval docks have been authorized recently, one at Philadelphia, the other at Norfolk. But heretofore the average time for building a naval dock has been seven years. In fact, for so deep a dock as battleships require, this time is always uncertain. Time and again the character of the soil and the hydrostatic pressure of its entrained water have sprung costly surprises on the builders.

So, an adequate dry dock system to meet the exigencies of early war is, at this time, virtally impossible for our navy. The hazard of a dreadnaught fleet costing nearly half a billion dollars for lack of a few dry docks at three or four millions each, will scarcely commend itself to the business sense of this nation.

It is pleasing to note that Congress seems to have awakened at last to the condition of our navy yards. Under the provisions of last year's Naval Act, a commission, headed by Rear Admiral Helm, is now investigating the advisability of establishing an additional Navy Yard on the Pacific coast, and of either improving existing yards, or establishing a new one, on the Atlantic coast south of Hatteras. With this commission a Board under Admiral Mayo is virtally cooperating in furnishing the Helm commission with the composite views of the fleet.

But, establishing navy yards, building dry docks, and, indeed, inducing Congress to act definitely on such subjects, involving as they do so much local politics, are all the work of years. For sixteen years the General Board of the Navy, headed by that gallant veteran, Admiral Dewey, has been advocating the fleet's expansion; but it was not until last August, when war's thunders were shaking the world, that Congress made reasonable provision to that end. And, if early war should come, this provision, like that for navy yards, will prove to be but eleventh hour foolish virgin work—everlastingly too late.

THE PASSIVE DEFENSE

During the nation-wide discussion of preparedness, one school of American thought has urged persistently an almost complete reliance on a Chinese wall of mines and submarines for the defense of our shores, citing Germany's example in this during the existing war. This sort of thing, is, in effect, a passive defense, and no such defense of an extended coast line has ever been successful.

As to mines and submarines, Admiral Fletcher says: "Submarines and mines cannot prevent a landing on our coast. Unless those submarines are backed up by heavy guns, there is no great difficulty for an invading fleet to protect itself. For example, it can send out its destroyers, its small craft, its boats, its nets, its areoplanes. It can take its time and destroy the submarines. It can put its nets across the harbor entrance and around its ships, so as to make the submarines nearly powerless. Eventually, it can capture or drive the submarines in, and sweep up all the mines."

Manifestly, the passive defense will not serve to guard our coasts. It is only surface command of the sea that counts in this.

How Large Should Our Navy Be?

Not for aggression, but to keep the peace and to exert fitly "the silent force of sea power," the United States needs a great navy. How big should that navy be?

If the Panama Canal were closed by accident or design, it would take sixty days for our fleet to steam from the Caribbean Sea around South America to Panama, and in war the difficulties of fueling it on that passage would be staggering. The Austro-Prussian War of 1866 was won at Sadowa in nineteen days after its declaration. By sixty days' delay in sudden war we might lose the lands of an empire in the Pacific Ocean.

Hence, from every viewpoint of strategy and common sense the conclusion is inevitable that we should keep permanently in each ocean a battle fleet strong enough to defeat decisively any probable enemy there.

This, in itself, means a great navy—especially if, as is not unlikely, we might have to face a coalition of the powers, with enemies both east and west. But, the General Board of the Navy states that we should go farther still, that "the Navy of the United States should ultimately be equal to the most powerful maintained by any other nation in the world." And surely the Board is right.

Admiral Mahan said: "The Monroe Doctrine is only as strong as the United States Navy." This is true with regard to the world at large, but with respect to all other nations than England and the United States the truth is that, heretofore, this Doctrine has been as strong as the British Fleet, for (except at the close of the Civil War, when we had the most powerful navy in the world) this Doctrine has existed simply by grace of England. And the reason is that she has not wished to see the vast lands south of us seized by other European nations.

Are we—in years to come as in the past—to maintain the Monroe Doctrine only by her grace, and to surrender it, if she should will, to suit changes in her international policy?

OUR NAVAL STRENGTH

Dreadnaughts

The battleship has been the backbone of every fleet since navies existed. There is nothing else on land or sea which is its equal in the concentration of enormous power.

No nation will attack us with any but a dreadnaught fleet, and only dreadnaughts can fight it. Hence, our naval strength lies fundamentally in the number and relative power of out dreadnaughts. The relative dreadnaught strength of battleships and battle cruisers, based on pre-war figures and deducting losses, is: Great Britian, 44; Germany, 24; and the United States, 12.

No one outside of England or Germany knows what they have built or are building since the war started. There have been persistent reports, however, as to feverish energy in shipbuilding in both countries, and Germany has ample facilities for building at the rate of 25 dreadnaughts a year, while England could probable double this figure under stress.

So the United States has a hard road to travel to reach even second place among the navies of the world. It is true that, since July, 1914, we have laid down three dreadnaughts, that the keels of two more will soon be laid, and that four more have been authorized for immediate construction. But it takes at least three years to build a battleship or battle cruiser, so that the last of the total of 16 dreadnaughts authorized by the recent Naval Appropriation Act will not be completed before 1922—at which time our dreadnaught strength will be 27, as against the pre-war strength, deducting losses, of 44 for Great Britain and 24 for Germany.

The question of destroyers is even more pressing. Primarily, the destroyer's function is torpedo attack on an enemy fleet in battle. It can act also in protecting commerce and as a scout in moderate weather. But its surpassing service during this war has been in guarding Allied battleships from submarine attack.

England's pre-war proportion of destroyers to battleships was about 4 to 1, and this number she has found far too few as time went on. It takes five of them to convoy a battleship and it took all she had at first to guard her Grand Fleet off the Orkneys, leaving her 1800 miles of coast line wide open for submarine attack on merchant vessels. To the British lack of these small, swift, and handy craft is due very largely her great losses of merchant vessels.

In 1922 our proportion of destroyers to battleships will be short by about 100 vessels of the British pre-war proportion of 4 to 1. Our deficiency with regard to the present proportion in the British fleet must be far greater. And yet, as the recent raid of the U-53 off Nantucket Shoals proves, we may yet need them in swarms on our 3000-mile eastern coast line. We might better lack a dreadnaught or an adequate fleet of submarines of our own than a strong force of destroyers.

As to submarines: The coast-defender type has shown its value during this war, and an adequate force of these vessels—not exceeding 800 tons' surface displacement and operating from protected bases—would worry an invading fleet seriously, and force it to make ceaseless attempts to trap or sink its under-water foes.

The fleet submarine—the large boat which, submerged, could charge with the fleet in action—is still but a dream. Her requirements are beyond the present state of the art. The ardent desire of every navy is to have such a vessel, with an engine exhaust which will not leave a white trail on the surface to betray her. She will surely come some day. Captain Simon Lake, the Nestor of submarine inventors, writes me:

"The high-speed submarine is going to come. How soon, I do not know. I do not believe anyone else can answer that question, as it all depends on the engines. Germany is, in all probability, away ahead of us in engine development today, but progress is being made, and as soon as we can get reliable high-powered engines we shall have reliable high-speed submarines capable of accompanying a fleet.

APPLIED SCIENCE A MIGHTY FACTOR IN MODERN WAR

And now, gentlemen, I must close this brief review of our naval unpreparedness. The conditions which I have set forth vitally affect every citizen of this country, but, most of all, men like you who by their knowledge and training are best fitted to cope with them.

To engineers of all branches of the profession, I could not give a more forceful message than that addressed recently by Rear Admiral Bradley A. Fiske to the members of the American Society of Mechanical Engineers. He said:

"There are no other men in the United States so immediately and directly powerful in developing the fleet and naval stations as the engineers. While the strategist estimates the general situation, and determines the application of the general principles of strategy to each situation as it arises, and while the tactician handles the units of personnel and material in actual battle and in preparation for it, it is the engineer who provides the strategist and the tactician with the mechanisms with which to carry out their respective and collective aims.

It is the engineer who enables the strategist and the tactician, and who often forces the strategist and the tactician, to put his art abreast of the developments of the physical arts and sciences, and to take advantage of them. It is the engineer who has given to the world the gun, the torpedo, the submarine, the battleship, the wireless telegraph, the searchlight, and the areoplane. It was the original military engineer—the youthful David, afterwards king—who made the first recorded triumph of science and art over mere physical strength, when at a distance great in those days, he killed Goliath with his sling.

Therefore, for the reason that the engineers of any country have so much power to exert for the safeguarding of their country, and because men are always responsible for the power committed to their keeping, it is the high duty of all American engineers, and of you gentlemen who represent them, so to direct this power as to secure the peace and prosperity of the United States.

THE HYDROELECTRIC DEVELOPMENT OF THE TURNERS FALLS POWER & ELECTRIC COMPANY AT MONTAGUE CITY, MASS.

By B. R. Connell

Power and Mining Engineering Department, General Electric Company

This article is of interest as being a description of the largest single hydroelectric development so far contemplated in the New England States, and as indicative of the rapidly increasing industrial activities of the central Massachusetts section. Its interconnections with the Greenfield Electric Light & Power Company, the Easthampton Gas Company, the United Electric Company of Springfield, and the New England Power Company make practically certain a continuous supply of power and show the increasing tendency of power companies to interconnect their lines for exchange of power in case of emergencies and unusually heavy demands.—Editor.

General

The Turners Falls Power & Electric Company during the past year completed the installation of the fourth generating unit in their new station at Montague City, Mass. This station when completed will be the largest single hydroelectric development in New England, and was made necessary by the rapid expansion of the Company's business in the growing manufacturing centers of central Massachusetts.

The present company is the outgrowth of a company originally chartered in 1792 as the "Proprietors of the Upper Locks and Canals of the Connecticut River" to provide passage for small river boats around the rapids and falls of the river. After the methods of transportation changed so as to make the original conception of the company useless, a new company, known as the Turners Falls Company, acquired the rights of the older corporation to develop power at the available locations. This was in 1866, and the latter name was held until April, 1915, when the present name was adopted and other holdings merged into the new organization.

Hydraulic Arrangement

Fig. 1 will show the general features of the hydraulic development. After the Turners Falls Company was organized, a crib dam was constructed across the Connecticut River at the location shown. This was recently replaced by a concrete structure, with a gate-house for controlling the flow of water to the canal. The gate-house is of brick, with the gates arranged so that they may be operated by motors or a water-wheel which is installed in the structure. This canal originally supplied hydraulic power to mills in Turners Falls, and about 1904 was lengthened and enlarged to supply the company's first hydroelectric development, which operates under a head of 39 ft. and develops about 7000 h.p.

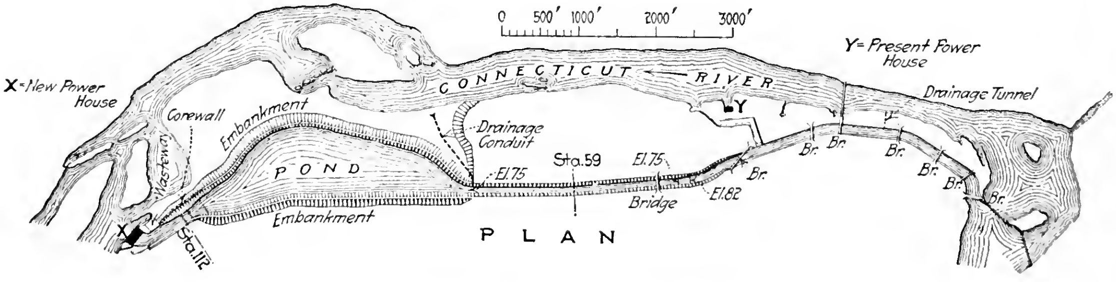


Fig. 1. General View of the Development

To obtain the benefit of the full fall of the river within the company's water rights at this point it was decided to locate a new development about two miles below the dam, at Montague City. To do this it was necessary to enlarge part of the old canal and extend it to the new station. For the first 3900 feet the new canal is approximately 127 feet wide and 18 feet deep, cut in rock; and for the next 3300 feet it is about 86 feet wide and 25 feet deep, with riprapped sides. It then gradually opens into a forebay which has been formed by embankments just above the station. This forebay is of sufficient capacity to take care of sudden fluctuations in load without causing too rapid a flow in the canal before the head-gates at the dam can be adjusted.

Fig. 2. View of Station from Canal Side

Power House

The power house forms the central part of the structure at the end of the forebay. On the upstream side of the power house is a concrete spillway with gates to drain the canal in case of emergency. These gates are motor operated and are of sufficient size to pass the full canal flow, which is approximately 10,000 second-feet. The spillway will also facilitate the removal of ice from the canal.

On the downstream end of the power house is located a concrete log sluice and a small bay where it is planned to install later, if necessary, an electric hoist to handle logs. This would require much less water than to pass the logs over the main dam.

As will be seen from Fig. 3, the power house itself is a brick and steel structure set on a heavy concrete sub-structure on ledge foundation, with concrete floors, and concrete roof supported on trusses. The penstocks or intakes are formed in the concrete foundation and divided into three sections from the headgates to the scroll cases of the wheels, and so designed as to cause as small a loss as possible from resistance. Fig. 4 shows a cross section of the power house and the hydraulic arrangement. A separate headgate is provided for each of the three intakes to each wheel pit. These are set in piers and are protected by racks made of special rack bars and spaced 3½ inches between bars.

The gates are the Broome type and are constructed of heavy steel plates run on a continuous chain of rollers between the tracks on the gates and guides, and designed specially to secure tightness and ease of operation. A Gantry crane, electrically driven and running on the head wall, operates the gates. This crane also carries a specially designed mechanical rack raking device. Fig. 5 shows a view of this equipment.

Fig. 3. View of the Power House and Spillway from the River Side

The power house is 235 feet long and 99 feet wide at the widest part, with the generator room running the entire length of the station. This room is 43 feet wide and about 52 feet to the roof. The transformer compartments are on the main generator floor and are 15 feet in depth, and together with a workroom and the station service apparatus room extend the entire length of the building. Above these compartments is the switchboard gallery which occupies the center section, a stock room being on the upstream end and the office of the operating superintendent of the system on the other end. The switchboard gallery section is carried up to the roof to provide the required head room for the bus structure and the outgoing low-voltage lines. Above the two end sections are the high-tension switch and bus rooms.

The generator room is provided with a 60-ton motor-operated crane for handling the apparatus, and a standard gauge side track is run far enough into the station to be within reach of the crane. This allowed all the heavy apparatus to be shipped direct to the station without transferring or trucking, and made a considerable saving in the installation. For supplying outside air to the generators two air ducts are built in the concrete foundations running from the tailrace side of the building to each generator pit.

The generators are set on 37 foot centers, which allows ample room for repairing or dismantling the machines. The station is

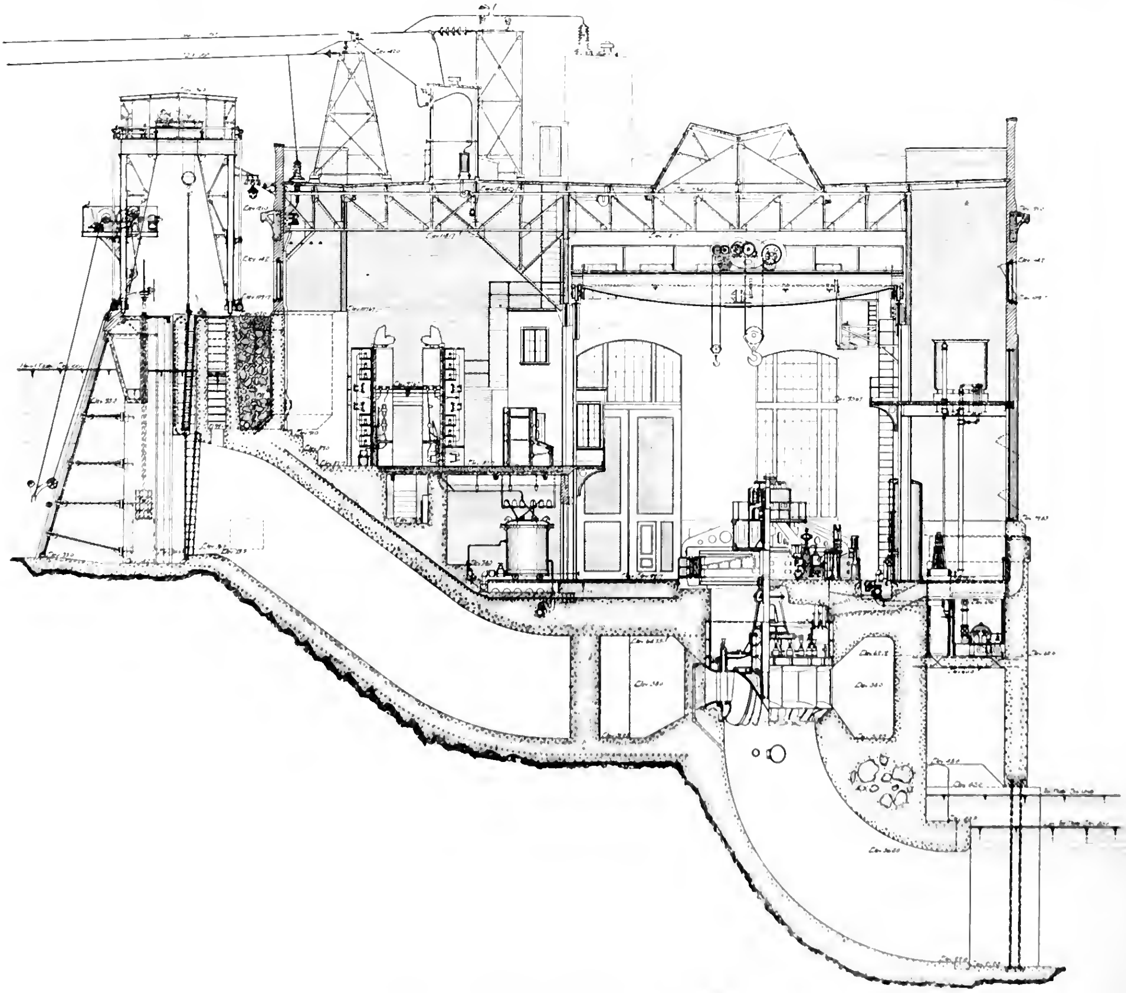


Fig. 4. General Cross Section of Power House

now completed for the ultimate installation of six units.

Waterwheel and Governing Equipment

The turbines are vertical shaft, single-runner, Francis type units with a cast iron speed ring, and have a single downward discharge into concrete formed draft tubes. The effective head with all machines operating is 54 feet, and under this head and full gate opening the wheels develop 10,300 h.p. The rated speed is 97.3 r.p.m. with a free speed of approximately 189 r.p.m. under the maximum head.

The runner is 12 feet in outside diameter and is a one-piece iron casting. The wheel is designed for a specific speed of 66 r.p.m. and the weight of each runner is 59,000 lb.

The inlet to the turbine is controlled by wicket gates, which are single piece steel castings connected to the main operating gate ring. This gate ring is operated by two servomotors controlled by the governors which, with their pressure tanks, are located on the main generator floor at each machine. The governors are gear-driven from the main shaft and are actuated by water treated with soluble oil under a pressure of 220 lbs., this water being supplied from a central motor-driven pumping outfit located in a pit near the center of the building. Two 325-gallon centrifugal pumps are installed, one acting as spare, with space for a third pump when the six machines are installed.

Five air-operated shoe brakes are installed on each unit to stop the rotating element quickly. These are equalled spaced on alternate foundation plates of the generator and operate on a machined surface of the generator rotor. The waterwheels and governors were supplied by the I. P. Morris Co.

Generators and Exciters

The present generating equipment consists of four units, three installed in 1915 and one in 1916, each rated 7500 kv-a. (6000-kw. 0.8 power-factor), 97.3 r.p.m., 6600-volts, maximum rated at 50 deg. C. temperature rise.

The generators are designed with a regulation of approximately 8 per cent at 1.0 power-factor and with an internal reactance to limit the current of each machine to approximately 5½ times full load current on instantaneous short circuit and 2¾ times for sustained short circuit.

The armature winding consists of form wound coils Y-connected, with the neutral lead brought out to a switch in the pit of each machine and so connected that any generator may be grounded. Temperature coils are installed in the armature windings and connected to indicating meters on the bench control board. The armature frame is made up of four sections, the total weight being approximately 70,000 lbs. and the overall diameter 24 ft. 2 inches.

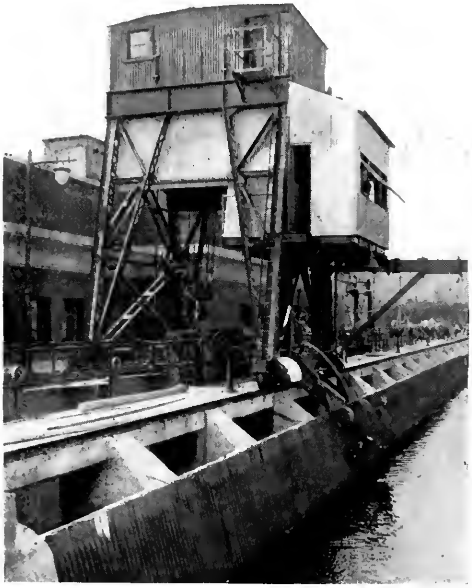


Fig. 5. Gantry Crane and Special Rack Raking Device

The rotor consists of a steel rim cast in four sections which are securely bolted together and to a solid cast iron spider. The total weight of the rotor and generator shaft is 120,000 lbs. and it is designed to withstand 100 per cent overspeed with an ample margin of safety. The flywheel effect (WR^2) is approximately 7,000,000 pound feet.

The weight of the entire revolving element, including the waterwheel runner and water thrust, is carried by a standard Kingsbury bearing which is supported by a heavy bracket arm construction as shown in Fig. 6. A guide bearing is supplied with the generator and located below the thrust bearing which, together with the lignum-vitae bearing of the waterwheel, serves to align the complete unit. Each machine is provided with a stairway and gallery on

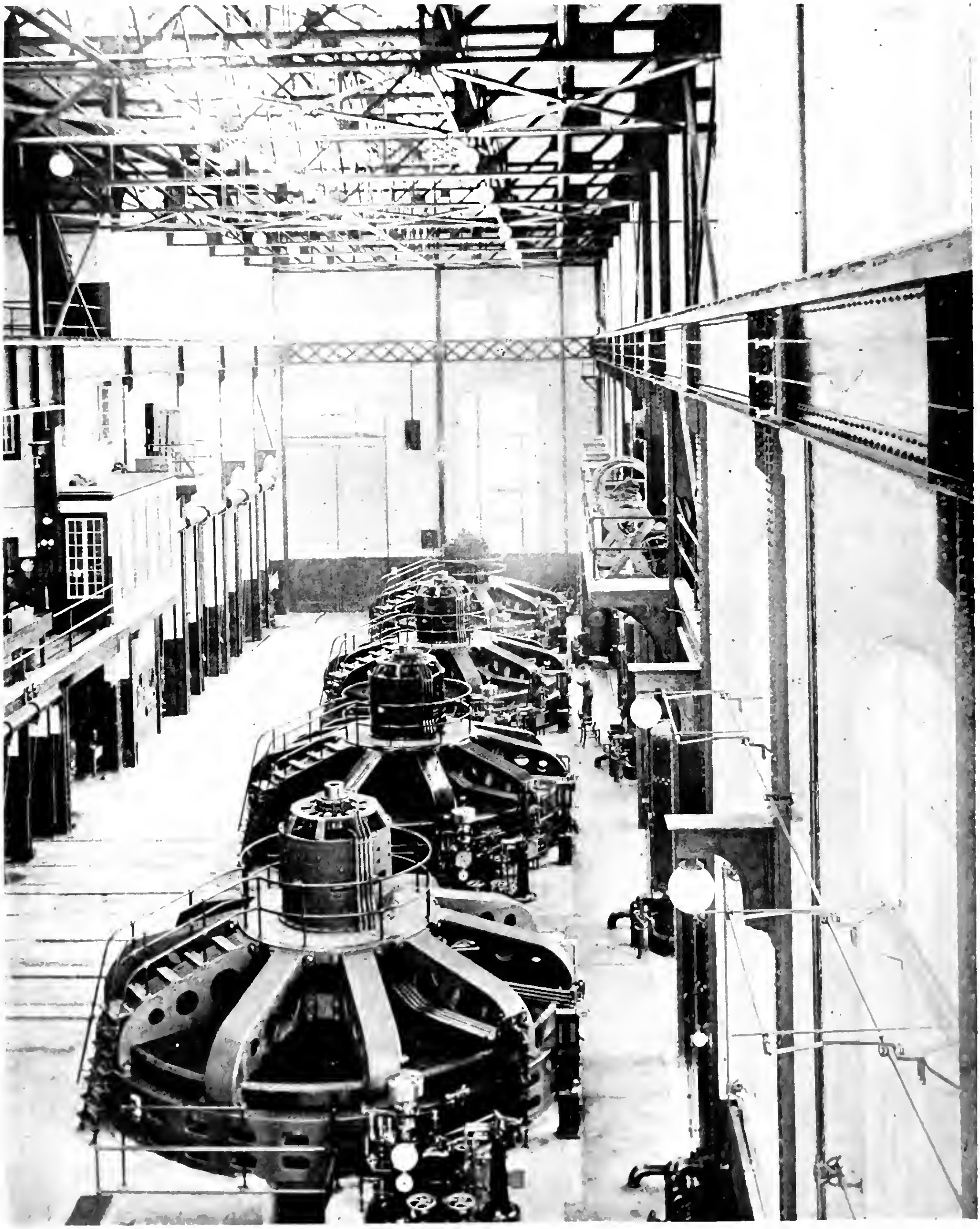


Fig. 6 Interior of Power House showing the 7500-Kv-a. Generators

the thrust deck to facilitate inspection of the exciters, collector rings, etc.

The excitation of the generators is furnished by a direct-connected exciter on each generator. The exciter is rated 95 kw., 97.3 r.p.m., 250 volts, and is shunt wound with interpoles and mounted directly above the thrust bearing.

As will be noted by referring to the station wiring, Fig. 12, each exciter is connected only to its own generator, but a spare motor-driven unit is installed which can be connected to any generator in case of emergency. A double-pole generator field switch, solenoid operated, is mounted on a panel at the frame of the machine so that the exciter main leads are as short as possible. Each field panel also contains a double-pole, double-throw switch for transferring the generator excitation from the direct-connected exciter to the spare unit.

No generator field rheostats are furnished, the voltage control being effected through the exciter field, this method cutting down the rheostat losses to a minimum. This is an important item on large slow speed generators of this type and can be accomplished where each machine has independent exciter control.

The spare exciter is rated 100 kw., 900 r.p.m., 250 volts. It is compound wound and is driven by a 150-h.p., 550-volt form "K" induction motor supplied from the station service transformers.

Transformers

The transformers are located in compartments on the generator floor, as previously mentioned. Each compartment is fitted with an automatic steel fire curtain. These compartments have depressed floors with a drain emptying into the river so that in case of trouble the oil will not spread into the station. A hand valve is also located outside the compartment so that the oil can be drained from the transformer to the oil tank or river with the curtains lowered. The ultimate installation will consist of four 66,000-volt banks for the high-tension distribution and two 13,200-volt banks for the local distribution.

Three of the 66,000-volt and one of the 13,200-volt banks are at present installed. Two banks of the high-tension transformers that were installed originally consist of three 3500-kv-a. units each; the third bank, which was installed during the past year, consisting of three 5000-kv-a. units. These transformers are water cooled, oil insulated, and are all maximum rated at 50 deg. C. temperature rise. They are of the core type construction and are designed to withstand momentary short circuit. The tank is of the plain boiler type construction, as shown by Fig. 8, which gives a general view of the 3500-kv-a. units. Each transformer is equipped with alarm thermometers, sight-flow water indicators, and pressure gauges with alarm connections. They are arranged with two 2½ per cent full capacity taps above and below 66,000 volts on the high-tension side, and a series-multiple connection for 13200/6600 volts on the secondary side, and are delta connected on both primary and secondary sides.

The 13200-volt bank consists of three 1500-kv-a. single-phase, water-cooled, oil-insulated units, also delta connected on both primary and secondary side. They are also arranged with two 2½ per cent full capacity taps above and below 13200 volts, and with a 2200/6600-volt secondary connection. The general design of the transformers and arrangement of the compartments is the same as for the main high-voltage units (Fig. 7.)

The station service transformers, lighting transformers, battery charging set, and induction motor exciter set with its compensator and rheostat, are installed in a compartment between the transformers. The service transformers consist of three self-cooled units rated 100-kv-a., 6900/13800 volts primary to 608 volts secondary. These supply all the station motors including pumps, head-gates and cranes. The lighting is supplied by a 15-kv-a., 6900/13800 to 115/230-volt transformer.

Switchboard and System of Connections

As shown in Fig. 10, the main switchboard is of the benchboard type and consists of eleven bench sections of natural black slate, each with a rear vertical panel. The board is located in a gallery overlooking the generator floor and is in the center of the station.

The bench section contains a mimic bus showing the station connections, synchronizing and potential receptacles, and control switches for the main circuit switches, which are all solenoid or motor-operated.

The front vertical section contains H-E indicating instruments for the exciters, generators, and all the main alternating-current circuits. On the vertical rear sections are mounted integrating and curve-drawing

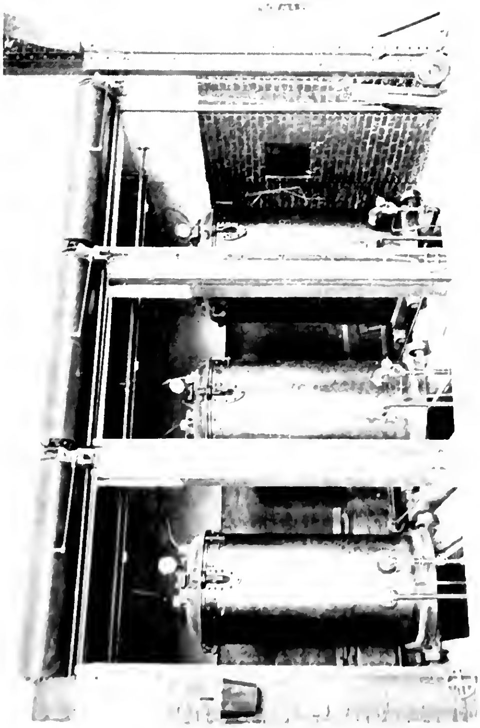


Fig. 7. Low-tension 1500-kv-a. Transformers in Compartments

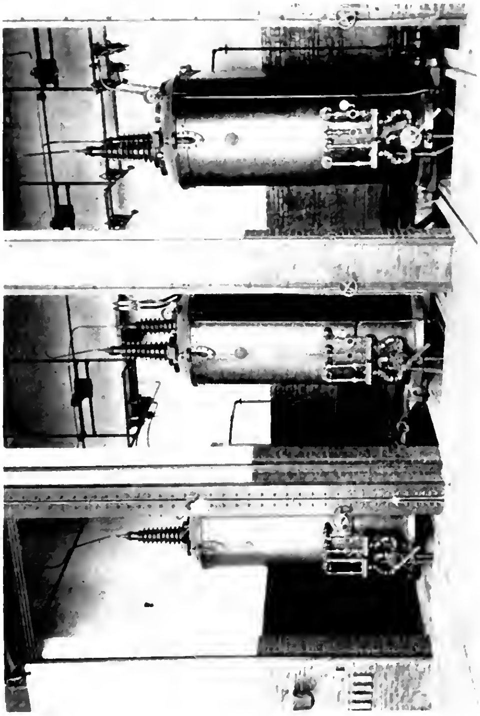


Fig. 8. High-tension 3500-kv-a. Transformers in Compartments

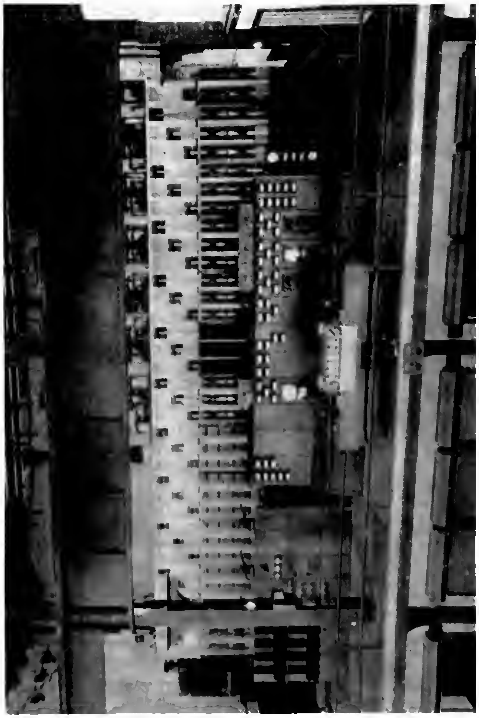


Fig. 9. View of Switchboard Operating Gallery

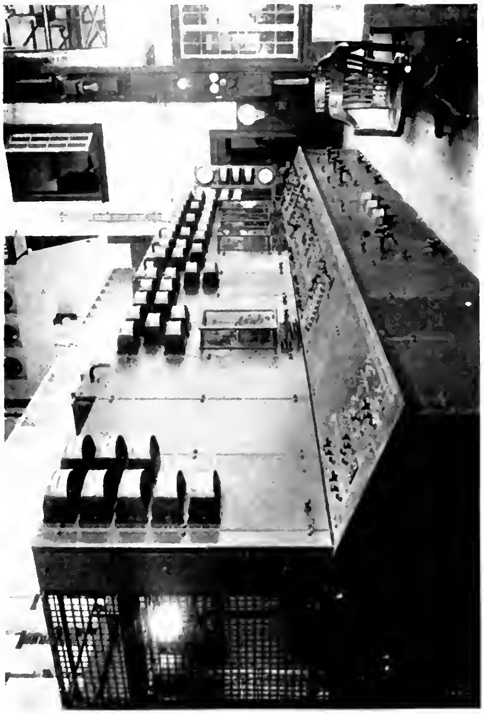


Fig. 10. Benchboard and Operating Desk

meters for the outgoing lines, relays and testing links. Above the board are mounted the exciter rheostats, which are chain-operated with the exception of that for the motor driven exciter, which is solenoid operated. This exciter is not wired for T-A regulator control, but each of the direct connected exciters are controlled by an individual K-10 regulator mounted on the vertical section of its respective generating panel.

To the left of the benchboard is the station service and auxiliary board, consisting of 5 vertical panels of natural black slate. This board contains the control equipment for all the station auxiliary motors, cranes, lights, etc., and two additional panels are installed on which is mounted a mimic bus showing a one-line diagram of the entire system for the convenience of the operators. Lights controlled from the operating table show where switches are closed. In front of the bench and directly overlooking the station is the operating desk, on which are telephones connecting with the entire system, as the Montague City station serves as the load-dispatching station of the system.

To the right of the bench is the station superintendent's and operator's office, and at the rear is the low-tension bus structure. All the main oil switches are of the H-motor-operated type.

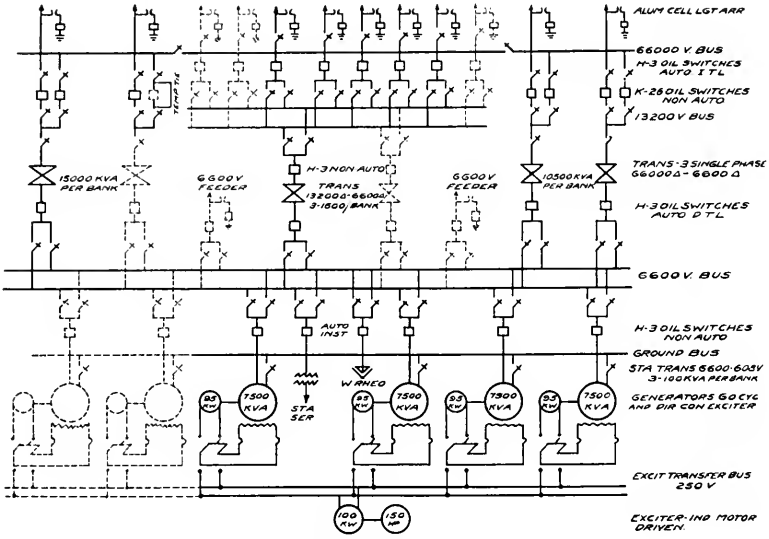


Fig. 12. Diagram of Station Connections

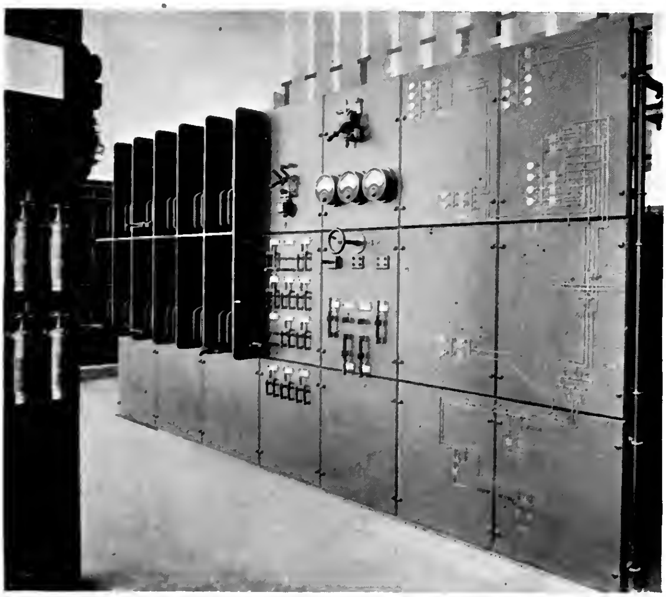


Fig. 11. View of Auxiliary Switchboard

The bus and switch cell structure is of concrete construction, the center core wall being cast in built-up forms; the cell slabs, etc., being cast in molds and then assembled to form the complete structure. The oil switches are mounted in two rows, one consisting of the 6600-volt and the other of the 13200-volt switches, with a passage way between the two rows at the switch cell level to facilitate inspection and repairs, as the entire bus and switch cell structure is built up from the switchboard floor level. (Fig. 9.)

The switches on the generators are non-automatic, while those on the low-tension transformer circuits are automatic, being fitted with definite trial limit overload relays. The 6600-volt feeders and 13200-volt outgoing lines are also supplied with switches having instantaneous relays on the 6600-volt and definite time limit on the 13200-volt lines.

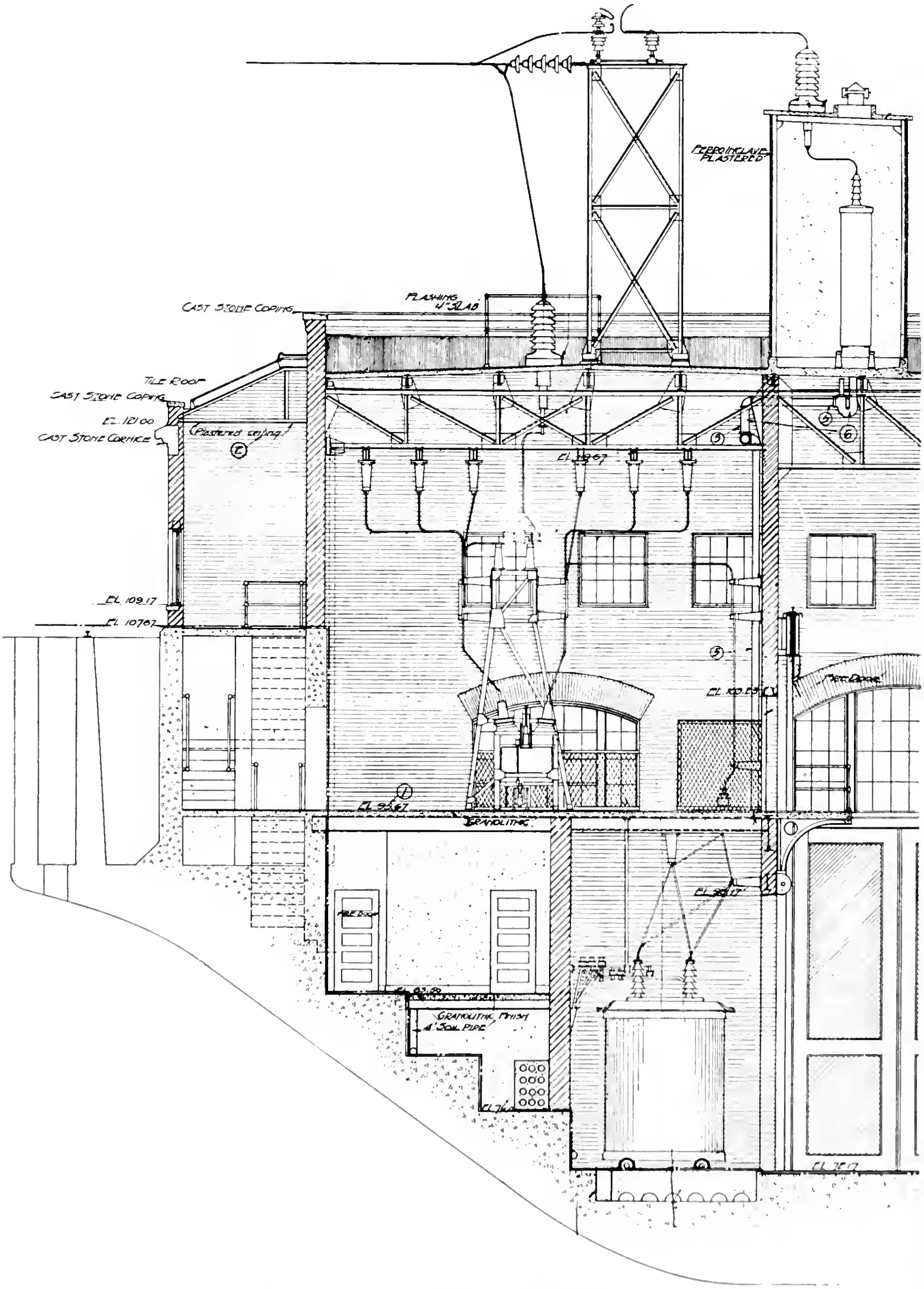


Fig. 13. Cross Section Through the Transformer and High-tension Switch Room

The high-tension oil switches are the K-26 type with each pole in a separate tank, the complete switch being mounted on steel frame work with hand-operated tank-raising and lowering devices. Bushing current transformers are installed in the line switches only, although the tie switches are designed so that bushing transformers may be installed later if desired, for the sake of interchangeability.

The high-tension switches are all non-automatic, and from the wiring diagram, Fig. 12, it will be seen that each transformer and its line may be considered as a unit. All switching is done on the low-tension side in accordance with the latest practice to limit strains on the high-tension apparatus A high-tension bus is installed so that any transformer may be thrown on any line, or two lines operated from one transformer bank in case of emergency.

Until the fourth transformer bank is installed, lines Nos. 3 and 4 will be operated from bank No. 6, and therefore induction type overload relays are soon to be installed on these lines to prevent trouble in one line from interfering with the other line.

The high-tension switch room is divided into two sections, this arrangement giving additional room for the low-tension bus structure and outgoing lines. The transfer bus is arranged so that it can be sectionalized from either high-tension gallery. The high-tension busses consist of 15/16 in. copper tubing supported on post insulators which are mounted on a supporting steel frame work. Fig. 13 shows a section of the station through the high-tension transformer and switch rooms.

Lines Nos. 1 and 2 are each rated 10500-kv-a., and Nos. 3 and 4 15000-kv-a. There are five 13200-volt lines at present installed, and provision is made for three additional 13200-volt and two 6600-volt lines. One 6600-volt circuit is rated 10000-kw. and is connected to a water rheostat which is used for station testing, and the second supplies the station service transformers.

To supply power for the oil switch control circuits, emergency lighting, etc., a 60-cell, 125-volt storage battery is installed. This has a 300 amperes maximum instantaneous discharge rate and a normal 15 amperes, 8 hour rate. A 3½-kw. battery-charging set is supplied, and is operated continuously with the battery floating.

All the outgoing lines, with the exception of two 13200-volt lines, are carried through roof entrance bushings to supporting structures on the station roof, where the lines are dead-ended. The tap to the aluminum lightning arrester is taken off here, and the arresters are placed in pent houses on the roof. This arrangement not only eliminates the lightning arresters from the station proper but makes the arrester connections as short as possible, which is a desirable feature. The arresters are all of the four tank type, and each line is supplied with a choke coil mounted just below the roof bushing.

Two 13200-volt lines leave the station as underground feeders running to Greenfield, and on these lines the lightning arresters without choke coils are used as static dischargers.

Station Auxiliary Apparatus and Special Equipment

A complete oil piping system is installed so that the oil from the transformers, oil switches, lightning arresters, etc., may be circulated through a filter press and the storage tanks.

For the generator thrust and guide bearing a Peterson oil filtering system of the central plant type is installed. The filter and storage tank is located on a small gallery on the river side of the power house over the pump pit. From here the oil flows by gravity to the bearings, and from the bearings to two sump tanks in the pump pit, whence it is again pumped to the gallery.

Each generator is supplied with a sight flow indicator and thermometer in both the feed and discharge line of the thrust and guide bearings; the indicators in the feed lines being arranged with alarm connections. A recording oil meter is installed in the thrust bearing feed line and a curve-drawing meter in its discharge line. Fig. 14 shows this equipment as well as the field switch panels. An alarm thermometer is also being installed in each bearing, with the bulb in the oil as it is discharged from the bearing shoes, to keep a close watch of the temperature. In each Kingsbury bearing there is installed a set of cooling coils so that in case the oil pumps are shut down by accident or for repairs, the generators may be run continuously by shutting off the discharge lines, as the storage tank has capacity to supply the guide bearings for a considerable time.

A signal system connects the operating gallery and the generator floor. On each generator bench panel is mounted a signal box with six signals and a general call button as follows: Emergency, Stand-

Fig. 14. View of Governors, Field Panels and Oiling System

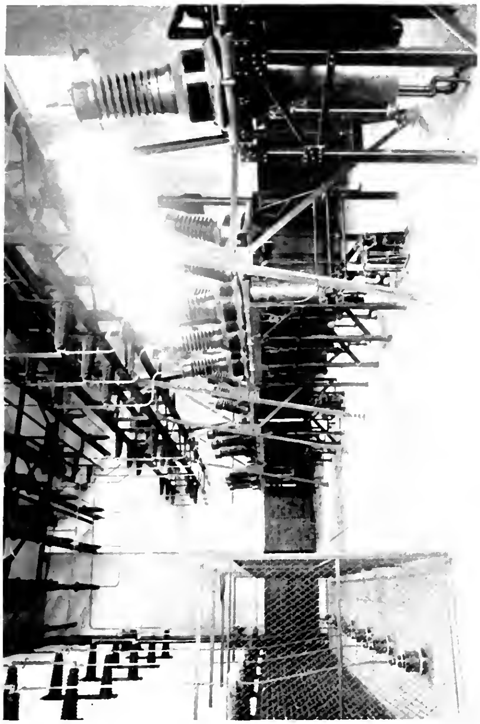


Fig. 15. High-tension Room

Fig. 16. Lightning Arrester Equipment and Tower Construction on Roof

Fig. 17. View of Typical Outdoor Substation

by, Start, Stop, Field Switch Up, Field Switch Down, all of which connect with a corresponding box mounted on a pedestal at each machine. There is also a signal box and pedestal for the motor-operated exciter and a general station call box on the switchboard gallery and main floor. The signal box with illuminated dial for the alarms from the transformers, generator bearings, etc., is mounted on a column near the operator's table.

A complete grounding system is installed for the generators, instrument transformers, lightning arresters, transformer and switch cases, etc. Four separate cables are run from the corners of the building to plates buried in the river bottom. The lightning arresters are grounded through a separate circuit so as to prevent any disturbances on these circuits from reaching the other apparatus.

For purposes of testing a water rheostat was constructed and installed in the head race. The rheostat consists of seven iron plates, 8 feet long by 4½ feet wide, these plates being mounted in a channel iron frame work fitted with eye-bolts for handling, and all bolted together and supported by insulators, which also serve to insulate the three phases. A load of over 10,000 kw. was carried by this rheostat during the tests which were made on the generators and wheels after the initial installation.

Two water level indicators, consisting of glass pressure tubes, are mounted on the wall near the operator's board and indicate the level of the head water outside and inside the penstock gates. A curve-drawing meter is also furnished to record the head throughout the day. An indicator is also installed in the main gate house at the dam, which is connected by telephone with the operator's board.

A discharge level indicator is also mounted in the station, with a float in the tail race and a graduated scale and target mounted on the wall having figures large enough to be read across the station by the operator on the switchboard gallery.

Lighting and Heating Systems, Etc.

The station is well lighted in the day time by numerous windows on all three sides of the building. These are also arranged for ventilation, and a monitor is built in the roof which serves as an outlet for the heated air as well as to supply light.

At night the generator room is lighted by 16 lamps in the roof trusses and 16 on wall brackets. These are evenly distributed about the room, and each is fitted with a 200-watt gas-filled lamp with frosted globe. A number of smaller fixtures are distributed about the room for emergency lights, and these are fitted with 60-watt gas-filled lamps. The switchboard operating gallery is lighted in a similar manner to the main station, the various other rooms being supplied with smaller units. An automatic lighting switch is supplied to throw the emergency lights to the battery circuit in case of failure of the alternating-current voltage. A steam boiler and heating system is installed to heat the station in winter when necessary.

Distribution System and Connection Stations

The 13200-volt lines feed into the Company's extensive 13200-volt network which feeds Turners Falls, Millers Falls, Greenfield, and other nearby towns. They also can serve, if necessary, to transfer power from the other hydroelectric and steam stations to the Montague City plant for high-tension distribution.

As mentioned above, this company has a plant at the upper end of the canal having a capacity of 5050-kv-a. in six horizontal units operating under a 39-foot head. This station originally fed into the 66000-volt system, but with the completion of the new plant the 66000-volt apparatus was taken out and the station operated on the 13200-volt system as a reserve plant.

The Gardners Falls hydroelectric station of the Greenfield Electric Light & Power Company, with an installed capacity of 2680-kw., connects with the 13200-volt distributing system, as does also a standby steam plant of 2750-kw. capacity of this company at Greenfield. The Gardners Falls plant is located about 1½ miles below Shelburne Falls on the Deerfield River and contains two 940-kw. vertical and two 400-kw. horizontal, 2300-volt units. The voltage is stepped up to 13200 volts by three banks of three phase 1200-kv-a. transformers.

At Mt. Tom the 3250-kw. steam plant of the Easthampton Gas Company can be connected to the system, and at Springfield connection can also be made with the United Electric Company circuits for the transfer of 10,000-kw.

The 66,000-volt distribution consists of a 43 mile double circuit transmission line running to Springfield, Mass., with substations at Amherst, Chicopee, and Agawam.

From Amherst two lines run to Mt. Tom and Easthampton, a distance of approximately 8 miles. A second double circuit line has recently been put in operation from the generating station to Leverett, with one circuit extended as far as Amherst, both tower lines being built over the same right of way. At Leverett an outdoor switching and metering station is installed to tie this system with the 66,000-volt lines of the New England Power Company running from its Deerfield river plants to Millbury, Mass., for the interchange of power between the two systems. Fig. 16 shows one of the outdoor substations of the company at Chicopee, Mass.

The transmission line is designed with spacings for ultimate service at 110,000 volts, but is insulated at present for 66,000 volts. The towers are of steel construction with a standard spacing of eleven to the mile. Several river crossings are necessary, the longest span being 1500 ft.

Suspension insulators are used, four for standard construction and five in strain with double strings at angle towers and crossings. The conductor is 1/0 copper for lines Nos. 1 and 2 and 2/0 for lines Nos. 3 and 4, and is strung on a 10 foot vertical spacing. One ground wire is used at the apex of each tower, and the company's private telephone line is run on the main towers of lines Nos. 1 and 2.

Organization, Etc.

The entire engineering work for the new plant and system, including the detail layout and construction, was done by the Company's own engineering organization, with Mr. F. L. Hunt as Chief Engineer, Mr. H. M. Turner as Hydraulic Engineer, and Mr. H. A. Moody as Resident Engineer at the Power House. Mr. A. T. Safford acted as Consulting Hydraulic Engineer. The entire electrical equipment for the plant was furnished by the General Electric Co.

ALQUIST GEARING FOR SHIP PROPULSION

By W. L. R. Emmet

Consulting Engineer, General Electric Company

The feature of the Alquist gear that renders it specially suitable for the transmission of large amounts of power is its flexibility, which permits it to yield at points under excessive pressure. This flexibility is secured by building the gear of plates between which there is a small clearance, this clearance allowing a slight lateral movement of the periphery which relieves the stress on the helical teeth. Some results secured in ship propulsion with this style of gearing are given in tabular form.—Editor.

The designs described in this paper are based upon the inventions of Mr. Karl Alquist. Mr. Alquist is an accomplished engineer and was formerly connected with the Turbine Department of the English branch of the General Electric Company, the British Thomson-Houston Company. His gear inventions were first brought to the attention of the writer early in the year 1911. For some time previous Mr. Alquist had endeavored to arouse interest in his methods in England and on the Continent but had accomplished nothing. At that time the General Electric Company had not begun the commercial manufacture of high-speed spiral gears, but had for some time been conducting experiments to determine the limits of speed, pressure, etc., which were practicable with such gearing. The importance of high-speed gearing in connection with turbine and electrical applications is obvious and the General Electric Company was working with a view to a development of the best standards.

Certain features of Mr. Alquist's proposals appealed strongly to the writer, and arrangements were made with Mr. Alquist to come to America and assist in experimental developments along the line of his inventions.

The result of this undertaking has been that many sets of gearing have been built and experimented with exhaustively under a variety of conditions, and by these experiments certain standards of practicability have been established and extensive commercial developments have been undertaken. Gearing of this character has been applied to about seventy-two sets where steam turbines drive electric generators of various types. Contracts have been closed for machinery for the propulsion of seventy ships aggregating 215,200 horse power. Some of these electric generating sets have been in service one and one-half years and about seven of the ship sets are in service, some of them having made many long voyages. Among these are high-pressure cruising units for the battleship

"Nevada" which have been in service for some time and shown very fine results. Among the ship equipments not yet completed are included the propelling machinery for Destroyer No. 69, built at Mare Island, and new propelling machinery for the scout cruiser "Salem." In all of this practical experience no case of trouble with gearing has developed and no appreciable deterioration of gears has been observed.

One of the important reasons for adopting this type of gearing was that its design tended to afford a distribution of strains and means by which excessive strains would not be imposed upon any part through slight imperfections, distortions, or inaccuracies. The uniform success which has been accomplished with an entirely new product shows that this expectation has been amply justified. Some of the gears which have been used have been very imperfect, both in the matter of material and workmanship, and have been used under extremely trying conditions. That they have not failed has afforded the strongest evidence of the general reliability of the method.

The character of construction used in this gearing is shown by one of the drawings, Fig. 1. The gear is built up of a number of plates machined to a form which gives them the desired degree of lateral flexibility. These plates are put together, engaging solidly at the hub and also engaging on a narrow edge at the periphery. When so built together they form a solid cylinder which can be spirally cut in the ordinary manner. After cutting, the edge engagements are relieved with a small dividing tool so that each disk operates independently and is free to deflect laterally under the side pressure which results from its diagonal engagement with the pinion. The parts are so proportioned that this lateral deflection can at no time involve fiber strains which could possibly cause destructive fatigue. A very small amount of this lateral deflection is sufficient to afford the desired distribution of load, and this amount can easily be given without approaching dangerous periodic strains.

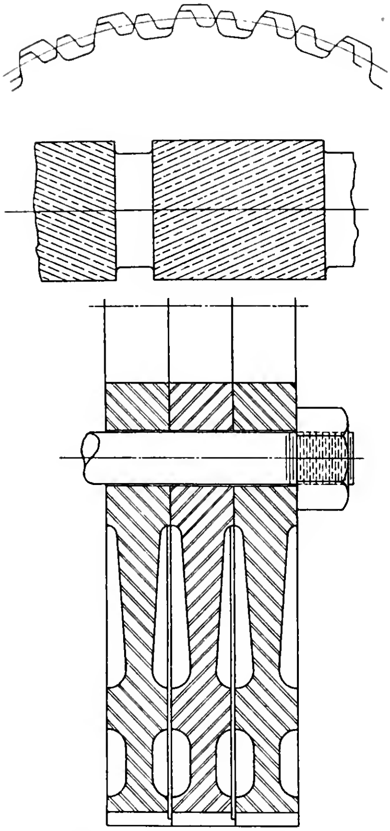


Fig. 1. Construction of Alquist Flexible Reduction Gear

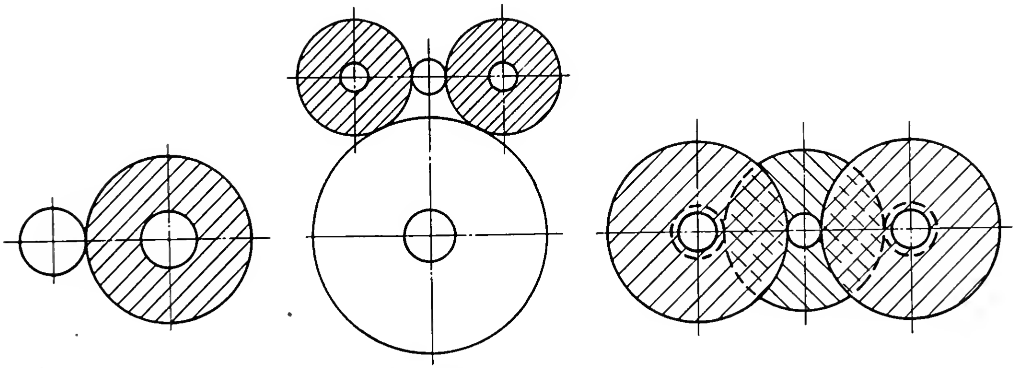


Fig. 2. Various Arrangements of Pinions and Gears

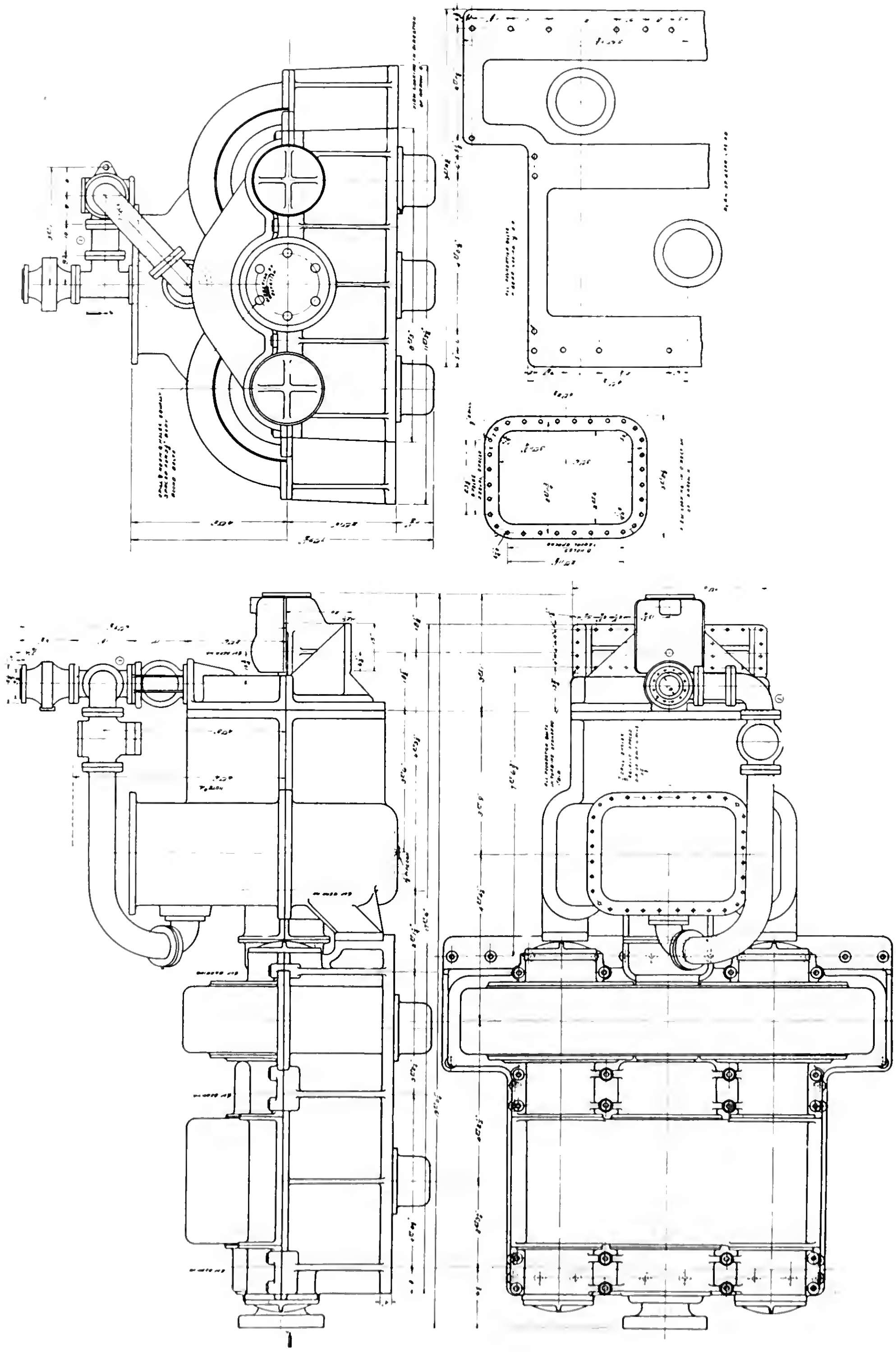


Fig. 3. 2400-h.p. Curtis Turbine with Reduction Gear for Ship Propulsion, 3500 to 90 r.p.m.

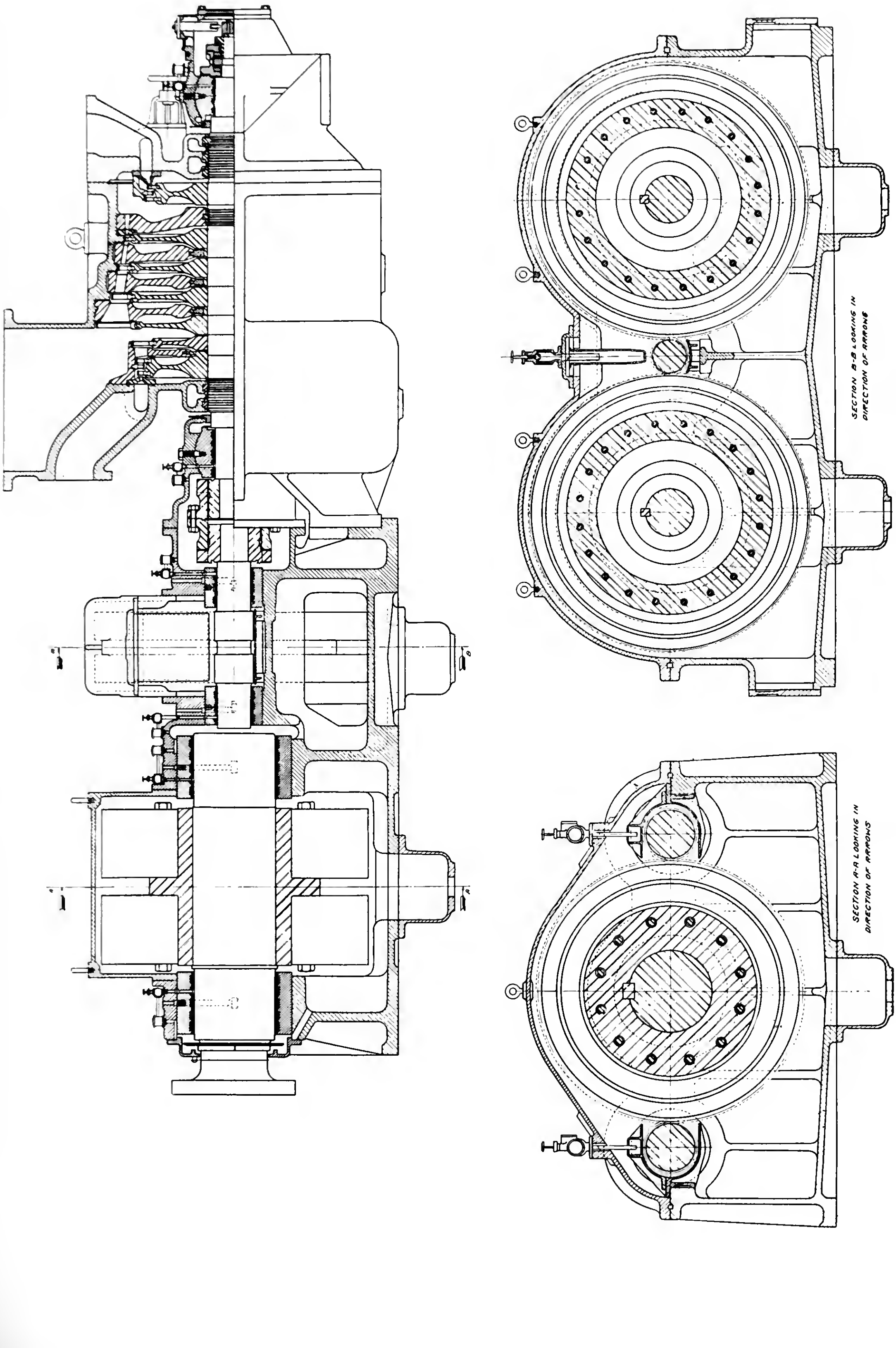


Fig. 4. Sectional Views of Turbines and Reduction Gears for Ship Propulsion

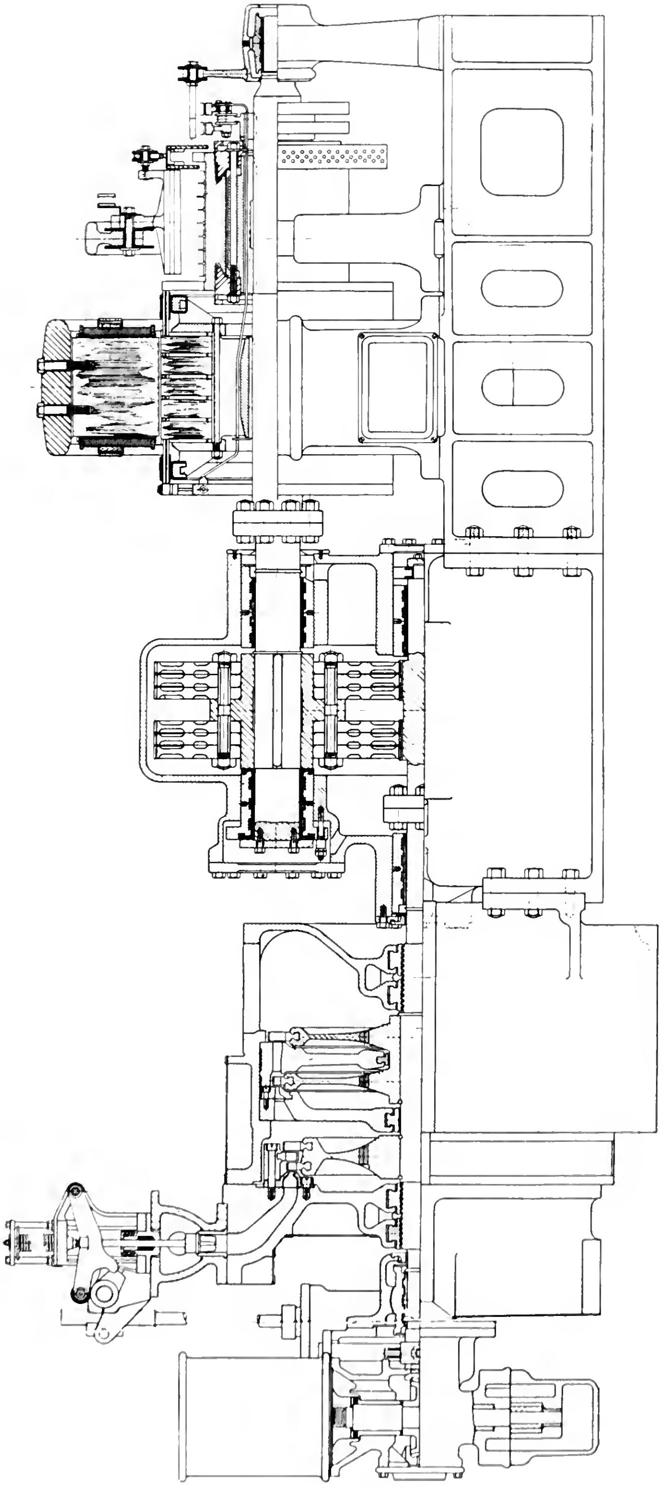


Fig. 5. 300-kw. Curtis Turbine Geared to Generator, 5000 to 1000 r.p.m.

To appreciate the value of this flexibility and load distribution, various peculiarties of solid and spiral gearing must be considered. In the first place, where gears are inflexible, there must always be a tendency to increase strain at the loaded end of the pinion through torsional deflection of the pinion. There is also a tendency to inequality of strain on different parts of the surface through the lateral deflection of the pinion under load. These inequalities can be partially compensated by elevating the bearings or evening the pressure on the bearings, but this compensation can only be partial because the correction applies only to the two ends and not to the middle. Furthermore, the momentary and periodic strains on different points of solid spiral gearing may be seriously affected by vibrations of supporting structures, irregularities of machine work or gear cutting, and other causes. If for any reason such conditions cause any tooth or part of a tooth to receive periodically excessive strains, fatigue may result and a broken tooth may destroy the whole gear.

To obviate the possibility of breakage under such conditions, it is often desirable in solid gearing to use relatively large teeth in order that these possible irregular strains on teeth or parts of teeth will not involve danger of breakage. For other reasons, however, the use of large teeth is distinctly undesirable in spiral gearing. Spiral gears tend to engage by point contacts at or near the pitch line, and the ability of these point contacts to bear pressure without fatigue of the surface metal is governed largely by flatness of the surfaces engaging rather than by the size of the teeth carrying these surfaces. The flatness of the surface is a function of the pinion diameter and not of the pitch. If we double the number of teeth in a spiral gear we have twice the number of driving points in action, and the flatness of all of these points is the same in both cases if the pitch diameters are the same. These matters are illustrated in the sketches in Fig. 1.

With gearing of the Alquist type we can use very small teeth without any danger of incurring excessive strains on individual teeth, which might involve risk of the development of fatigue cracks. In this connection it should be borne in mind that experiments have shown that the strongest steel, if subjected to periodic deflections, will break after a fiber strain of 20,000 pounds per square inch has been applied a million or more times.

In the work which is now being done by the General Electric Company, gears of the type described are applied in three ways. First, a single reduction has been accomplished by engaging one solid pinion with a flexible gear of this type; second, by engaging a solid pinion with two flexible idlers, which idlers in turn engage with a solid large gear; and third, in a double reduction where a solid, high-speed pinion engages flexible gears on two countershafts, these countershafts carrying solid pinions, both of which engage a flexible gear on the same low-speed shaft. In these two latter applications the flexibility of the gears serves to equalize the loads between all of the driving points, and the use of a plurality of driving points on the large gear reduces the length of face necessary on that gear. These different methods of application are illustrated by diagrams in Fig. 2, and are also shown by the photographs and drawings of actual machines which are attached to this paper.

In both of these cases where a single high-speed pinion drives two flexible gears, other very positive advantages are accom-

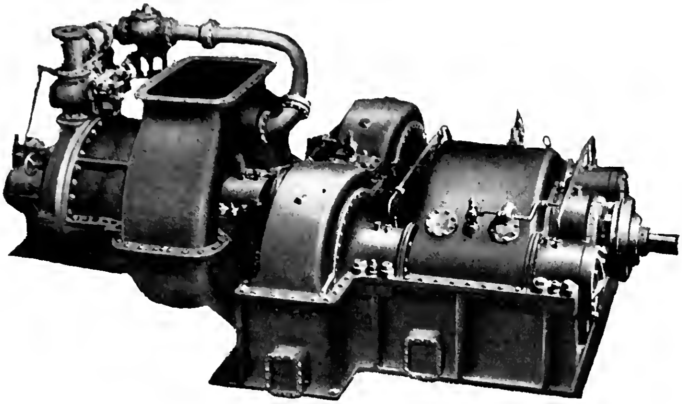


Fig. 6. Curtis Turbine and One Plane Flexible Type Speed Reduction Gear for Ship Propulsion

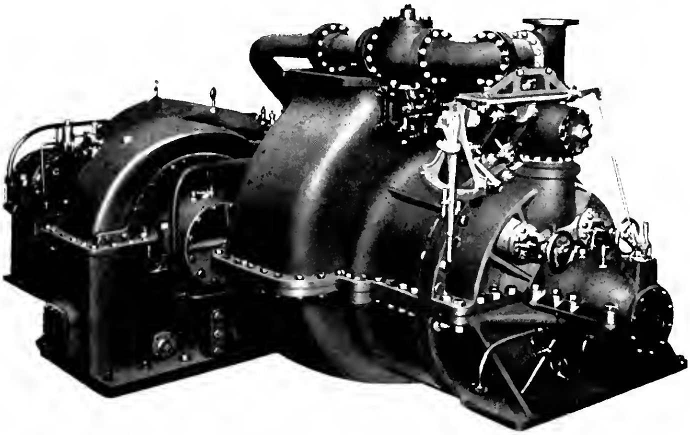


Fig. 7. Curtis Turbine and One Plane Flexible Type Speed Reduction Gear for Ship Propulsion, showing Control

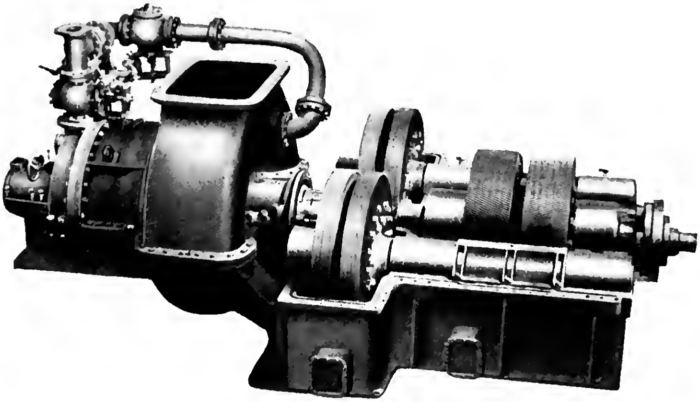


Fig. 8. Curtis Turbine and One Plane Flexible Type Speed Reduction Gear for Ship Propulsion. Top Half of Gear Housing Removed

plished. The pinion is relieved of bending strains, and pressure on the high-speed bearings is avoided.

Experiments have been made in Schenectady which carefully analyze the losses of high-speed gears under various conditions of load and pressure, and these experiments have indicated that low peripheral speeds are more efficient than high speeds. With solid gears, low speeds involve difficulties because they diminish pinion diameters and increase pinion lengths, thus complicating the troubles which may arise through deflection and torsion of pinions and pressure upon pinion bearings. Since the flexibility of Alquist gears enables us to compensate easily for all possible degrees of torsional yield in the pinion, we can with such gears safely reduce peripheral speeds by making the gears longer and of smaller diameter. Such reductions of diameter

S. S. "LA BREA"

Voyage	Date	Total Distance in Knots	Average Speed in Knots per Hour	Total Barrels Delivered	Name of Port	Total Fuel Used Steaming on Voyage in Barrels	Total Barrels per Knots Steaming	Total Barrels Used in Port	Total Barrels per Knot Steaming and in Port	Time in Port, Hours	Barrels Discharged per Hour	Cost at 80c. per Barrel per Knot Steaming and in Port (Fuel)	Shaft Horse Power Hours	Pounds of Oil per Shaft Horse Power
1	Mar. 9 to 15 1916	650	9.5	62578	Oleum	574	.883	142	1.10	36½	1714	$0.88	116000	1.67
2	Mar. 15 to 26	2037	11.33	73600	Seattle	1459	.716	152	.79	37½	1962	.632	505000	.941
3	Mar. 28 to Apr. 6	2108	11.01	64676 8462	Vancover Seattle	1584	.751	155	.824	26 13½	2487 640	.659	530000	1.01
4	Apr. 8 May 16	9254.5	10.97	52109 19045	Taltal Anto-pagasta	6896	.745	117	757	33¾ 15½	1544 1228	.605	233000	1.00
5	May 17 to 23	450	11.20	77292	Oleum	321	.713	134	1.01	39	1980	.808	118000	.911
6	May 24 to July 1st	9196.5	10.65	71824	Anto pagasta	6900	.75	109	.762	25	2660	.609	2200000	1.06
7	July 1st to Aug 9	9186	10.39	71791	Port San Luis to Anto pagasta Chile and Return	6875	.748	107	.76	42.3	1697	.609	2230000	1.04

Average speed. 10.9 Total pounds of oil steaming = 8270000 Total shaft horse power hours = 802900
Pounds of oil per shaft horse power = 1.03

S. S. "LOS ANGELES"

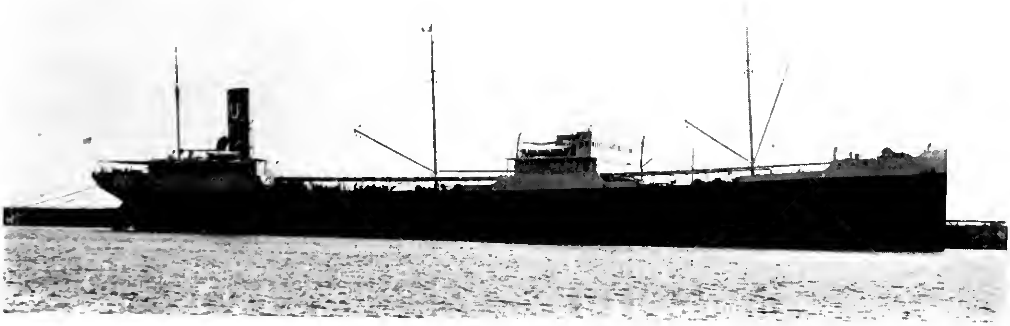
1	Apr. 9 to 15th	423	9.4	67674	Oleum	556	1.31	164	1.70	64½	1099	$1.36	74600	2.48
2	Apr. 16 to 25	1845	10.13	74739	Vancouver	1656	.897	218	1.01	33¾	2214	.808	394000	1.41
3	Apr. 27 to May 25	6549	10.22	73734	Panama	5579	.851	169	.877	16¾	1577	.701	1420000	1.315
	May 26 to 29	220	9.1	72372	Oleum	221	1.00	123	1.56	11	1770	1.24	39000	1.88
	May 30 June 27	6348	10.6	72538	Bal-Boa	5462	.86	159	.885	35	2072	.708	1460000	1.255
	June 29 Aug. 7-16	9151	10.24	71007	Port San Luis to Anto pagasta Chile and Return	8293	.906	186	.926	56.3	1261	.74	2130000	1.31

Average speed, 10.27. Total pounds of oil steaming = 7310000 Total shaft horse power = 538000
Pounds of oil per shaft horse power hour = 1.320

diminish weight and improve efficiency, and the fact that the Alquist method makes such reductions possible constitutes one of its important advantages.

The table shows a comparison of performances for two sister ships, the "La Brea" and the "Los Angeles," operated by the Union Oil Company of Los Angeles. Both of these ships are new, carry similar cargoes, and burn the same fuel oil in the same boilers under similar conditions. The "La Brea" is fitted with geared-turbine equipment, and the "Los Angeles" is fitted with triple expansion engines of the best type. The "Los Angeles" is equipped with steam-driven oil-handling pumps of the ordinary type, and the "La Brea" is fitted with a new arrangement of pumps driven from the upper deck by General Electric motors. The table illustrates the superiority of the oil-handling machinery as well as that which propels the ships. The horse-power hours given in this table are calculated from the propeller and hull data given by the naval architect of the Union Iron Works who built the ships, and based upon model tank experiments which were made in Washington. The models of the ships are identical, the "La Brea" propeller operating at 90 revolutions per minute and that of the "Los Angeles" at 65 revolutions per minute.

The seventh voyage of the "La Brea" and the sixth voyage of the "Los Angeles" were made over the same course and at nearly the same time. The relation of fuel economy of these two voyages almost exactly corresponds to that shown by the average of all the voyages and tends to verify the accuracy of the whole comparison.



Steamship "La Brae" Powered with 2600-h.p. Curtis Turbine Driving through Alquist Reduction Gears

A SURVEY OF THE AUTOMOBILE HEADLIGHT SITUATION*

By W. F. Little

Electrical Testing Laboratories, New York City

Perhaps the principal difficulty in developing a genuinely satisfactory headlight for automobile use is the elimination of glare. The following article is primarily a survey of this phase of the headlight situation. One feature of particular interest is a tabulated symposium of the convergence and divergence of opinion as to what constitutes the best projection characteristics for automobile headlights. Descriptions of the various devices which have been developed with the view toward attaining such characteristics are given in considerable detail.—Editor.

In the interests of simplicity this article deals only with headlights using concentrated filament electric lamps. In nearly all cases, however, the same principles may be applied to headlights using other light sources.

Automobile headlights depend in most part upon a reflecting paraboloid and a concentrated light source for their basis of light projection. Each infinitesimal portion of the reflecting area of a paraboloid with a source of light at the focus will reflect a cone of light equal in solid angle to the solid angle subtended by the light source at that point on the reflecting surface. In other words each infinitesimal reflecting area will project the image of the light source at its focus in the direction of the reflector axis.

The center portion of the reflector will therefore project a more divergent beam by reason of the shorter distance between the filament and reflector than will the outer zone of the reflector. Fig. 1-*A* represents the divergence of the beam as reflected by the center and rim of the reflector. The beam intensity or candle-power is then (with the lamp properly focused) dependent upon the filament brightness, reflection coefficient and reflector diameter, while the quantity of light reflected is dependent upon the total light from the lamp, the reflection coefficient and the solid angle subtended by the reflector.

With the light source behind the focus of the paraboloid, a diverging beam will be produced (Fig. 1-*B*). Conversely, with the light source in front of the focus a converging or crossing beam will be produced (Fig. 1-*C*).

The Theoretical Projector

The theoretical projector consisting of a true paraboloid and a point light source would reflect only parallel rays of light. The diameter of the beam at any distance would be equal to the diameter of the reflector, and a surface illuminated by the beam would be the same brightness irrespective of its distance from the reflector. In this case each infinitesimal reflecting area would project not a cone (as in the case of the finite source) but a single beam. Therefore, viewing the reflector from any single point in the beam the appearance would be that of two points of light, one the source, the other the reflection of the source.

The true paraboloid and the point source have to do only with the fundamental theory of light projection. As the former is almost unattainable, and the latter entirely so—at least from a practical standpoint—they need not be further considered.

Misconceptions

Possibly the most common misconception in regard to automobile headlights is the opinion that the elimination of the upper half of the reflector will obviate all upward reflected light. This is true only in the case of the diverging beam, whereas should the source be moved forward, producing a converging beam, the obscuration of the top of the reflector would eliminate the lower half of the beam.

Another misconception often encountered is that lenses increase light. As a matter of fact, though they may increase light in certain directions, they transmit no more light than a flat glass, and frequently much less. In no instance can a lens used as a cover glass for a well-focused parabolic headlight increase the beam candle-power.

It is also believed by many that reflectors increase light. Here again light is increased in certain directions by reflection, but with each re-direction there is absorption and thus the total light is reduced.

Unfortunately general advertising has strengthened some of these opinions by stating that with the use of certain lenses, reflectors or devices light is increased.

Practical Projectors

Since the focus of a perfectly formed paraboloid is a point, and as any light source has a material size, it is obvious that in no case can the entire source be wholly at the focus. However, assuming this perfect paraboloid with some part of the light source at the focus, a beam candle-power will result

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* This article is based on a paper by the author presented before the New York Section of the Illuminating Engineering Society, New York, January 10, 1917.

which depends on the product of the brightness of that portion of the source on the projected area of the reflector and the reflection coefficient of the reflector, *viz.*, the brightness of the entire reflector is equal to the brightness of the light source times the reflection coefficient. The beam spread will vary with the focal distance and size of the light source. Therefore, with the same source a 10-in. reflector with a 1-in. focus will have a considerably wider beam spread than a 10-in. reflector with a 2-in. focus.

The lamp itself forms no insignificant part in the means of light control. The filament winding has a very material effect upon the uniformity of light distribution throughout the beam. Bulb reflections in some cases may cause a considerable glare by forming images in a position other than that of the filament itself. To obviate this a number of remedies have been suggested, such as the use of tubular lamps, the use of round bulb lamps with the filament accurately centered, etc.

The centering of the filament with respect to the base is extremely important, as a crooked base or crooked stem may throw the filament to one side by a fraction of an inch, and seriously distort the beam. Most reflectors are equipped with an adjustable socket for forward and backward movement, but this will not correct for a crooked base or stem. Some manufacturers have found it advisable to use a special lamp basing, a device for accurately centering the filament.

Headlights, particularly those of short focal lengths, require very accurate placing of the filament, and as a rule any directing device used with a headlight complicates rather than simplifies this adjustment. Therefore, for satisfactory results the reflector must be properly formed, the filament accurately located, and the light controlling device not only accurately formed but accurately placed. The locating of the filament and light controlling device is usually left to the amateur, who knows but little of the optics of headlights. Therefore, simplicity is highly desirable.

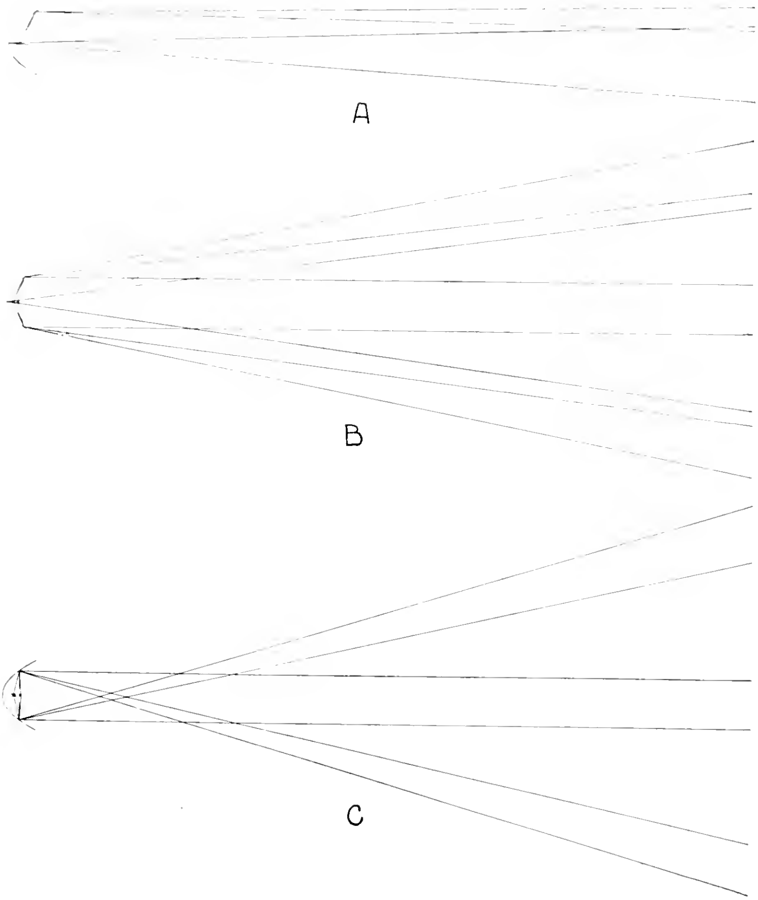


Fig. 1. Convergence and Divergence of Beams

The main problem in headlight design is that of applying the light effectively for driving purposes without producing glare. The angle which separates this useful light upon the roadway from that which would produce glare is very small. Also assuming that it is possible and practicable to keep all of the light below a plane passing through the headlight axes, the inequalities in the roadbed would cause this plane to shift to the extent of producing glare when the headlights point upward, and producing but little useful light when they point downward. A balance should be secured between objectionable glare on the one hand and useful driving light on the other.

Requirements

In order to obtain opinions concerning the requirements for headlight design, questions were sent to a number of men who have given thought to the subject. Several of these have very kindly given their views, which are summarized in Table I.

It must be understood that Table I does not represent a fixed opinion on the part of any of the participants. Most answers as received were qualified by such expressions as "In my mind there is no one ideal distribution characteristic for automobile headlights." "Conditions are different in city and country driving," etc.

The table represents an attempt to tabulate in each case, the compromise which seems the most acceptable to the individual. It has been made up by the author from more detailed expressions of the contributors' views, and the wording has not been submitted to the contributors for approval.

Methods Employed

A number of " non-glare " headlight devices have been developed. The principles upon which these depend may be classified as follows:

REDUCTION OF GLARE

1. By dimming the light.
2. By diffusing the light.
3. By cutting off disturbing light.
4. By re-direction of the light.
5. By special type of reflector.
6. By change in the color of the light.
7. By tilting the reflector.

Several of the devices available make use of two or more of these principles. The first and simpler principle is the mere dimming of the lights by means of a rheostat or by throwing the two incandescent lamps in series without changing the light distribution. As the beam candle-power is directly proportional to the brightness of the source, the reduction of the beam by this method of avoiding glare would be followed by a similar decrease of light upon the roadway.

The second principle, that of reducing the brightness of the beam by diffusion, is applied in the form of a diffusing front glass either clear or frosted. Any degree of diffusion required may thus be obtained. The diffusion has the effect of reducing the beam intensity and contributing the light so gained to the illumination of objects contained within a much wider angle.

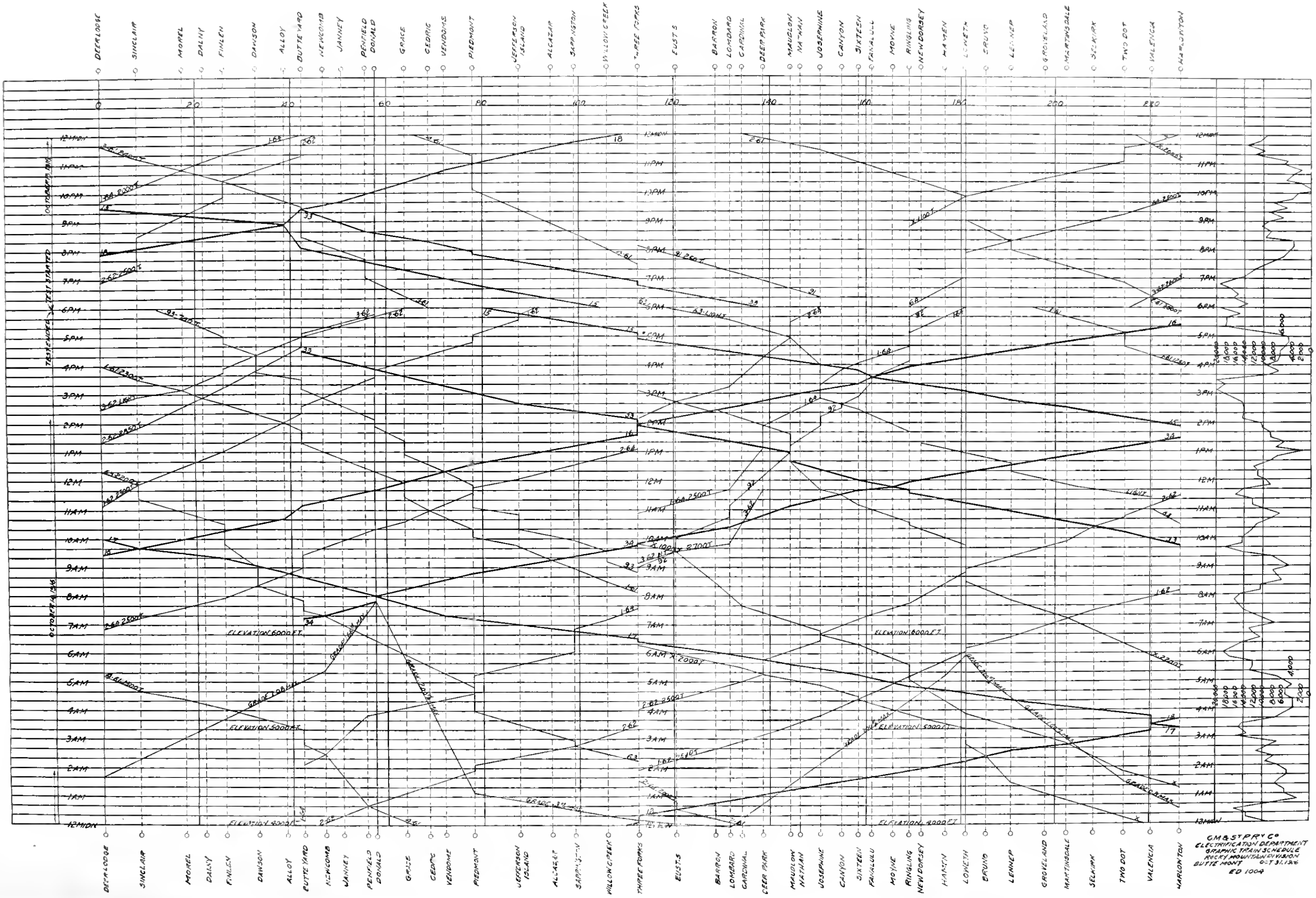
The third principle, that of cutting out portions of the beam, depends on the fact that if the front end of the lamp filament is placed at the focus, the divergence of the beam reflected from the top of the reflector will all be above the horizontal, while that from the bottom will all be below the horizontal or axis of the reflector. Hence, if no reflected light from the upper half is allowed to emerge, all the light of the headlight will be along the axis and below it. This may be done by a blind over the top half of the glass front or by a cap over the top of the lamp bulb. This elimination of course reduces the beam candle-power and total flux to an extent which in many instances amounts to one half or more. A variation is made upon this method in some cases by frosting rather than rendering opaque the upper half of the reflector or lamp. Opaque caps covering the upper half of the lamp bulb, when black, will accomplish the same purpose as eliminating half of the reflector. If the opaque cap has a reflecting interior surface, the available flux impinging at the lower surface of the reflector is greatly increased, but the efficiency is still less than that of the same unit not so equipped.

The fourth principle, that of the reduction of light above the horizontal by re-direction, is applied principally by the use of prismatic glass fronts which tend to re-direct all reflected light or by prisms surrounding the lower portion of the bulb.

The fifth principle involves the use of a split or double reflector having its upper and lower halves of different focal length or having the foci separated by the filament length; also may be accomplished by having the upper and lower portions of different shape.

The sixth principle, that of reduction in apparent brightness and reduction in glare by the change in color of light, is accomplished either by using a colored glass reflector or colored glass front, and in some cases a colored glass bulb. It is asserted that a yellow beam of light will produce less glare and penetrate a fog better than the same intensity beam of unmodified light.

* * * The sum and substance of all of the papers so far presented has been a conglomerate mass of conflicting and personal opinions. At this time there is no absolutely authoritative information on the subject. It must be borne in mind that the subject of yellow light for headlight work is


DEER LODGE
SINCLAIR
MOREL
DALNY
FINLEN
DAWSON
ALLOY
BUTTE YARD
NEWCOMB
JANNEY
PENFIELD
DONALD
GRACE
CEDRIC
VENDOME
PIEDMONT
JEFFERSON ISLAND
ALCAZAR
SAPPINGTON
WILLOW CREEK
THREE FORKS
EUSTIS
BARRON
LOMBARD
CARDINAL
DEER PARK
MAUDLOW
NATHAN
JOSEPHINE
CANYON
SIXTEEN
FANALULU
MOYNE
RINGLING
NEW DORSEY
HAMEN
LOWETH
BRUNO
LENNEP
GROVELAND
MARTINSDALE
SELKIRK
TWO DOT
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TEST ENDED
TEST STARTED
ELEVATION 6000 FT.
ELEVATION 5000 FT.
ELEVATION 4000 FT.
GRADE 1.66% MAX.
GRADE 2.0% MAX.
GRADE 1% MAX.
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
C M & St P Ry Co
ELECTRIFICATION DEPARTMENT
GRAPHIC TRAIN SCHEDULE
ROCKY MOUNTAIN DIVISION
BUTTE MONT OCT 31, 1916
ED 1004

TABLE I

SYMPOSIUM OF ILLUMINATION EQUIPMENTS FOR AUTOMOBILE HEADLIGHTS

Questions	G. H. Stickney	Louis J. Stern	E. C. Patterson	F. H. Ford	E. J. Edwards	Robert L. Sim	Dr. Louis Bell	Dr. H. P. Gage	A. McMurtry	C. C. Lindsay	A. L. Powell	John E. Ryan	Dr. C. H. Sharp
1. Please indicate the light distribution characteristic which in your opinion is ideal for automobile headlights with special reference to the following features:													
(a)—Angular distance of beam maximum below horizontal	1½°	0°	No beam	⅛°	2°	Horizontal or slightly below, falling off rapidly above and slowly below horizontal	Very slightly below horizontal	Very slightly below horizontal	0°	No beam	1½°	2°	—
(b)—Distance ahead of car at which center of beam should strike a level roadway	150 to 300 feet	500 feet	—	600 feet	100 to 200 feet for good headlight. 50 feet for poor	The further the better	Long driving light	Infinite distance	Infinite distance	—	100 to 200 feet	250 feet	—
(c)—Width of beam on level roadway at 50 feet	6 feet	30 feet	—	—	8 feet	The broader the better	Sufficient direct light	10 feet	No beam	—	5 feet	15 feet	For country driving, narrow intense beam which does not reach altitude sufficient to shine in the eyes of the opposing driver
Ditto at 100 feet	10 feet	—	—	—	14 feet	—	Cover roadway	15 feet	Width of roadway	—	10 feet	30 feet	
Ditto at 200 feet	12 feet	—	—	20 feet	20 feet	—	Cover roadway	25 feet	Ability to discern objects on road	—	20 feet	60 feet	
Ditto at 300 feet	16 feet	—	—	—	25 feet	—	Cover roadway	37½ feet	Ditto	—	—	—	
Ditto at 500 feet	20 feet	—	—	—	35 feet Entire width at 25 feet	—	Cover roadway	62 feet	Ditto	—	—	—	
(d)—Proportion of reflected light which should be directed above the horizontal	Preferably not over 10 per cent.	None	—	None	As near as practicable	Of parallel rays, the less the better	None	Small amount	None		None	One-third of the total light generated from either half of the reflector should be diffused	—
2. Please state the distance at which the glare from most headlights is found to be most objectionable	City 0-600 ft. Country 0-1,000 ft.	20 to 80 feet	From their appearance to passing	0 to 400 feet	200 feet for unmodified parabola	100 to 200 feet	Variable	100 to 200 feet	200 feet to passing	From 200 to 250 feet to passing	200 feet to passing	100 feet	Nearby
3. In your opinion is a height of 42 inches satisfactory as a limit below which the beam should be confined? If it is not satisfactory, do you consider any alternative?	Yes	Not entirely. 48 inches better	No—Eliminate beam	Yes	Yes	Yes	Yes	Yes	Yes	No—Eliminate beam	Yes	Yes	Yes
4. Have you any practicable means to suggest for determining what is and what is not objectionable glare from automobile headlights?	That which obliterates adjacent objects	Indefinite. Should be based upon experiments	When subject cannot read fine print after being subjected to the light	No	Experimentation. 100 or more candlepower decided interference with vision	No	When surroundings of headlight can be seen unaccompanied by halo, glare is not objectionable	Above 1,000 beam candlepower	No	No	Ability of driver to look at approaching car and clearly see objects between it and him	Ability to distinguish the light source at a distance of 50 to 75 feet	No
Remarks	Conditions different for country and city driving. Background influence over glare	—	Any light emitting a ray or beam of light is obnoxious, dangerous, and in many sections illegal	—	—	—	—	—	—	—	—	—	—

not the same as yellow light for general illumination.

* * *

I have made many tests of various headlights which produce yellow light, but find no reduction in glare except that directly traceable to the lesser intensity of the headlight, due to the absorption of the glass. So far as my tests are concerned I cannot find that there is any basis for the claim that a light of this characteristic will penetrate fog, dust, smoke or mist to any greater degree than will a white light of equal intensity. There is this about yellow light which appears to be advantageous, and that is, when driving a car through a rainstorm or a heavy fog, the diffractive halation or back glare is somewhat reduced. There are, however, no scientific data on this point.*

The seventh principle, that of tilting the headlights downward to the point where very little reflected light is above the horizontal, is a simple expedient, and in many cases would probably result in quite as effectual a glare remedy as many other devices employed. This expedient is not looked upon with favor by the law makers, in spite of the fact that for a well-designed headlight pointed downward at an angle of 3 deg., the maximum would strike a level roadway 67 ft. in front of the car and the reflected light at the horizontal would be less than 40 per cent. of the beam intensity, while 1 deg. above for the reflected light would be about 15 per cent. of the maximum. In many of the devices now in use the cut-off between the maximum and horizontal is not as good as the figures just shown. This is indicated in Table II.

It is interesting to note that in spite of the use of almost any device modifying the natural light distribution from an automobile headlight, an opposing driver will invariably allow his headlights to burn full intensity without modification unless one's own headlights are dimmed in passing.

The several devices available for reducing glare may be classified as

1. Control of light between the source and reflector
2. Control of light by the reflector
3. Control of light after leaving the reflector

The first class includes coloring, frosting or otherwise changing the surface of the bulb; and the use of caps and prisms.

The second class involves varying the contours and forms of the reflectors.

The third class involves the use of glass fronts made in the various forms, and of blinds. The various glass fronts used to control the reflected light may be divided into two classes, the prismatic and diffusing.

The following is a brief description of some of the typical devices which have been developed, and which make use of the foregoing principles for their operation:

The *Fracto Lens* consists of curved prisms partially surrounding the lamp which are intended to be so located that all of the light striking one-half of the reflector must pass through these prisms. The prisms virtually move the filament backward, by the distance of the filament length. Therefore, with the prisms placed below the bulb, the complete length of the filament should be ahead of the reflector focus causing the upper portion of the reflector to produce a converging or downward beam. The light passing downward through the prisms is moved backwards, producing a diverging downward beam. Under these circumstances if all adjustments are correct the beam candle-power should be somewhat reduced and the beam spread somewhat increased by the diverging beam. The extent to which this device performs its function will depend upon the accuracy of the prisms, the reflector and the lamp, and upon the correct location of each.

The *Lennon Cap* is a hemispherical metal cap with nickel-plated surface. This cap snaps on a 21/16-in. bulb and follows its contour. The concave nickel-plated surface acts as a spherical mirror and produces an image of the filament in front of the actual filament. Therefore, the actual filament should be placed in front of the focus with the cap on the lower side of the bulb. A converging or downward beam will be formed by both the filament and the image. The beam produced by the image will cross near the reflector and will be widely distributed below the reflector axis. The cap extends sufficiently far around the end of the bulb to eliminate most of the direct light from the filament.

The *Perrin Cap* is quite similar in construction and method of operation to the Lennon cap, with the exception that the outer end of the cap is cut away, allowing egress to the direct light at and below the horizontal. Attached to this end is a small semi-circular portion of metal similar in curvature to the cap and bulb and held in place against the bulb by two spiral springs. This small metal piece prevents the direct light from the filament from being thrown upwards.

The *Ames Deflector* is another device of the cap variety, constructed to snap on the upper side of a 1½-inch bulb. The cap is silver plated and acts as a spherical mirror. It is divided into three reflecting surfaces, two of which are spherical, the third flat. The spherical surfaces are so designed that they produce two filament images, one behind the other, and each behind the filament, thus virtually lengthening the filament to three times its length. To produce the desired adjustment, the entire filament and filament images are located just behind the paraboloid focus. This produces a diverging semicircular beam with a flat top at the horizontal and a considerable illumination along the roadway from the beam maximum to the car.

The *Ames Headlamps* are of several varieties, and depend for their operation upon the use of spherical and ellipsoidal surfaces for the upper reflecting surface. Some of these headlamps have the electric lamp mounted at an angle of forty degrees to the horizontal, and the filament located entirely above

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* Abstract of paper read at Toledo meeting of C. E. R. A., November 23 to 24, by Mr. K. W. Mackall, Electrical Engineer, Ohio Brass Company, Mansfield, Ohio.

the focus. This feature allows of a considerable latitude in the location of the filament, and a helical or V-shaped filament may be used with equal success.

The *Matisse Headlight* makes use of a silvered glass reflector, having ground surfaces. The concave surface is spherical and the convex parabolic, thus making the reflector the converse of the Mangin mirror, namely, thick in the center and thin at the edges. The reflector design produces a very concentrated beam by reason of its long focal length, namely 2¼ in. Its diameter is 10 in. and its depth 3½ in. In front of the lamp is placed a spherical mirror 3 in. in diameter in such a position that it intercepts that portion of the beam (the center) which is the most widely divergent. The small spherical mirror produces an image of the filament and this image is placed slightly above the actual filament. Both the filament and the image are located above the reflector axis. The filament produces a concentrated beam of high power approximately 1 deg. below the reflector axis, and the image may be adjusted to produce a secondary beam at any required angle of inclination. This headlight therefore produces two beams, both of which are highly concentrated, and may be adjusted so that practically all of the reflected light is below the reflector axis.

TABLE II

COMPARISON OF THREE TYPICAL NON-GLARE HEADLIGHT FRONTS WITH AN UNMODIFIED BEAM TILTED DOWNWARD BY 3° CANDLE-POWER AT DIFFERENT ANGLES

Degrees	Beam Strikes the Road Feet	Unmodified Tilted Downward 3° Per Cent	HEADLIGHT NO. 1		HEADLIGHT NO. 2		HEADLIGHT NO. 3	
			Per Cent of C-p. Unmodified	Per Cent of 3° Below	Per Cent of C-p. Unmodified	Per Cent of 3° Below	Per Cent of C-p. Unmodified	Per Cent of 3° Below
2° above horiz.		4	4	10	10	110	4	20
1° above horiz.		14	5	13	10	110	5	25
0° horiz.	8	37	10	25	11	122	5	25
1° below horiz.	200	53	20	51	11	122	7	35
2° below horiz.	100	91	34	87	10	110	11	55
3° below horiz.	67	100	39	100	9	100	20	100
4° below horiz.	50	98	36	92	8	89	33	165
5° below horiz.	43						43	215
6° below horiz.	38						43	215

The *Adams-Bagnall tilting device* makes use of an electrically operated mechanism in the housing of one headlight. The two reflectors are mechanically attached, so that with the operation of one is secured the control of both. The mechanism is operated (by the driver) with a push button. The reflectors will go through one complete cycle in something less than two seconds. Their tilt can be adjusted at will.

The *Rand Reflector* is composed of two half paraboloids split horizontally in the center, having a common focal point, and the upper half paraboloid inclined downward at an angle of 2 to 7 deg. Both halves throw diverging and downward beams.

The *Edwards Headlight* is a combination consisting of a parabolic lower part and an ellipsoidal upper part. This device if perfectly made would give no light above the horizontal, not even the direct light from the filament. Proper adjustment requires that the filament be placed a little more than half its axial length back of the parabolic part. The ellipsoid is arranged to have one of its foci at the proper position of the filament and the other, through which the intercepted rays are directed, at a point on the axis of the lamp just back of the plane of the front glass. The lower portion of this device, being parabolic, distributes the light accordingly. The upper portion, being an ellipsoid, distributes the light downward in substantially the same way as would obtain should the source be placed in the plane of the glass front with all of the light eliminated in the upward direction. The angular spread of light below the horizontal from the ellipsoid would be substantially 180 deg., and the image of the source would be visible from any position below the axis in front of the plane passing through the glass fronts.

The *Offset Reflector* is virtually two half reflectors, the division being made horizontally. The lower half has a focal length greater than the upper by the length of the filament. Therefore, the entire filament is behind the focus for the lower reflector and ahead of the focus for the upper reflector, and the lower half reflector throws a downward and diverging beam—the upper half reflector a downward converging beam.

The *Conaphore Prismatic Glass Front* has horizontal prisms approximately ¾-in. high and ⅛-in. deep across the surface of the glass. These prisms are warped surfaces with the deeper cuttings in the center. The reflected light is bent downwards by half the beam spread. Therefore, the entire beam spread is below the horizontal. As the center produces a more widely divergent beam than the edges of the reflector, the deeper cuttings are in the center. This produces asymmetric light distribution with the maximum intensity slightly below the horizontal and reducing rapidly above the horizontal and much less rapidly below the horizontal. In addition, the prisms in the center of the glass are cut in the form of cylinders in order to distribute the light sidewise and widen out the beam. These glass fronts are made up in both crystal and no-glare (amber) glass.

The *Totalux Glass Fronts* are of the prismatic type. The upper two-thirds of the front is divided in two sets of prisms sloping diagonally downward from the center at an angle of 45 deg. The lower third of the front is left unmodified. The prisms are so formed that all of the light passing through them is thrown below the horizontal and the two sets divert the light away from the axis. Therefore, the unmodified reflected light forms the main portion of the beam, and the prisms distribute the light over the roadway at a shorter distance from the headlight. A single headlight would produce three separate and distinct beams. Combining the two headlights, these beams superimpose making substantially one wide spread beam.

The *Osgood Lens* is a glass front over which are a series of prisms. The lower prisms are designed to bend the light from the lower portion of the reflector slightly downward, and the upper or projecting prisms to throw the light more sharply down and to distribute it nearby. The latest form of Osgood lens has horizontal prisms across the entire front to bend the reflected light slightly below the horizontal. A rib at the center serves to distribute the beam slightly sidewise.

The *Legalite Lens* is a front, having horizontal prisms across the entire surface. The prisms are graduated in depth and formation, so that all of the reflected light is slightly diverted toward the roadway. The opposite side of the lens is a section of a cylinder with a vertical axis thus distributing the light sidewise.

The *Hess Lens* consists of parallel horizontal bars etched on the inside and outside of the glass front. These bars are approximately ¼-in. wide, alternated with a clear glass of the same width, and cover the upper two-thirds of the front. It is designed with a view to allowing the greatest possible egress of parallel rays in the direction of the reflector axis, and the least possible egress of upward light, the idea being that rays other than parallel will be caught and diffused by the bars.

The *Warner Lens* consists of a multiplicity of small lenses over the glass front. These lenses are designed to break up and diffuse the light in a limited solid angle in the direction of the reflector axis. The extent to which the beam is spread and diffused will, of course, vary with the formation of the lenses. As glare is a function of unit brightness from the point of vision, so also is the candlepower in that direction. Therefore, the reduction in glare will be followed with a corresponding reduction in intensity. As the distribution of light is more or less constant over a comparatively wide angle, the intensity in the direction of the roadway is, of course, similar to the intensity above the roadway.

The *Star Lens* is a glass front upon which is sandblasted a many pointed star. The only part that is clear is that at the extreme edge between the numerous points. This clear portion, however, allows a concentrated beam of comparatively low intensity to pass through in the direction of the reflector axis. The remaining portion of the reflected light and much of the direct light is diffused by the etched surface.

The *Prysmolite Front* is of the diffusing glass type having horizontal and vertical prisms over the entire front, forming a checkered surface, the prisms being approximately ⅛ in. between centers. This glass produces two sheets of light at right angles to each other, intersecting at the reflector axis. These sheets are caused by the light passing through the glass normally where the inside and outside surfaces are parallel, *viz.*, at the bottom and top of the prisms.

The *Alpha Front* is another of the diffusing glass type, consisting of a ripple glass with a cut star in the center. The rippling of the glass is sufficient to break up the light and distribute it over a narrow angle.

The *Melolite Shield* consists of a diffusing material back of the cover glass intercepting and diffusing all of the reflected light except that from a narrow ring around the edge of the reflector. This ring produces a concentrated beam of comparatively low intensity.

The *Glare-off Blind* is a tin shield placed inside of the upper part of the front glass. This blind obscures the upper half of the reflector and the center to the diameter of approximately 3 in. With the lamp behind the focus a diverging and downward beam is produced by the reflected light. As considerably more than half of the reflecting surface is obscured a corresponding reduction in total light results.

The *Monarch Dimmer* is a blind obscuring the upper half of the reflector. With a diverging beam and a well formed reflector no reflected light is thrown above horizontal.

The *Saferlite front glass* is a sheet of prismatic glass with prisms finely cut (approximately 30 to the inch) over the entire surface, which serve to break up and diffuse the light over a comparatively narrow angle, thus giving a uniform brightness over the entire surface.

The *Matisse* front glass has numerous small lenses of the same size arranged in concentric rings over the outside surface, leaving the center portion, to the diameter of approximately three inches, smooth, and frosted on the inside. This device is a compromise between the concentrated and diffused systems.

The *Radialite front glass* is also a compromise between the concentrating and diffusing systems, and has two clear sectors on either side of the axis with the upper and lower sectors sandblasted, allowing unmodified light to pass out at the side, and diffused light at the top and bottom.

LITERATURE OF THE NITROGEN INDUSTRIES, 1912–1916

By Helen R. Hosmer

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The two previous installments of this article, published in our January and February issues, considered the description and chemistry of processes for the production of nitrogen compounds, and the extent of their production and consumption. The review of the literature on the subject is concluded in this installment with a consideration of the costs of the several processes, and an appendix dealing with the recovery of nitrogen compounds from coke ovens, producer gas plants, etc., and with the uses made of cyanamide.—**Editor.**

PART IV: COSTS

GENERAL

Price of Nitrogen

1915 The price of combined nitrogen (50, 47) is fixed by the price of Chile saltpeter, of which the 95 per cent pure contains about 15.5 per cent of nitrogen. When the latter sells for 2 cents per lb. for the 15 per cent grade, the price of nitrogen is 13.2 cents per lb. and the price of ammonium sulphate containing 21 per cent of nitrogen should be 2.7 cents per lb. The cost of converting nitrate into nitric acid increases its value 50 per cent. Hence there is this added margin for the direct production of acid by other processes.

The price of Chile saltpeter has averaged since 1909, $35 to $40 per ton f.o.b. Chile, or $45 f.o.b. Liverpool. The present cost of production is from $10 to $20 per ton, leaving a profit on the mining of $5 to $10 after paying a tax to the Chilean government of $12.25 per ton.

The Liverpool price of ammonium sulphate approximates that of sodium nitrate, varying from $45 to $60 per ton. The nitrogen content is about 21 per cent.

The cost of converting ammonia into ammonium sulphate is about $15 per ton of the salt, and the cost to the by-product coke oven of producing the ammonia required for a ton is about $10.

1915 Peacock (47) considers that it will be necessary to get the production cost at the factory down to 4 cents per lb. of ammonia, in order to have any process of nitrogen fixation compete successfully with by- product ammonium sulphate. This seems to necessitate a process giving other by-products of value. A low priced ammonia once obtained, oxidation processes will follow easily. A concentrated end product such as potassium or ammonium nitrate, or ammonium phosphate, with a factory cost not exceeding 5 cents per lb. of combined nitrogen in the form of ammonia will probably be necessary in order to meet the competative resources of by-product ammonia.

Summers (50) also believes that the solution of the problem must be sought through improvement of processes. 1915

Carlson (57) gives the value of a kilogram of nitrogen in the various forms showing the increase from the value as element up to a complex drug like veronal. 1914

Fixation Costs

Washburn (12) claims that the arc process is at a great disadvantage compared with the cyanamide. For the fixation of a unit of nitrogen the former requires from five to six times as much power as the latter. The production of 180,000 net tons of concentrated nitric acid per annum requires 540,000 continuous horse-power by the former and 100,000 continuous horse-power by the latter method. At the moderate American cost of installation of $100 per continuous horse-power, the total installation cost of the arc process for the above rate of production would be $80,000,000—and for the cyanamide process, $30,000,000. Even at an installation cost of $60 per continuous horse-power on the switchboard, concentrated nitric acid costs a third more by the arc process. Even with power at the abnormally low figure of $10 operative cost per continuous horse-power on the switchboard, the pound of nitrogen by the arc process costs for power alone as much as the total cost of the pound of nitrogen by the cyanamide process, including power, materials, labor, interest, amortization, and depreciation. 1916

He also states that the cost of production of nitric acid by the cyanamide process as it is being established by an English Company throughout the allied countries is substantially 70 per cent of the cost of production from Chilean nitrate.

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(50) Summers, Transactions Amer. Electrochemical Society, *27* 339–83 (1915).

Proceedings, Amer. Institute of Electrical Engineers, *34*, 337–81 (1915).

Abstract, Metallurgical and Chemical Engineering, *13*, 241–4 (1915).

(47) Peacock, Transactions, Amer. Electrochemical Society, *27*, 409–17 (1915).

(57) Carlson, Zeitschrift fur angewandte Chemie, *27* (3) 724-5 (1914).

(12) Washburn," The Facts in the Nitrogen Case." (1916).

The German nitrogen monopoly agrees to sell nitrogen after the war at a maximum price of less than half what farmers normally pay (22) in the United States. 1916

Germany has expended on her nitrogen fixation industry since the beginning of the war, $100,000,000 (22). 1916

Washburn (16) gives the cost of Chilean nitrate as $2.40 to $2.60 per unit of ammonia (20 lb.) (=$50 a ton), and of cyanamide as 80–90 cents per unit of ammonia.

1916 Norton (15) believes from observation of European practice that the minimum sized plant for economical fixation of nitrogen is about 30,000 horse-power.

He also states that in order to compete with the cyanamide process using power at $20 per horse-power, the arc processes must get power at $3 or $4 a horse-power, but if the final product desired be nitric acid, the arc process can compete at $7, $8 or $10 per horse-power.

1915 Summers (50) considers in detail the relative costs of the various processes for fixing nitrogen. From certain initial estimates of costs of labor, etc., he concludes that under the best conditions the manufacture cannot meet expenses and pay more than $15 per kilowatt year. Hence the acid cannot find application in fertilizers, and the process can be utilized only if it may be coupled with some other product.

He computes that the electrical power requirements of the various processes are as follows:

Direct oxidation processes require per kg. of nitrogen	65.0 kw-hr.
Cyanamide process, aside from preparation of nitrogen gas, requires per kg. of nitrogen	16.6 kw-hr.
Serpek process, besides energy from coal, requires per kg. of nitrogen	12.0 kw-hr.
Haber synthetic ammonia process, besides preparation of nitrogen and hydrogen, compression and refrigerating, requires per kg. of nitrogen	1.5 kw-hr.

1915 Baur (34) gives the yields and costs of the various arc processes as follows:

	Yield, g. of HNO_3 per kw-hr.	Price in Centimes per kw-hr.	Cost in Pfennigs per kg. N
Moscicki		0.30	15
Pauling	60	0.60	30
Birkeland	70	1.20	60
Schönherr	75	....	..

Hence at a market price of 1.23 M. per kg. of nitrogen as calcium nitrate, this substance can only be made at a profit, where power can be obtained in sufficient quantities at a price less than 0.5 centimes per kilowatt-hour.

The lime nitrogen process requires about 2 kw-yr. per ton of nitrogen fixed, and the Haber or synthetic ammonia process, 3 kw-yr. per 1000 kg. of nitrogen.

Washburn (51) while giving no specific cost 1915 data, draws comparisons which he states are derived from actual working records, between the costs of the various processes.

Under the most favorable conditions the factory cost, exclusive of all power costs, of nitrogen in the form of commercial nitric acid, made by the arc process, is greater than the total cost of nitrogen as cyanamide, including power used at $10 per continuous horse-power year. Hence the cyanamide process can fix nitrogen, with power at $10 per horse-power year, cheaper than the cheapest of the arc processes with power free, or with all labor, raw materials and supplies free, and a charge of from $8 to $10 per horse-power year. The total cost of nitrogen in nitric acid from the arc process cannot by any chance be less than double that of nitrogen in cyanamide, thus giving the latter form a wide margin for its conversion into nitric acid, if desired. The indications are that weak nitric acid can be made by the cyanamide process for about ¾ of the cost by the arc process, but as power is brought below $10 per continuous horse-power year, the production cost of the latter process will diminish until it becomes about the same as for the former at $4 per horse-power year.

The cost of producing ammonia gas by the Haber process under the most favorable conditions, is nearly double that by the cyanamide process.

The investment necessitated by the arc process per unit of nitrogen as weak nitric acid, assuming the investment for power to be between $50 and $75 per horse-power upon the switchboard, is about three times that per unit of nitrogen as ammonia, or twice that

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(22) Washburn, Statement before House Committee on Military Affairs, Feb. 11, 1916. Statement before House Committee on Agriculture, Feb. 1, 1916.

(16) Statement before the Senate Committee on Agriculture and Forestry, March 16, 1896 (S. 4971).

(15) Norton Statement before Senate Committee on Agriculture and Forestry, 1916 (S. 4971).

(50) Summers, Transactions Amer. Electrochemical Society, *27*, 339–83 (1915).

Proceedings, Amer. Institute of Electrical Engineers, *34*, 337–81 (1915).

Abstract, Metallurgical and Chemical Engineering, *13*, 241–4 (1915).

(34) Baur, Schweizerische Wasserwirtschaft, *7*, No. 16 and 17.

Elektrotechnische Zeitschrift, *36*, 694–5 (1915).

(51) Washburn, Transactions, Amer. Electrochemical Society, *27*, 385–402 (1915).

Metallurgical and Chemical Engineering, *13*, 309–14 (1915).

per unit of nitrogen as nitric acid derived from cyanamide. The fixed investment for ammonia production for the cyanamide process may be as low as one and one-half times the market value of the annual product compared with three times for the Haber process. For nitric acid by the cyanamide process the investment may be only one and one-fourth times the annual product, while for the arc process, with a power investment of $75 per continuous horse-power, the fixed investment would be from three to four times.

In the United States the majority of manufacturing concerns vary in fixed investment from one to one and a half times the market value of the annual product, exceeding this proportion only in very special cases. The most reliable class of investments such as public utility corporations, do not exceed $4 to $6 investment per dollar of gross revenue.

1915 Washburn (51) points out that though the Haber process demands relatively little power, yet the cost in the vicinity of New York of the electrical energy demanded is as much as the total power cost for cyanamide at other available sites. Its successful employment by the Badische Company is due to their pressing need for a way of disposing of large quantities of by-product sulphuric acid.

1915 Peacock (47) believes that synthetic ammonia processes such as that of Haber may have local application, but will never become commercially important.

The plant investment required for the production of cyanamide ammonia is about half that for Haber, or synthetic ammonia. The cyanamid plant costs per unit of nitrogen fixed, about one-quarter as much as the arc process plant, and even the cyanamide-ammonia-nitric-acid plant costs only from one-third to one-half as much to install as the arc. The electric power required per unit of nitrogen fixed is one-fifth, and the labor about the same as that of the arc process. The further conversion of the ammonia into nitric acid requires only a small fraction of additional power and labor. Moreover, the cyanamide is readily transported, and can be easily and economically converted into ammonia and nitric acid by small units at the
1915 point where used (41).

1914 Haber (62) states that the Frank and Caro or cyanamide process fixes 50 g. of nitrogen per kw-hr. including all power.

The energy consumption in the fixation of one ton of nitrogen as calcium cyanamide is
1913 given by Pranke (96) as about three horse-power years including manufacture of carbide and all subsequent factory operations.

1913 Kroczek (89) gives the horse-power consumption of the various processes as follows:

	H.P. hr. Per kg. (2.2 lb.)
Kawalsky-Pauling	97
Birkeland-Eyde	84
Schönherr	80
Calcium cyanamide	33
Aluminum nitride	16

1912 Scott (124) gives the nitrogen content and comparative prices of various artificial fertilizers as follows:

	Per Cent Nitrogen	Price Per Ton (Long)
Ammonium sulphate from gas works	19.75	13 L
Chile nitrate	15.50	9 L 15s
Norwegian calcium nitrate	12.75	8 L 10s
Calcium cyanamide	18.00	10 L

1910 Roeber (146) gives the yields of the various processes as,

Schönherr (Badische Co.)	75 g.	HNO_3 per kw-hr.
Birkeland-Eyde	70	HNO_3 per kw-hr.
Pauling	60–75	HNO_3 per kw-hr.
Cyanamide	76	HNO_3 per kw-hr.

1912 Scott (124) gives the yield of the Birkeland-Eyde process as 500-550 kg. of nitric acid or 853–938 kg. of calcium nitrate per kw-yr. The best yield at Notodden has been 900 kg. of 100 per cent nitric acid per kw-yr.

The Pauling process guarantees 60 g. of 100 per cent nitric acid per kw-hr. and a cost of 120 francs per kilowatt as cost of the electrochemical plant itself.

1912 Dobbelstein (113) gives the costs of installation and operation for a plant employing the Hauser method with coke oven gases.

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(51) Washburn, Transactions, Amer. Electrochemical Society, *27*, 385–402 (1915).
Metallurgical and Chemical Engineering, *13*, 309–14 (1915).

(47) Peacock, Transactions, Amer. Electrochemical Society, *27*, 409–17 (1915).

(41) Landis, Journal Industrial and Engineering Chemistry, 7, 433–8 (1915).
Metallurgical and Chemical Engineering, *13*, 213–8 (1915).

(62) Haber, Journal, Society of Chemical Industry, *33*, 52–4 (1914).

(96) Pranke, "Cyanamiffe," (Chemical Publishing Co., Easton, Pa. 1913 106 PP.)

(89) Kroczek, Gas World, *59*, 378 (1913).
Chemical Abstracts, 7, 3922 (1913).

(124) Scott, "Manufacture of nitrates from the atmosphere. Smithsonian Report for 1913, pp. 359–84, (1914). (Publication 2291). Reprinted from Journal, Royal Society of Arts, (London) *60*, No. 3104, (1912).

(146) Roeber, Mineral Industry, *19*, 58–67 (1910).

(113) Dobbelstein, Stahl und Eisen, *32*, 1571–7 (1912).
Abstract, Journal, Society of Chemical Industry *31*, *982* (1912).

1914 Reference (81) gives the yields of the Serpek process as 2 tons of alumina and 500 kg. of fixed nitrogen (as ammonia) per kw-yr.

1911 Beckman (132) describes the general financial status of the nitrogen fixation industry as being "well paying" and gives income figures. He makes a mistake, however, in stating that the Birkeland-Eyde process has
1911 been abandoned (See [133].)

1911 Franklin (137) gives a very general review of the status of nitrogen fixation processes, considering only the Birkeland-Eyde, Schönherr, and cyanamide processes, and their relative costs, with data taken from other authors.

1910 Roeber (146) gives a good general review of the various processes for nitrogen fixation, with costs, and present status of industry.

1910 Voorhees (147) discusses the relative costs and actual value to the farmer of the various constituents of artificial fertilizers, and shows where economy should be effected.

Ammonia from Calcium Cyanamide

1916 Landis (23) gives estimates on the plant and operating costs for the production of 30,000 lb. of ammonia per day, based on designs made by the American Cyanamide Company, in the light of European practice, and after six months experience in America with a small plant, imported from Germany. These involve the use of an autoclave unit of nine shells requiring a continuous motor load of about 200 h.p.

The plant, without power or pumping plants, equipped to put out as final product an ammonia gas saturated with moisture at the temperature of the condenser water available may be erected for $120,000. This does not include cost of land, foundations, or sludge disposal. The cost of operation, including the items of power, steam, water, labor, chemicals, repairs, interest, depreciation, etc., comes to $451.43 per day, or $0.01505 per pound of ammonia. The detailed items are given in the original.

1914 Laboratory experiments by Manuelli (68) have shown the yield to be from 90–99 per cent of the theoretical. The cost should be about 20 centimes per kilo of nitrogen.

Oxidation of Ammonia

1916 Zeisberg (4) gives costs deduced for American conditions from the costs given in reference (106) and compares them with estimates from other sources for small and large plants.

He gives the cost of making nitric acid from sodium nitrate as at least 1.75 cents per lb. for labor, repairs, and sulphuric acid and with sodium nitrate at 2.64 cents per lb. the cost of the nitrogen used per lb. of nitric acid would be 3.750 cents compared with 4.280 cents for the Ostwald process. But the Ostwald process will become increasingly more profitable as the price of Chile nitrate and consequently of ammonia becomes less. These estimates are based on an 85 per cent efficiency for the Ostwald process and a 97 per cent efficiency for the retort method of making nitirc acid. Zeisberg concludes that ammonia itself is so valuable that there is little hope that the Ostwald process can ever compete successfully with the arc processes for the production of nitric acid.

1916 Kaiser (31) claims to be able to oxidize ammonia to nitric acid with a 90–95 per cent yield at a cost of 1.25 kg. of coke per kg. of ammonia, besides the power for driving fans.

1914 Dieffenbach (60) computes that at the selling price existing, oxidation of ammonia to nitric acid is less profitable than conversion to sulphate. But in factories producing dilute nitric acid, absorption by nitric acid should be yet more economical.

1913 In reference (106) the cost of manufacture of nitric acid from ammonia from gas liquor are given for a plant capable of producing monthly 148.4 tons of 53 per cent nitric acid from 25 tons of nitrogen in the form of ammonia. The cost of plant is estimated at $55,000, and the items are given. Operating costs per month should be as follows:

Power..........	14,400 h.p. hrs. at 3 cents—	$437.50
Steam..........	20,000 kg.	337.70
Total operation including above and interest, labor, etc......		2,187.50
Costs per ton of 100 per cent HNO_3........		39.94

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(81) Zeitschrift, Vereines deutschen Ingenieure, *58*, 66–7 (1914).

(132) Beckman, Metallurgical and Chemical Engineering, *9*, 340 (1911).

(133) Birkeland, Garfield, Metallurgical and Chemical Engineering, *9*, 436; 485 (1911).

(137) Franklin, General Electric Review, *14*, 472–5 (1911).
Chemical Engineer, *14*, 453–6 (1911).

(146) Roeber, Mineral Industry, *19*, 58–67 (1910).

(147) Voorhees, Journal Industrial and Engineering Chemistry, 2, 153–5 (1910).

(23) Landis, Journal Industrial and Engineering Chemistry, *8*, 156–60 (1916).

(68) Manuelli, Annali Chim. Appl. *1*, 388–96 (1914).
Abstract, Journal, Society of Chemical Industry, *33*, 690–1 (1914).

(4) Zeisberg, Metallurgical and Chemical Eng'g. *15*, 299–304 (1916).

(106) Metallurgical and Chemical Engineering, *11*, 438–42 (1913).

(31) Kaiser, Chemiker Zeitung, *40*, 14 (1916)
Abstract, Chemical Abstracts, *10*, 806 (1916).

(60) Dieffenbach, Chemische Industrie, *37*, 265–9 (1914).

These figures include the plant and cost of production of ammonia gas from gas liquors. Detailed items are given with estimates of profits. The estimates are based on English conditions.

PART V: APPENDIX

RECOVERY OF NITROGEN COMPOUNDS

1913 **By-Product Coke Ovens**

Christopher (83) gives a history of the development of ammonia recovery from coke ovens with the yields at various periods, descriptions of the types of ovens, with comparative working costs and values of the products. A bibliography is included.

The yields obtained in 1870 are given as 10 gallons of tar and 16 lb. of ammonium sulphate per ton of coal in gas works, and 5 to 11 gallons of tar and 4 to 6 lb. of ammonium sulphate from coke ovens. This had been increased in 1881 by the Simon-Carves plant to 6.12 gallons of tar and 28 lb. of ammonium sulphate.

Producer-Gas Plants

A further resource for the recovery of nitrogen compounds is the ammonia-recovery producer-gas plant. The Lymn apparatus is a recent system based upon the general principles of the Mond process, but with the high and bulky towers replaced by vertical washers. The form and operation is fully described and illustrated. Operating costs are given for a plant producing from 2812 to 2830 kw. hr. per hour, with a consumption of from 64.6 to 70.2 tons of coal yielding from 1.76 to 1.94 tons of ammonium sulphate in 24 hours. The nitrogen content of the coal used was 0.8 per cent, and the cost $3.00 to $3.25 per ton. Including a 10 per cent
1915 depreciation charge, the cost of gas is 0.14 per kw-hr. Further details are given. (54)

Coal Gas Manufacture

1914 Wagner (72) describes and gives the costs, etc., for recovery of ammonia and other products in coal gas distillation by the Feld system. The raw liquor usually contains from 1 to 2 per cent of ammonia from which all but about 0.005 per cent is recovered.

The operating costs, without depreciation and interest, for the ammonia recovery from a plant carbonizing 300 tons of coal per day should be for a 250 day year:

$32530 if aqua ammonia, and
$12811 if ammonium sulphate be the final product.

With ammonia at 8 cents per lb., aqua ammonia of 26 deg. at $102 a ton, and ammonium sulphate at $60 a ton, the annual profits for the two processes should be $47,030, and $30,809, respectively.

If the Bueb process for the extraction of cyanogen be combined with the above Feld process, the operating expenses will be $11,546 and the profit $48,039.

Tutwiller (71) describes in detail the methods 1914
of coal gas manufacture and by-product recovery, giving cuts and diagrams of apparatus. He gives analyses, proximate and ultimate, of a typical coal. He also describes in detail the concentration of ammoniacal solutions, illustrating with cuts and diagrams. His article is very full.

Rittman and Whitaker (48) give a "biblio- 1915
graphy of the chemistry of gas manufacture of 274 references covering the headings:

Carbonization and distillation of coal
Gas producers, water-gas
Petroleum-oil distillation
Oil gas
Reactions of hydrocarbons
High temperature and high pressure reactions
Low temperature carbonization
Chemical equilibrium and catalysis
General Literature
Books.

Peat Producer-Gas Plants

Lymn (25) gives an historical resumé of
the development of producer-gas by-product 1916
recovery in Europe and outlines the latest features of his own system. He mentions the systems and improvements of Young and Beilby, Mond, Duff, Grossley and others, describing each and discussing the advantages of each. The article is very fully illustrated with diagrams, etc. He gives detailed costs of operation and estimates on three different types of installation. He gives the yield of a Lymn plant as 61 lb. of ammonium sulphate per ton of coal, which is a "nitrogen efficiency of 70 per cent." He also discusses the adaptability of various fuels and states that peat containing 60 per cent of water can be used. Plants burning peat have been in operation in Europe for several years.

Nature (17) in the course of an article dis-
cussing the distillation of peat in producer-gas 1916
plants gives figures on the recovery of by-

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(83) Christopher, Journal, Society Chemical Industry, *32*, 115-24 (1913).

(54) Metallurgical and Chemical Engineering, *13*, 456-8, (1915).

(72) Wagner, Scientific Amer. Supplement *80*, 316-9 (1915).
Metallurgical and Chemical Engineering, *12*, 696-702 (1914).
Amer. Gas Institute, (1914).

(71) Tutwiller, Journal, Franklin Institute, *178*, 383-416 (1914).

(48) Rittman, Whitaker, Bibliography of the Chemistry of gas manufacture.
Bureau of Mines, Tech. paper 120, (1915).

(25) Lymn, Journal, Amer. Society Mechanical Engineers, *37*, 253-66 (1915).

(17) Nature, *97*, 19-23 (1916).

products. Peat contains from 0.5 to 2.5 per cent of nitrogen, almost all of which may be liberated as ammonia by passing steam over the material heated to 350–550 deg. The following yields have been obtained from large-scale experiments:

	Germany	Italy	England
Nitrogen content in per cent...........	1.0	1.58	2.3 2.2
(Moisture content)....	(40–60)	(15)	(58) (63)
Ammonium sulphate recovered per ton of theoretically dry peat	70 lb.	115 lb.	215 lb. 168 lb.

Producer-gas plants treating peat are in successful operation at Portadown, Ireland, (400 brake-horse-power), near Osnabruck, Germany, (3000 h.p.) and at Orentano, Italy, (700 metric h.p.). The last two recover ammonium sulphate. The German plant consumes 210 tons of peat (60 per cent moisture) in 24 hours. The Irish plant using peat at 5 s. a ton obtains power at $\frac{1}{16}$ penny per h.p. hr. It is stated that the amount of combustible matter in the world's peat deposits exceeds that in all the known coal fields.

Miscellaneous

Ammonia Recovery from Waste Liquors. Knoedler (43) has been able to recover 28
1915 per cent ammonia from waste liquors of the
Welsbach Company containing about 1 per cent, by a distillation plant which he describes in detail, at a cost of operation of $2.24 per 1000 lb. The output of his plant was 3000 lb. of 26 per cent ammonia per day.

Ammonium Chloride from Recovery Plants. A process has been patented and is being applied by the Berlin-Anhaltische Machinenbau Aktien-Gesellschaft for the manufacture of ammonium chloride instead of ammonium sulphate from by-product ammonia, with the idea of supplying the market for the pure salt, and also avoiding a future over-production of sulphate. (76)

Wagner (72) in the course of an illustrated
1914 article on coal gas residuals and the Feld
1914 system, describes processes and apparatus for
the recovery of ammonia gas by continuous stills and its conversion into ammonium sulphate.

The results obtained by slow distillation of coal in vacuum at various temperatures are discussed by Cobb, Burgess and Wheeler. (58)

A tar scrubber for the direct process (101)
1914 for ammonia recovery from gases, avoiding
the customary absorption and redistillation is 1913
described, with cuts, by Strommenger. A good sulphate containing 25 per cent of NH_3 is obtained.

Heck (87) describes in some detail the operation of the Brunck direct, and the Koppers
semi-direct, processes, with estimates of the 1913
relative saving effected by each.

Ohnesorge (94) outlines the history and recent development of the direct process for
recovery of ammonium sulphate. 1913

The direct-process using a Pelouze extractor is briefly described by Pfudel (121).

Brown (134) gives working directions for the
operation of a waste ammonia recovery plant 1912
and for concentration and testing of the 1911
product.

Cooper (135) has carried out some experiments upon the direct recovery of ammonia,
and gives the diagram of his tar extractor. 1911

PRODUCTS MADE FROM CYANAMIDE

Cyanamide is capable of a number of conversions to products, such as urea, dicyanamide, creatinin.

Washburn states that the United States imports annually for the celluloid industry $50,000 worth of high grade urea which can now be supplied from this source. Urea is also applicable in the manufacture of explosives, when not prohibitively expensive. (51)

Its nitrogen can be converted almost
quantitatively into cyanides by fusion with 1915
salt, giving a yield equal to nearly 25 per cent of the weight of the cyanide equivalent.

Clennell (35) discusses the chemistry of this reaction, and of others for making cyanides,
as given by the literature and patents. 1915

Cyanamide itself is an excellent agent for case hardening ,and hundreds of tons are

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(43) Knoedler, Journal Industrial and Engineering Chemistry, 7, 1061–4 (1915).

(76) Chemische Zeits, *13*, 117 (1914).
Abstract, Journal Industrial and Engineering Chem., *6*, 778–9 (1914).

(72) Wagner, Scientific Amer. Supplement *80*, 316–9 (1915).
Metallurgical and Chemical Engineering, *12*, 696–702 (1914).
Amer. Gas Institute, (1914).

(58) Cobb, Journal of Gas Lighting, *126*, 329–31 (1914).
Abstract, Journal, Society of Chemical Industry, **33**, 541 (1914)
Burgess, Wheeler, Journal, Chemical Society, *105*, 131–4 (1914).

(101) Strommenger, Stahl und Eisen, *33*, (2) 1694–5 (1913).

(87) Heck, Stahl und Eisen, *33*, 777–82 (1913).

(94) Ohnesorge, Zeitschrift für angewandte Chemie, *26*, 593–6 (1913).

(121) Pfudel, Journal für Gasbeleuchtung, *54*, 1272–3 (1911).
Abstract, Journal, Society of Chemical Industry, *31*, 64–5 (1912).

(134) Brown, Chemical Engineer, *14*, 456–61 (1911).

(135) Cooper, Chemical Engineer, *13*, 111 (1911).

(51) Washburn, Transactions, Amer. Electrochemical Society, *27*, 385–402 (1915).
Metallurgical and Chemical Engineering, *13*, 309–14 (1915).

(35) Clennel, Metallurgical and Chemical Engineering, *13*, 756–8 (1915).

being used abroad in the manufacture of war
materials, and will probably find extensive
use here when the peculiarities of the trade
1915 have been overcome. (44)

1912 Sulzer (127) makes ammonia and formic acid from calcium cyanamide by fusing with charcoal and sodium carbonate, and then heating with water in an autoclave.

1914 Carlson (57) discusses in a general way the use of cyanamide as a raw material for the manufacture of other products such as cyanides, urea, veronal and other drugs. He gives the value of a kilogram in the various forms from element to complex drug.

NOMENCLATURE OF CYANAMID INDUSTRY

1913 The following definitions of terms used in the Cyanamid industry are given by Pranke: (96)

Lime-nitrogen. Crude calcium cyanamide, ground to a fine powder after removal from the ovens in which it is formed. It contains about 55 per cent of calcium cyanamide, $CN\,NCa$, about 2 per cent calcium carbide, and about 20 per cent of free calcium oxide.

Cyanamid. This is a trade name for the completely hydrated material prepared for use as a fertilizer in the United States. It contains about 45 per cent calcium cyanamide, 27 per cent calcium hydroxide and no carbide. The name is always capitalized and has no final "e".

Cyanamide. The compound represented by the formula CN, NH_2. It is sometimes referred to as acid cyanamide, or free cyanamide.

Calcium Cyanamide. The chemical compound of the formula $CN.NCa$, or $CaCN_2$, as it is frequently written.

Calcium Cyanamid. The name used by the United States Department of Agriculture and by some State Departments of Agriculture to designate the commercial Cyanamid. It is sometimes used to indicate the substance represented by the formula $CN.NCa$, but for the sake of clearness the compound $CN.NCa$ will be called calcium cyanamide in the present paper.

Nitrolim. The trade name for the material sold in England for agricultural purposes. It is a lime-nitrogen to which has been added just enough water to destroy the carbide. Practically all the free lime is present as calcium oxide.

Kalkstickstoff. The commercial material manufactured in Germany for use as a fertilizer. It is similar to nitrolim.

Stickstoffkalk. A crude calcium cyanamide made by nitrifying a calcium carbide which contains about 10 per cent of calcium chloride. Its manufacture in Westergeln, Germany, under the Polzeniusz patents was discontinued in 1910.

Calciocianamide. The Italian commercial product, completely hydrated.

Cyanamide de Calcium. The French commercial product, completely hydrated.

EQUIVALENTS

1 M. (Mark) = \$0.238
1 (pfennig) = 1/100 M.
1 L (pound) = \$4.8665
1 s (shilling) = 1/20 L
1 fr. (franc) = \$0.193
1 (centime) = 1/100 franc
1 kg (1000 g.) = 2.205 lb. (avoirdupois)
1 kw-hr. = 1.359 h.p.
1 long ton = 2240 lb.
1 metric ton = 2204.62 lb.

POWER COSTS

The average coal consumption per kw-hr. (3) was found to be 2.77 lb. (bituminous) at a modern 18,500 kw. steam turbine plant at Worcester, Mass. The unit cost of production per kw-hr. was 5.3 mills for fuel (\$4.28 per ton) and 1.12 mills for operating labor cost. The cost analysis is given. 1916

Dunn (9) discusses the relative construction and operation costs of hydro-electric and steam plants for the generation of electricity. He gives comparative unit analyses of cost of operation. 1916

Stillwell (11) gives similar data and also shows the variation in total cost of power for various costs of coal. 1916

Scheuer (20) gives the cost of power from hard and soft coal of different prices in Germany, with and without by-product recovery. He also gives statistics of coal production and by-product yields of various kinds. 1916

Baekeland (13) states that at \$1.25 a ton for good steam coal power can be obtained cheaper than the price now paid at Niagara. 1916

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(44) Landis, Journal Industrial and Engineering Chemistry, *7*, 433 8 (1915).
Metallurgical and Chemical Engineering, *13*, 213 8 (1915).

(127) Sulzer, Zeitschrift fur angewandte Chemie, *25*, 1268 73, (1912).
Abstract, Journal, Society of Chemical Industry, *31*, 682 (1912).

(57) Carlson, Zeitschrift fur angewandte chemie, *27* (3) 724–5, (1914)

(96) Pranke, "Cyanamide" (Chemical Publishing Co., Easton, Pa., 1913, 106 pp.).

(3) Electrical World, *68*, 671 (1916).

(9) Dunn, Proc. Amer. Institute of Electrical Engineers, *35*, 575 90 (1916).

(11) Stillwell, Proc. Amer. Institute of Electrical Engineers, *35*, 561 74 (1916).

(20) Scheuer, Elektrotechnische Zeitschrift, *37*, 64 7 (1916).

(13) Baekeland, Statement before Senate Committee on Agriculture and Forestry, 1916 (S. 4971).

1916 In reference (22) Washburn discusses the relation of the water power problem to nitrogen fixation, describing the difference between Norwegian and United States water powers. He gives estimated costs of installing plants, etc.

There is considerable interest in the possibility that certain of these processes might be adapted to utilized off-peak and off-season
1915 loads. (50)

1914 In figuring the cost (81) of water power, it is the tendency abroad to include only operating costs, and not the investment on the plant, contrary to the practice in the United States. This should be taken into consideration in making comparisons. There are many plants in operation in the chemical industries abroad, whose real costs of power production are no lower than many of the more favored locations in this country.

1912 Scott (124) discusses the power question as it affects Great Britain, and goes into comparison and details in regard to the cost of installation of hydro-electric, and steam plants, and the relative advantages of coal and gas-fuel, and of surface combustion. He gives the capital and running costs for a producer-gas engine power station for 3000 brake horse power.

In Norway (124) the electric horse-power year costs $4 to $6 compared with $10 to $15 in the U.S. 1912

Lyon and Keeney (90) give the cost of power used for various electro-chemical processes in 25 different localities from hydro-electric and steam plants. 1913

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(22) Washburn, Statement before House Committee on Military Affairs, Feb. 11, 1916.
Statement before House Committee on Agriculture, Feb. 1, 1916.

(50) Summers, Transactions Amer. Electrochemical Society, *27*, 339–83 (1915).
Proceedings, Amer. Institute of Electrical Engineers, *34*, 337–81 (1915).
Abstract, Metallurgical and Chemical Engineering, *13*, 241–4 (1915).

(81) Zeitschrift, Vereines deutschen Ingenieure, *58*, 66–7 (1914).

(124) Scott, "Manufacture of nitrates from the atmosphere. Smithsonian Report for 1913, pp. 359–84, (1914). (Publication 2291). Reprinted from Journal, Royal Society of Arts, (London) *60*, No. 3104, (1912).

(90) Lyon, Keeney, Transactions, Amer. Electrochem Society, *24*, 119–47 (1913).

AN IMPROVED FORM OF PHOSPHOROSCOPE

By W. S. Andrews
Consulting Engineering Department, General Electric Company

The author describes an interesting piece of apparatus called the phosphoroscope, which he has designed to determine the fluorescence and phosphorescence of various compounds. Much data, in a hitherto little known field, have been compiled by the use of this apparatus.—Editor.

It is well known that certain substances, both organic and inorganic, exhibit the curious phenomenon of fluorescence when exposed to suitable exciting radiations.

Ultra-violet light, which is invisible to the human eye, is a potent exciter of fluorescence, and an apparatus for producing this form of radiation by means of high-tension disruptive sparks between iron points is described and illustrated in the Review for April, 1916.

Certain compounds show luminescence only while they are under the exciting radiation, and appear to lose it instantaneously when the latter is cut off. This effect is termed fluorescence. Other compounds retain their luminescence for a longer or shorter period after the excitation ceases, and this effect is named phosphorescence. There is, however, no marked boundary between fluorescence and phosphorescence, and it is probable that they are both due to the same atomic mechanism concerning which we know little or nothing. It is also probable that nearly all fluorescent substances are actually phosphorescent for a certain time, although the period may be so brief that the unaided eye fails to perceive it.

The Phosphoroscope is an instrument by means of which this afterglow is visualized continuously even when its period is very short, so that many interesting cases of phosphorescence can be seen which would otherwise remain unnoticed. It also permits spectroscopic observation of short period phosphorescence, and photographs of the spectra may thus be made.

It is the purpose of this article to describe and illustrate a form of phosphoroscope which has been recently designed and which has proved very serviceable in practical use.

This instrument operates by projecting ultra-violet rays intermittently, at short regular intervals on to the substance to be examined and then exposing the latter to the eye during the intermissions, while the exciting rays are cut off, the substance being otherwise in a light proof chamber.

This result is obtained by the revolution of a light cylindrical chamber, at a high speed by an electric motor, inside a stationary cylindrical chamber. The outer chamber has two apertures, through one of which the ultra-violet rays are admitted to the inner chamber, the other opening being fitted with an eye piece for observation. The revolving cylinder or shutter also has two openings which are so spaced that when the ultra-violet rays are projected into its interior, the eye piece is closed, and when the ultra-violet rays are cut off, the interior of the revolving cylinder is opened to the eye piece. A light aluminum shelf is supported laterally in the center of the revolving cylinder by a circular disk that closes one end of the outer cylinder, and the substance to be examined is placed on this shelf.

Under the above arrangement it is apparent that as the shutter revolves, any object on the shelf will receive the ultra-violet radiation for an instant, then the rays will be cut off, and the shelf and whatever may be on it will be exposed to view through the eye piece. These operations being repeated from 3000 to 4000 times per minute (according to the r.p.m. of the motor) will present to the eye a practically continuous picture of the object on the shelf, if it is phosphorescent, otherwise the interior will be perfectly dark.

The phosphorescent substance will receive twice as many excitations per minute as the motor revolves the shutter in that time, so that its luminescence is continuously revived. If its period of decay is not shorter than the interval elapsing between its excitation and the opening of the eye piece, its phosphorescence will be seen through the latter. Also, the period of its decay, if very short, can be readily determined by varying the speed of the motor and calculating the time between exposure and observation.

Fig. 1 is a perspective view of the phosphoroscope at an angle from one end. Fig. 2 is a perspective view from the other end, and Fig. 3 is a front view with end removed, showing the shelf and the way in which it is withdrawn for receiving the substance to be examined. The short tube projecting at an upward angle from this end piece permits the observation of the shelf and its contents without the interposition of the shutter so that its fluorescence can be seen continuously. Certain compounds, such as salts of salicylic acid and barium platino-cyanide show vivid fluorescent colors through this eye piece although their period of decay is so short that they exhibit no sign of phosphorescence when viewed through the front eye piece.

The inclined cylindrical chamber shown in the cuts contains the two iron points used for producing the ultra-violet rays, and the eye piece on the same is fitted with a colored glass so that the high-tension disruptive discharge may be viewed without injury to the

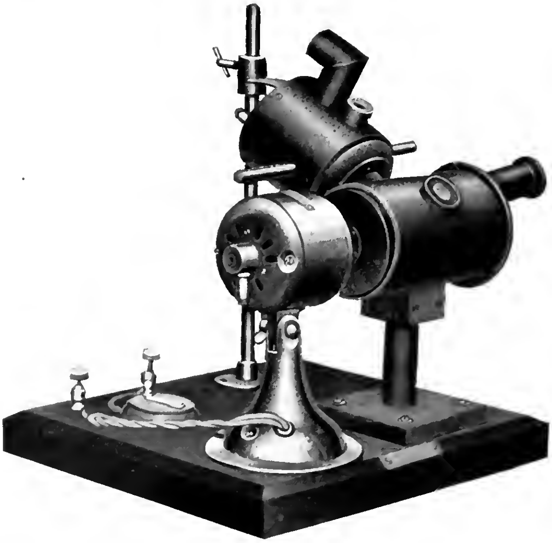


Fig. 1

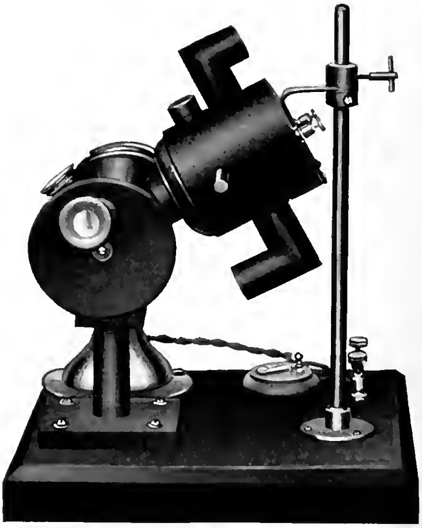


Fig. 2

The Phosphoroscope

eye when it is regulated by the insulated handles that project on each side of the chamber. The lower right angle tube at the bottom admits a current of air which is carried off by the upper right angle tube which thus serves as a chimney and prevents over heating of the interior of the chamber.

An interesting optical experiment can be made with this apparatus as follows: Place on the shelf a piece of card coated with powdered willemite which will show a brilliant green phosphorescence through the front eye piece. Then put a silver coin on the card and it will appear through the eye piece as a jet black disk on a bright green field. The rays of phosphorescent green light are projected in upward directions from the surface of the willemite and as the interior of the revolving shutter is painted dead black, no light can be reflected downwards on the coin, so that the surface of the latter is seen in complete darkness and it is therefore jet black. If the coin is viewed through the end eye piece it appears in its natural color by the direct although intermittent rays of visible light that are projected on it from the disruptive discharge between the iron points.

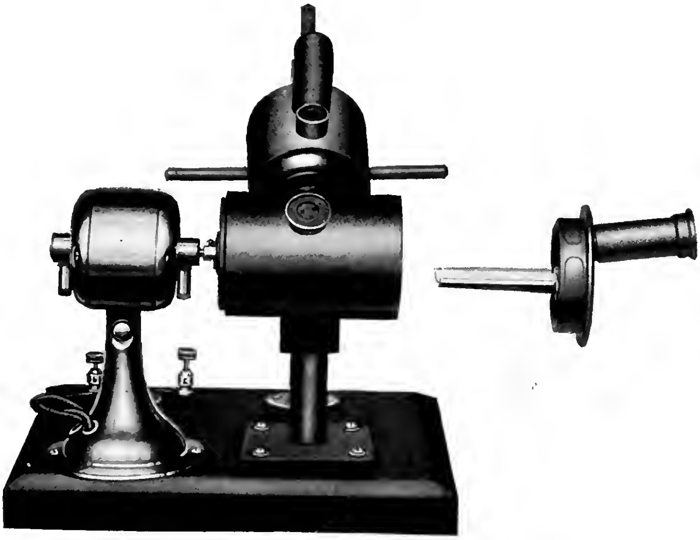


Fig. 3. Phosphoroscope, showing Shelf Removed for Introduction of Substance to be Examined

G. H. HILL

IN MEMORIAM

George Henry Hill, Assistant Engineer of the Railway & Traction Department of the General Electric Company, died after a short illness from pneumonia at his home in Schenectady on the night of January 31st. Up to a week before his death he had attended to his various duties and his condition had been serious only two or three days.

Mr. Hill possessed to an unusual degree a capacity for making friends and loyal supporters among all who came in contact with him. From his most intimate friends to his most casual business acquaintances, all who knew him came to realize his breadth of mind and his unfailing generosity and thoughtfulness. His reputation for fairness and square dealing invariably won for him an unswerving loyalty among all associates in business and private life.

Many important developments in the application of electric power to new uses owe their success to his efforts. Early in his career as an engineer, he invented and patented the electric system for operating bulkhead doors on shipboard, which many years ago was standardized by the Navy Department for United States naval vessels and is used on commercial and naval vessels in many parts of the world. Later he assisted in the development of the multiple unit system of train control and in connection with this work produced the multiple unit automatic system substantially as it exists today.

During the past few years Mr. Hill has devoted considerable time to the electrification of steam railroads and has been an ardent supporter of high-voltage direct current for interurban railways and for steam trunk line electrification. More recently he has been engaged in exhaustive studies of the interference of transmission and railway feeder lines with telephone and telegraph circuits.

Mr. Hill was born at Williamsport, Pa., on December 11, 1872, where he attended the local preparatory schools and Dickinson Seminary. After completing his preparatory work, he entered John Hopkins University at Baltimore, graduating from the Electrical Engineering Course in 1895. Immediately upon graduation, he became associated with Frank J. Sprague who was at that time engaged in the development of electrically operated elevators and multiple unit control for railway service. He was advanced rapidly and soon became Chief of Construction of the Elevator Department with his office in New York City. When the Sprague Electric Company gave up its elevator business in 1900 he became Chief Engineer for the Company at Bloomfield, N. J., and was directly responsible with Mr. Sprague for the development of multiple unit control for railway trains.

In 1902 the Sprague patents and interests were taken over by the General Electric Company and Mr. Hill came to Schenectady to follow the further development of train control. Within two years he had become Assistant to Mr. F. E. Case in supervision of all train control for the General Electric Company.

In 1906, Mr. Hill became Assistant Engineer of the Railway & Traction Department in charge of the group of engineers dealing with the general problems arising in connection with the electric railway apparatus and engineering. In this position his ability and experience were invaluable and he was one of the Company's most important advisors, aiding in the solution of many difficult problems connected with the railway industry.

Articles from his pen on railway subjects have frequently appeared in the technical press and in the Proceedings of the American Institute of Electrical Engineers, of which he was an active member. During the year 1915, he served as Chairman of the Local Section of the A. I. E. E. and his administration is remembered as one of the most successful in the history of the Schenectady Section.

During his active career, Mr. Hill has made many inventions in the railway and other electrical fields and between forty and fifty patents have been granted to him. Perhaps the most important of these are: Electric System for Water Tight Doors, Patented June 5, 1900; System of Motor Control for Railway, Patented June 14, 1904; and Electrical Controlling Apparatus, Patented December 27, 1904. The first of these is the broad patent on the electrically operated system for operating bulkhead doors on shipboard and the other two are fundamental patents on the multiple-unit automatic train-control system.

Mr. Hill was married in 1899 to Miss Hazel Thompson of Bloomfield, N. J. He was prominent in the social affairs of Schenectady, and was a member of the Mohawk Club, Mohawk Golf Club and the Edison Club.

QUESTION AND ANSWER SECTION

The purpose of this department of the REVIEW is two-fold.

First, it enables all subscribers to avail themselves of the consulting service of a highly specialized corps of engineering experts, or of such other authority as the problem may require. This service provides for answers by mail with as little delay as possible of such questions as come within the scope of the REVIEW.

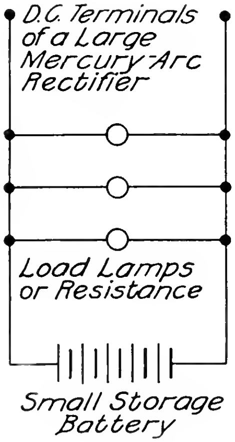
Second, it publishes for the benefit of all REVIEW readers questions and answers of general interest and of educational value. When the original question deals with only one phase of an interesting subject, the editor may feel warranted in discussing allied questions so as to provide a more complete treatment of the whole subject.

To avoid the possibility of an incorrect or incomplete answer, the querist should be particularly careful to include sufficient data to permit of an intelligent understanding of the situation. Address letters of inquiry to the Editor, Question and Answer Section, General Electric Review, Schenectady, N. Y.

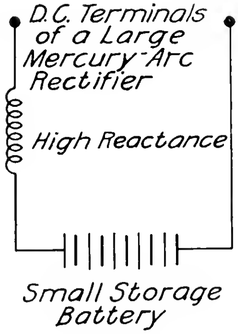
MERCURY-ARC RECTIFIER; LOW CURRENT CHARGING

(209) Can a heavy current mercury-arc rectifier, such as is used for charging electric automobile storage batteries and the like, be also used for charging ignition cells?

While a small capacity rectifier is naturally the best unit for charging ignition cells, the large rectifier named could be used provided the voltage at the low end of its range is not too high. However, there would be several disadvantages to its employment for that purpose. One arises from the fact that any generating or converting apparatus operates at low efficiency when delivering a relatively small output. Another is that the minimum current necessary to maintain the arc of so large a rectifier would probably exceed the desired charging current for the ignition cell.



(209) Fig. 1



(209) Fig. 2

However, for emergency purposes or where efficiency is of small consequence, the large rectifier can be operated under the conditions shown in Fig. 1. While the incandescent lamps (preferably carbon) or their equivalent in resistance create a waste, their use is necessitated to increase the output current of the rectifier to such a value as will maintain its arc. In using these connections, however, precaution should be taken that enough auxiliary load be used to prevent the output current falling below the minimum arc-maintaining value as the cells approach full charge. If this is not done, or a reverse-current relay is not inserted between the cells and the lamps, the cells will discharge through the lamps when the arc is extinguished.

There is another method for operation, namely, to insert a high reactance in series between the rectifier and the small battery load as shown in Fig. 2. This reactance will tend to allow the rectifier to operate at a considerably lower current and would, of course, be more efficient than the using of auxiliary resistance. Its main disadvantage is the very high cost of the reactance; probably two or three times that of the lamps or resistance.

Contrasted against these disadvantages to the utilization of a large-capacity rectifier for small cell charging is the suitability of the small rectifier, especially where considerable work of this character is to be done.

R.E.R.

TRANSIL OIL: COMPOSITION

(210) What is the chemical composition of transil oil?

Transil oil is a very complex mixture of hydrocarbons, being a fractional distillation product of petroleum. These hydrocarbons are usually made up of the series $C_n H_{2n+2}$.

In the refining of this oil great care is exercised to eliminate all acids, alkalis, free sulphur, and moisture as the presence of any of these in an insulating oil seriously lessens its value as an insulating medium.

F.R.F.

INDUCTION MOTOR: REVERSAL OF METERS

(211) When two single-phase watthour meters are used to measure the energy input to a two-phase induction motor, will not one meter run backward when the power-factor is less than 50 per cent?

Unlike the power-factor of a three-phase circuit, the power-factor of a two-phase circuit has no influence upon the direction in which the meters revolve. Each meter will run forward when the phase to which it is connected feeds energy to the motor.

The only condition under which one meter would reverse and run backward is that the voltage of the circuit be so very badly unbalanced that all the power is taken from one phase of the line and the line voltage of the second phase be less than the counter electromotive-force of the motor, thereby causing a return of energy to the second phase of the line. However, such a badly unbalanced condition would be very unusual.

J.A.H

GENERAL ELECTRIC REVIEW

A MONTHLY MAGAZINE FOR ENGINEERS

Manager, M. P. RICE

Editor, JOHN R. HEWETT

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Subscription Rates: United States and Mexico, $2.00 per year; Canada, $2.25 per year; Foreign, $2.50 per year; payable in advance. Remit by post-office or express money orders, bank checks or drafts, made payable to the *General Electric Review*, Schenectady, N. Y.

Entered as second-class matter, March 26, 1912, at the post-office at Schenectady, N. Y., under the Act of March, 1879.

VOL. XX., NO. 4

APRIL, 1917

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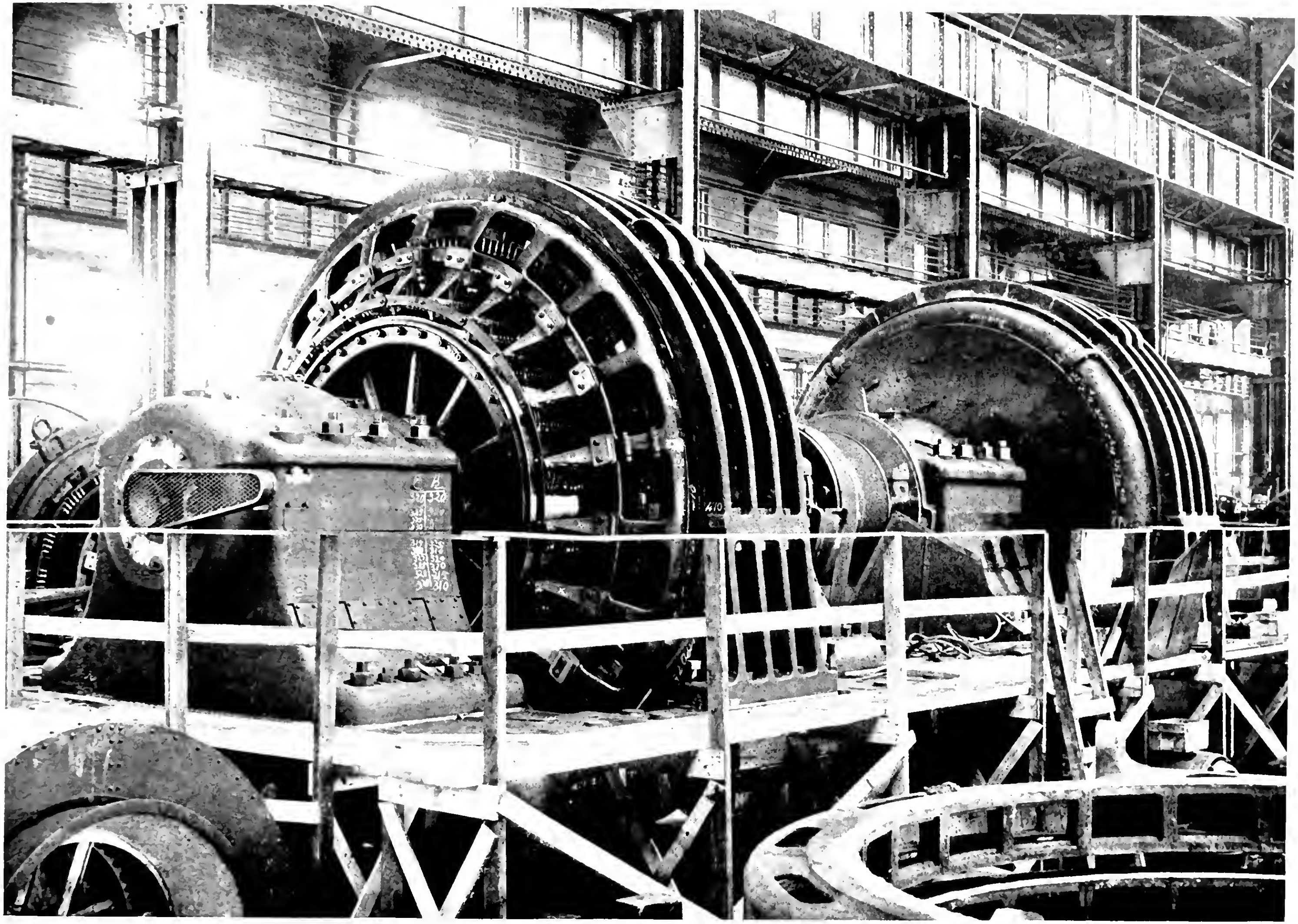

TWO REVERSING MOTORS FOR STEEL ROLLING MILL, COUPLED TOGETHER FOR LOCAL TEST

Machines have commutating poles and compensating pole-face windings. Rating of each, 2500 h.p. (continuous); 6500 h.p. (peaks); 120 r.p.m. (max); 500 volts

GENERAL ELECTRIC REVIEW

PATRIOTISM

The mention of Patriotism usually induces mental pictures of the national flag, soldiers, warships, victories, etc.—in short, symbols and weapons of militant war. In a crisis, the appeal to Patriotism arouses a spirit of courage, strength, and obligation to do and to dare as need be for the support and defense of a nation's existence and rights. This is the popular significance of Patriotism; but it is only a phase of the complete patriotic feeling.

Patriotism is more extensive. It is not confined to things militant; it is not restricted to times that are tense with international complications. Patriotism is the inspiration of the citizen to do thoughtful, energetic, conscientious work for the welfare of his nation, his state, his community, his educational institutions, his employer, his home.

The average American citizen works hard for his home or his dependents, but he is too prone to stop there. His interest in his employer's business is too frequently one of self-advancement only, his concern in his educational institutions is usually restricted to that particular school or college with which he has some personal connection, his attention to the civic management of his community is inclined to be indifferent, his interest in his home state is only somewhat greater because of the increased importance attached to a greater geographical area, and his assistance to the National executives he elected is too often confined to destructive criticism. Furthermore, he ordinarily displays gross inattention to the naturalization of alien residents—by giving only scanty consideration to what are the necessary qualifications, by neglecting to extend the welcome of fellowship to the newly-made citizens, and by being "too busy" to assist the newcomers in increasing their value as citizens.

The growing recognition of the need for awakening and promoting this "everyday" patriotism resulted in the calling of a Congress in Constructive Patriotism on January 25th, 26th and 27th, in Washington, D. C. The Congress was not empowered with legislative authority yet its appeal to public spirited citizens was so strong as to enlist the services of a remarkable gathering of renowned speakers and to attract some 2100 delegates from all over the Country, Alaska, Hawaii, and the Philippines.

ELECTRICAL MACHINERY SPECIFICATIONS

In the article by Mr. Hobart, which appears on page 291 of this issue, attention is drawn to the remarkable progress which has been made in Great Britain, Italy, Germany and America, in the matter of converging toward a common basis the specifications for electrical machinery. There has been a wide-spread conception of standardization to the effect that it discourages progress. We believe this conception to be quite erroneous as applied to the class of standardization considered in the article. The problem to which the Electrical Machinery Standards Committees of many countries are applying their efforts may be described as that of establishing a Common Denominator of Reference on which to base technical and commercial undertakings.

A prospective purchaser may require machinery for use under conditions where it is to serve a temporary purpose prior to being relegated to the "scrap heap." In such a case it obviously would be wasteful to incur the expenditure required for machinery of a quality conforming with approved standards. Such a purchaser will nevertheless find it of advantage to base the transaction on accepted standards and he may do this by requiring that the machinery shall conform with the American Rules, with certain definite modifications which he will clearly set forth as such in the specifications to which he requires that the machinery shall conform.

On the other hand, another purchaser may require machinery for operation under extraordinarily favorable conditions and where, moreover, the slightest interruption of service would be associated with enormous damage to some valuable product in the manufacture of which the machinery is to be employed. This purchaser might estimate that the exceptional circumstances justified outlays greatly in excess of the outlays which would be required for machinery conforming with accepted good practice. In the interests of having his specifications thoroughly definite, this purchaser would, nevertheless, find it advantageous to require that the machinery should conform with the American Rules with a definite number of carefully expressed exceptions, as for instance, that the temperature limits should be a stipulated number of degrees lower than those set forth in the

Rules, or that the dielectric tests should be more severe by a certain specified percentage.

Recourse to modifications is, however, rarely desirable, since in the preparation of the American Rules every endeavor has been made to arrive at a thoroughly sound balance of the many conflicting requirements involved. Thus, for example, departure as regards the stipulated dielectric test will usually unbalance the design of a machine with respect to its operating temperature. As another example, the consequence of an unusual departure with respect to the specified temperature limits may exert an unfavorable influence upon the shape of a machine's efficiency curve, or upon its regulation or its wave form.

CONGRESS ON CONSTRUCTIVE PATRIOTISM

By G. L. Alexander

Foreign Department, General Electric Company

This article presents the author's impressions of the salient discussions which took place at the Congress of Constructive Patriotism, held at the New Willard Hotel, Washington, D. C., January 25, 26 and 27, 1917. —Editor.

The Congress on Constructive Patriotism was promoted by the National Security League. The primary object involved was that of conserving the Nation's resources by bringing home to the people the need for every individual to render some service to the State and Nation through concerted efforts, thus bringing about a centralization of effort which would have at its head a National Commission that every one would respect.

The scope of the work was of very large magnitude, involving all the big National problems and the best means for their proper solution.

Perhaps the most outstanding feature was the desire of the delegates, coming as they did from all parts of the Country, to go on record and to show the Country's attitude respecting the great war now prevailing in Europe and which now looks very much as though it would embroil ourselves. Ex-Senator Elihu Root fittingly expressed the feeling of the Congress by stating that if "peace without victory" meant leaving unsettled the principles of equity involved he hoped that all the delegates present would pray for "peace with victory".

Nationalization of Strength

The salient features of the subjects discussed in the Congress will be briefly outlined.

The Nationalization of the Country's industrial and educational forces was most prominently dwelt upon.

Concerning the Nationalization of industrial strength, Mr. Howard E. Coffin of the Naval Advisory Board, and Designing Engineer of the Hudson Motor Company, pointed out the great amount of work which had been done and the results accomplished by the different Engineering Societies of the Country in preparing a compilation of data showing the industrial strength of the larger industries. This compilation will furnish both the Army and Navy Department with an exact knowledge of just what any manufacturer would be able to accomplish in any class of work which may be allotted to him in time of war or peace. These data will be invaluable, both to the Country and to the Industries themselves.

The war in Europe has taught us many things, one of which is that the remarkable efficiency displayed by some of the belligerients has only been attained by their really wonderful system of handling the industries of their countries, assigning to the respective trades that work which they can best do. The value of efficiency in all things represents no small part of the knowledge gained.

Regarding the Nationalization of educational strength, Mr. Edward A. Steiner of Grinnell College, Iowa, pointed out the great variety in the methods of teaching which exists in the Country and which result in producing pupils of diverse views in different sections of the Country, depending upon the section in which they live. He pointed out that there was no correlated effort in our educational life or industrial life, with the result that there is a perfect maze of methods and system being used, this making for a maximum of inefficiency. He also drew attention to the fact that while the National Government has had a Department of Agriculture for many years, it has never had a Department of Education.

As a step toward National supervision of all teaching, it was planned that the prominent men of the Country most fitted for such work should immediately interest themselves in this subject and take whatever steps possible to interest the Government.

Value of Citizenship

The feeling was almost unaminous that the preparatory schools and universities of the Country should devote some time to the study of Citizenship. It developed during the discussion that there were very few institutions of learning in the Country which make a study of Citizenship and its Duties a part of their curriculum.

The Department of the Interior, Washington, D. C., which department oversees whatever educational work the Federal Government undertakes, will be requested to communicate with all Universities and Colleges for the purpose of having these institutions embody a course of Citizenship as a part of their work.

Many speakers expressed the feeling that altogether too little weight was given to the taking out of citizenship papers by aliens. A movement has been underway for some time, promoted by some of the more prominent manufacturers, the movement having gained considerable headway, to create a greater desire by aliens for American citizenship. The awarding of citizenship papers is now done in many cases by classes. This affords the opportunity for some person prominent in the community to address the newly made citizens, impressing them with the importance of the step they have just taken and soliciting their interest in public questions, particularly inviting them to pay attention to the conduct of the city officials, and pointing out that they should all be a factor in the Community in which they live.

As an example of the attention which industry is giving to the value of citizenship, it was shown that the Packard Motor Car Company has circularized its factory advising the foreign employees to take out naturalization papers and explaining how it may be done. It was stated that the Company has an officer whose duty it is to collect data about the men in the Company's employ who may be eligible for citizenship. Foreign employees are frankly informed that failure to take out citizenship papers bars them from responsible positions.

Attention was also called to the fact that the value of all employees speaking and understanding a common language cannot be overestimated.

The representative of the Packard Company made a statement of considerable significance, namely, that welfare work was not inherently the work of any Industry, that it was a matter for the Community to take care of, presumably, the City.

Government Ownership

Several speakers expressed the opinion that Government ownership was wrong in principle, destroying as it would a healthy competition, but believed that Government control of some of the arteries of commerce would work out to the advantage of the manufacturer, the Government, and the people.

Industrial Engineering

The tabulation which is a part of this article reports the work of one Congressional Committee and clearly outlines how Industrial Engineering may be defined and gives, it is believed, many suggestions of value.

The Navy

The Congress went on record as being in favor of restoring our Navy to the position of second naval power in the Atlantic and first in the Pacific. The latter is just as important as the former.

This Country has many vital interests in the East which have befallen to it principally since the war with Spain, and which call for a naval strength in the Pacific comparable with the Country's interest therein.

Universal Military Training

The opinion was unanimous that universal military naval training is one of the most pressing needs of the Country. It was pointed out that if two years ago the subject were broached in this Country, a man so expressing himself would likely have been ridiculed. Today, however, the subject is so far advanced that the Military Committee of the House has a bill drawn up proposing such a measure. The Committee which studied this subject made the following recommendations:

(a) Military or Naval training for all physically fit young men prior to the age of 21, and preferably in their 19th year.
(b) The training to be intensive continuous field or sea training for a period necessary to produce an efficient soldier or sailor.
(c) The system to be under Executive Federal control.
(d) Obligation to serve in war as well as to train in time of peace.

Governmental Efficiency

The Congress went unanimously on record as favoring a National Executive budget system; that the Civil Service should be made more efficient; and that individual efficiency and loyalty should be properly rewarded in all branches of Government service, and throughout the Country.

International Relations

There was much discussion as to the advisability of our Government entering into an agreement with other Governments respecting the preservation of the peace of the World. It was felt that the subject was one which called for the deepest study and deliberation, and that before any such agreement was entered into it should be referred to the people of the Country for their approval or disapproval.

INDUSTRIAL ENGINEERING

Object	Method	Matter	Mechanism
I. TO INCLUDE IN INDUSTRIAL ENGINEERING THE HUMAN FACTOR IN INDUSTRIAL ORGANIZATION.	I. MONTHLY MAGAZINE Industrial Americanization.	I. STANDARDS 1. Legislative, state and national; safety compensation, insurance, etc. 2. Industrial methods and standards of various companies.	I. INDUSTRIAL ENGINEERING CORPORATION 1. Board of directors. 2. Board of editors for magazine and service. 3. Correspondents for gathering and disseminating information.
II. TO STANDARDIZE WELFARE WORK IN INDUSTRY IN POINT OF VIEW, PRINCIPLE AND METHOD	II. INDUSTRIAL SERVICE. 1. A frequently issued bulletin or workable plans. 2. Press releases. 3. Publication of studies. 4. Reprints of articles. 5. Conferences and addresses. 6. Analysis of individual industries.	II. MECHANICAL FACTORS IN CONSERVATION OF WORKMEN 1. Location of plant; transportation, cost, etc. 2. Plant construction, light, heat, ventilation, water supply and water. 3. Preventive equipment; safety appliances, lunch and washrooms.	
III. TO EXTEND SCIENTIFIC METHODS TO THE HUMAN PHASES OF INDUSTRIAL ORGANIZATION.	III. RESEARCH 1. To secure data for industrial service. 2. To survey possible fields of operation. 3. To make extensive studies of special subjects and methods.	III. HUMAN FACTORS IN CONSERVATION 1. Employment management, shop census, central employment office system of promotions and transfers. 2. Incentives to efficiency, wages, hours, insurance, profit sharing, cooperative management. 3. Vocational education: school work, corporation schools, apprenticeship. 4. Americanization: American industrial standards for foreign-born workmen, citizenship.	
IV. TO TRAIN MEN TO CARRY OUT THESE METHODS.	IV. ENGINEERING EDUCATION. 1. Revision of curricula in recognized schools to include human phases of industrial engineering. 2. Development of special courses. 3. Training of special instructions for industrial engineering. 4. Training of experts for practical work in plants.	IV. PLANT MANAGEMENT 1. Analysis of costs. 2. Relation of machinery to (a) Cost of production. (b) Labor Management. 3. Efficiency methods: schedule of time and costs. Detection of causes of low efficiency. Detection of causes of waste.	

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NIGHT FIRING ON U. S. BATTLESHIP

Half tone reproduction by courtesy "Sea Power"

Electricity plays an Important Part in the Handling of the Guns, Hoisting Ammunition, and Operating the Turrets on our Modern Battleships

ROENTGEN RAYS FROM SOURCES OTHER THAN THE FOCAL SPOT IN TUBES OF THE PURE ELECTRON DISCHARGE TYPE

By W. D. Coolidge and C. N. Moore

Research Laboratory, General Electric Company

The tests described in this article were undertaken to determine the source and amount of extraneous radiations from the electrodes of the Coolidge X-ray tube, and to what extent these radiations affect roentgenograms of the human body. Roentgenograms of the targets of tubes in which different methods of screening the extraneous rays are employed are shown; and in most cases the target of the standard tube, made under identical conditions, is also shown for comparison. The conclusion arrived at is, that if the shortest exposure consistent with satisfactory density of image is employed, the special tubes show no particular advantage over the standard tubes.—Editor.

Early in the history of the hot cathode type of roentgen tube, and before any other roentgenograms had been made with it, the pinhole-camera-picture method was applied in a preliminary study of the source of the roentgen rays from the tube. This work showed that the entire surface of the target was active in producing roentgen rays. In spite of this fact, however, experiments showed that good roentgenographs of the various parts of the human body could be produced with the tube.

Since that time, various workers have felt that still better roentgenographic results might be obtained if all rays other than those coming from the focal spot could be eliminated.

It seemed desirable to investigate the subject pretty thoroughly to learn, first, how the effect of roentgen rays other than those coming from the focal spot could best be minimized and, second, whether the elimination of this effect would result in roentgenographic images of greater diagnostic value. The investigation also seemed worth while for the light which it would throw on the *modus operandi* of the hot cathode type of roentgen tube and for the use to which such information could be put in the development of new forms of this tube. The investigation consisted mainly in a pinhole-camera-picture study of various forms of the tube.

The following pinhole-camera roentgenograms were all made under the same general conditions: The same diaphragm, with a hole 0.020 inches in diameter, was used throughout; the distance from the length axis of the tube to the pinhole was always the same, 15 in., and the distance from the pinhole to the photographic plate was 5 in.; and in all length-views of the target the tube was so placed that the neck of the target was directly opposite the pinhole (see Fig. 1). The plate was in a closed box made of lead ⅛ in. thick. Unless otherwise noted, the same voltage, that corresponding to a 7-in. spark gap between points, was used throughout, and the same current, 4 milliamperes, and the same time, 10 minutes. Time development for 4 minutes at the same definite temperature and with fresh developer was used on all of the plates. To still further guard against the possibility of unequal development, as well as to make comparison easier, a pinhole camera roentgenogram of the standard tube has in many cases been put on the same plate with the particular type which was being investigated. No protection of any kind, not even the usual lead glass bowl, was used around the tube and no cone or diaphragm.

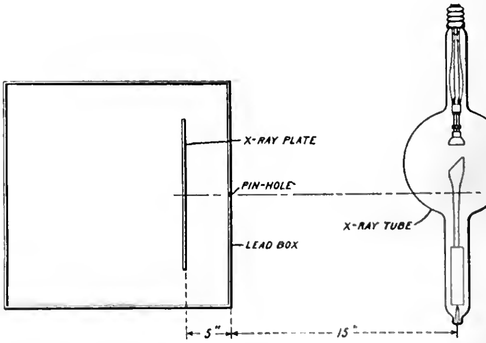

Fig. 1. Arrangement of Apparatus for making Pinhole-Camera Roentgenograms shown in this Article

Pinhole-Camera Roentgenograms made with the Standard Hot-Cathode Tube

Fig. 2 was made with a standard medium focus tube, operating with the voltage corresponding to a 7-in. spark gap between points and with 4 milliamperes of current for 40 minutes. The image of the focal spot is greatly overexposed, so that the roentgenogram gives a very exaggerated impression of the amount of radiation coming from the remainder of the target. The overexposure was intentional, the idea being to show the relative intensities of the radiation coming from those portions of the target other than the focal spot. The roentgenogram shows that the entire target, including the molybdenum stem and the adjacent end of the iron support-tube, gives off roentgen rays and must, therefore, be bombarded by cathode rays from some source or other. The circle described about the middle of the focal spot as a center indicates the location of the glass bulb. As will be pointed out in connection with some of the later plates, the production of roentgen rays from the entire surface of the target must be accounted for by the reflection* of cathode rays from the focal spot. These reflected rays, consisting as they do of negatively charged particles, electrons, cannot go to the cathode, as it is negatively charged. Nor can they go to the glass bulb, as it is charged to the potential of the cathode. They come away from the focal spot, as will be shown later, with almost as high a velocity as that with which they approached it; but, by the repulsion of the charges on the cathode and on the glass, they are forced to go back and strike the target again, and many of them are doubtless again reflected and again forced to return to the target. Roentgen rays must be produced with each collision with the target. It is clear from Fig. 2 that relatively few electrons are able to get into the anode arm, because of the repulsion of the negative charge on the bulb back of the anode and on the walls of the anode arm. The intensity of the rays coming from the stem will be seen to fall off very rapidly at the point where the circle crosses the stem.

Fig. 2. Roentgenogram made with Standard Medium-focus Tube

Those surfaces of the cathode structure which face the anode are also seen to give off roentgen rays. The origin of these is entirely different in its nature. They are secondary roentgen rays produced by the primary roentgen rays coming from the target.

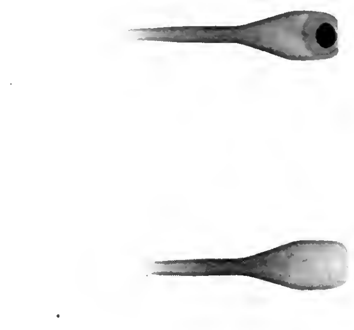

Fig. 3. Roentgenograms of Front and Back of Target. Note that, except for Working Face, Intensity is Practically the same Front and Back

Fig. 3 shows the front and back of a target. Except for the working face, the intensity is seen to be essentially the same both front and back. The intensity of radiation appears greater at the peripheral than it does in the central portion of the picture, and, in general, the greater the angle of inclination of the surface with reference to the plane of the photographic plate, the greater is the apparent intensity of radiation. This is simply due to the fact that the roentgen rays are emitted with equal intensity in all directions from each and every point in the surface.

In Fig. 4 the roentgenogram at the top was made with a 7-in. tube and that at the bottom with a $3\frac{3}{4}$ in. tube. The circle described about the middle of each focal spot as a center gives the location of the glass bulb in each case. The figure brings out strikingly the effect of the negative charge on the glass in determining the extent of the target to be bombarded by the reflected cathode rays. The total production of roentgen rays outside of the focal spot is doubtless the same in both

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*The term reflection has been used throughout this paper to include both true reflection and secondary emission.

cases. (No attempt has been made to confirm this quantitatively). But there is very little coming from that portion of the stem which is within the anode arm, and therefore there is, of necessity, a greater intensity of radiation from the body of the target in the small tube than there is in the large one.

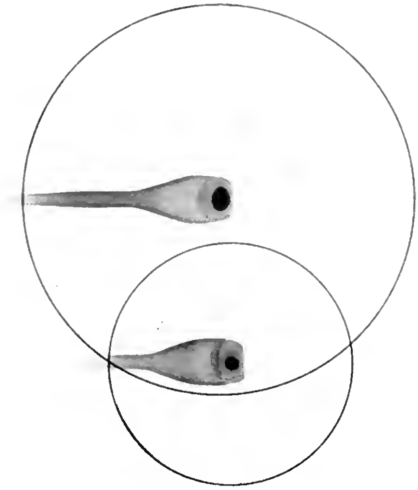

Fig. 4. Roentgenograms made with 7-in. and 3¾-in. Tubes

Fig. 5 shows the effect of voltage. Both roentgenograms were made with the same tube, the lower one with a 2-in. spark gap (between points) and the upper one with a 10-in. spark gap. The exposures were so chosen, by means of a preliminary set of experiments, that the photographic effect of the rays from the focal spot should be the same in both cases. This meant an exposure of 30000 milliampere seconds for the 2-in. spark gap and 3500 for the 10-in. spark gap. The body of the target, which is of tungsten, shows a somewhat different distribution of radiation in the two cases, the working face and the entire forward portion showing less radiation at the 2-in. spark gap, and the rear portion more. The molybdenum stem radiates very feebly at the 2-in. spark gap, so that there is no trouble in seeing where it is attached to the tungsten head of the target. The explanation for the feebler radiation of molybdenum is, as will be seen later, to be found in its lower atomic weight. At the 10-in. spark gap the molybdenum stem is seen to radiate even more strongly than the tungsten. This is due to the fact that, at this higher voltage, there is added to the general radiation of the molybdenum the characteristic radiation of that element.

To give an idea of the relative intensity and penetrating power of the radiations from the focal spot and from the balance of the target, two roentgenograms of a Benoist penetrometer were made, one with the rays from the front and the other with the rays from the back of the target. These are shown in Fig. 6. Both were made with a 2-in. spark gap. The one to the right was made by rays coming from the front of the target and was given, as measured in milliampere seconds, 1/10 the exposure of the other. The central circular areas show very nearly the same photographic action, indicating that the total radiation from the back of the target is, photographically measured, about 1/10 of that from the front. This means that in the ordinary roentgenogram, made from the front of the target, there will be, photographically measured, about 1/9 as much radiation from the body and stem of the target as there is from the focal spot. This fraction would, in ordinary work, be reduced a little by the use of a diaphragm and cone. The penetration is seen to be about 4½ Benoist from the back and 5 Benoist from the front.

With a 10-in. spark gap, as shown by Fig. 7, the conditions are seen to be much the same. As before, the right-hand roentgenogram was made from the front, and the other from the back of the target. The exposure from the front, as measured in milliampere seconds, was 1/9 of that from the back and was apparently a little too much. The factor of 1/10 used in the preceding figure would have been better. The penetration from the front was 9 Benoist, and from the back 8 Benoist.

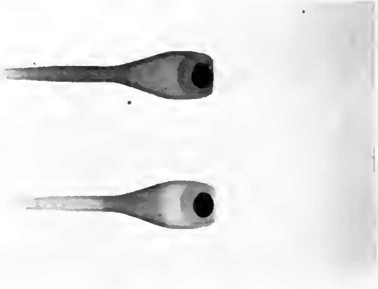

Fig. 5. Roentgenograms showing the effect of voltage. Upper, 10-in. Spark Gap; Lower, 2-in. Spark Gap

Photographically measured then, there appears to be from the front of the target, over this wide range of voltage, approximately 1/9 as much radiation coming from the balance of the surface as there is from the focal spot, and of but slightly less penetrating power.

METHODS FOR MINIMIZING THE EFFECT

Hooded Target

One of the different methods which has suggested itself for reducing the effect of the radiation from outside of the focal spot is the use of a metal hood attached to the working end of the target. This is illustrated in Fig. 8 and has been described in an earlier paper.* The cathode rays enter through a hole in the end of the hood and the roentgen rays emerge through a hole in the side. Fig. 9 shows the roentgenogram from such a hooded target, and above it, for comparison, that of the target in a standard tube. Fig. 10 shows the same thing except that the targets are turned sidewise. The position of the focal spot has, in the case of the hooded target, been indicated by those roentgen rays from the focal spot which penetrated the molybdenum hood, which in this case was only $\frac{1}{32}$ in. thick. A comparison of the two roentgenograms shows that the amount of radiation from the body and stem of the target is greatly reduced by the use of the hood. (Quantitative measurements with the ionization chamber show that with the design of hood used in this experiment, the reduction is to about 1/6 of what it would be without the hood).

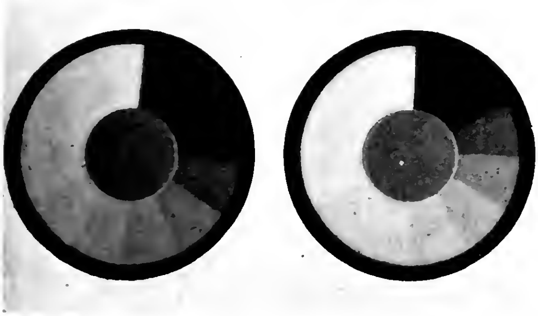

Fig. 6. Roentgenograms of a Benoist Penetrometer. Right, Rays from Front of Target; Left, Rays from Back of Target. Exposure for Front of Target 1 10 that for Back of Target. 2-in. Spark Gap

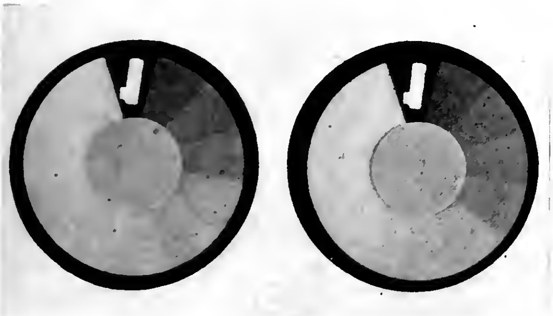

Fig. 7. Roentgenograms from Front and Back of Target as in Fig. 6, but with 10-in. Spark Gap. Exposure 1 to 9

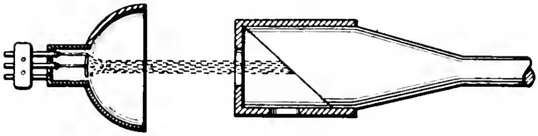

Fig. 8. Metal Hood on Working End of Target

The roentgenograms of the hooded target are, of themselves, sufficient to prove that at least all of that radiation from outside the focal spot which is eliminated by the use of a hood must be due to cathode rays reflected from the focal spot. Without such proof, one might think that much of this might be due to failure on the part of the cathode focusing device to bring to the focal spot all of the primary bundle of cathode rays. An inspection of the hooded target roentgenogram in Fig. 10 shows the true explanation. Through the hole in the side of the hood can be seen a small portion of the inner surface of the hood, and this area shows a very vigorous roentgen ray production. The hood is in good metallic contact with the target, and is therefore of necessity at the same potential as the latter. There is then no force to deflect any of the rapidly moving primary cathode ray stream out of its course and to bring it to the inner surface of the hood. The only possible explanation remaining then, is, that the vigorous bombardment of the inner surface of the hood, which manifests itself not only through roentgen ray production but also by a very rapid heating of the hood (upon starting to excite the tube with a cold target the hood comes to incandescence before the body of the target does), is due to cathode rays reflected from the focal spot.

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*W. D. Coolidge, Am. Journal of Roentgenology, Vol. II, p. 882 (1915).

The reflection is not prevented by the hood, but the roentgen rays resulting from the reflected cathode rays are produced on the inner surface of the hood instead of being produced on the outer surface of the target. The fact that the roentgenogram shows more intensity on the lower side of the target is easily accounted for by assuming that a few of the reflected rays come out through the hole in the side of the hood and then bombard the body and stem of the target on that same side.

Fig. 9. Lower, Roentgenogram of Hooded Target; Upper, Roentgenogram of Target of Standard Tube

Fig. 10. Same as Fig. 9, except that Targets are turned Sidewise

Fig. 11 shows two hooded targets differing only in this respect, that in the lower one a piece of thin tungsten foil (0.0008 in. thick) has been bound over the hole in the side of the hood. This would necessarily prevent any of the reflected cathode rays from escaping at this point. An inspection of the roentgenogram shows that the use of the foil has prevented the difference in intensity on the two sides of the target which is noticeable in the case of the hooded target without the foil. It seems most probable, especially in the light of Fig. 14, which will be described later, that the small amount of radiation remaining on the surface and stem in the case of the hooded target with the foil is due to reflected cathode rays coming from the focal spot and emerging through the hole in the end of the hood, through which the primary cathode rays enter. The number of electrons escaping in this way would naturally be relatively small, owing to the fact that the angle subtended by the hole is small, and to the further fact that these electrons have to move out against the electrostatic repulsion of the cathode.

Cathode Placed Very Close to Anode

Another method which has presented itself for reducing the intensity of the roentgen radiation from the body and stem of the target consists in bringing the cathode so close to the anode that the reflected cathode rays are driven almost straight back to the focal spot by the electrostatic repulsion of the cathode.

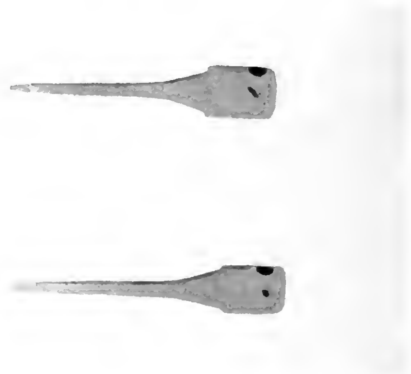

Fig. 11. Lower, Roentgenogram of Hooded Target: Upper, Roentgenogram of Hooded Target with Tungsten Foil

Fig. 12. Roentgenogram of Target of Tube in which Cathode is Placed Very Close to Anode

In Fig. 12 the front end of the molybdenum focusing tube of the cathode was only 2.5 mm. from the anode at its nearest point. (This front end of the focusing tube is clearly visible in the figure, due to the secondary roentgen rays emitted by it.) The roentgenogram shows that the reflected electrons which started out in this direction were forced, by electrostatic repulsion, to again bombard the target on its face, close to the focal spot. Those leaving in other directions, where the distance between the end of the cathode and the inclined face of the anode was greater, were able to get much further away from the focal spot.

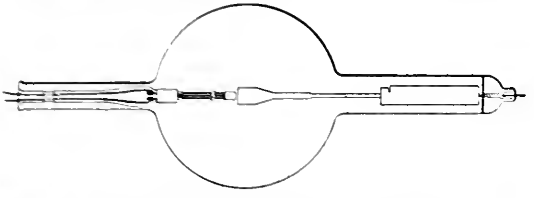

Fig. 13. Tube in which Working Face of Target is at Right Angles to Axis of Tube. Distance between focusing device and face of anode, 2.3 millimeters

Fig. 13 is the diagram of a tube representing a more radical experiment. In this tube the working face of the target was at right angles to the axis of the tube and the distance between the end of the focusing device and the face of the anode was only 2.3 mm. (In this tube, the filament spiral, to prevent its being pulled out under the strong electrostatic attraction, was set much further back than usual in the focusing device).

Fig. 14. Lower, Roentgenogram of Target of Tube shown in Fig. 13; Upper, Roentgenogram of Target of Standard Tube

At the bottom of Fig. 14 is seen the roentgenogram of this tube, the rays being taken from the face of the target in a direction making a very small angle with the face. The small round spot in the center of the target face is the focal spot, seen through the molybdenum focusing tube. The concentric circular ring around this is due to the reflected cathode rays which, instead of being allowed to bombard the target all over its surface, have been forced to return to points close to the focal spot. Comparison of this roentgenogram with that of the standard tube above it shows how very effective this method has been.

Influence of the Atomic Number of the Metal on which the Reflected Cathode Rays Fall

Fig. 15 is the roentgenogram of a target consisting of a tungsten button, 19 mm. in diameter, set in a block of copper 32 mm. in diameter, the latter being supported by a stem of molybdenum screwed into it. The line between the tungsten and the copper is quite marked in the roentgenogram, and the roentgen ray production is clearly less from the copper than it is from the tungsten. This is in accordance with data published by Kaye on the efficiency of different metals in producing general roentgen radiation (not including characteristic) under a given cathode ray bombardment. His measurements were made with 25,000 volts on the tube.

Fig. 15. Roentgenogram of Target Consisting of Tungsten Button set in Block of Copper

"INDEPENDENT" RADIATION

Metal	Atomic Weight	Intensity of Radiation
Platinum.	195.2	100
Tungsten.	184.0	91
Molybdenum. .	96.0	50
Copper.	63.6	33
Aluminum. . . .	27.	10

He found, as the table shows, that the efficiency decreases as the atomic weight decreases, and is approximately proportional to it. By calorizing the copper on the surface, or by otherwise covering it with aluminum, or by replacing the copper with magnesium or some metal of still lower atomic weight, it would be possible to still further reduce the roentgen ray production from the surface of the target outside of the focal spot. The method is different in principle from either of the preceding in that it involves no attempt to reduce the intensity of bombardment of the surface by the reflected cathode rays, but rather reduces the efficiency of the roentgen ray production resulting from this bombardment.

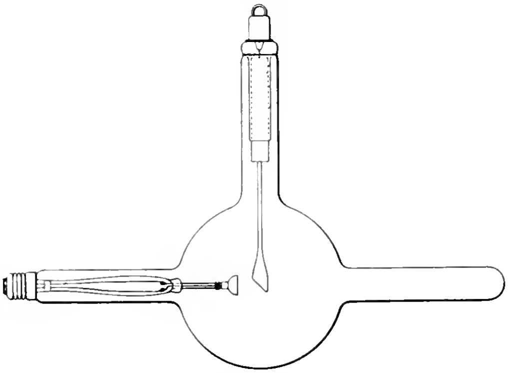

Fig. 16. Tube in which Target is placed at Right Angles to Length-Axis of Tube

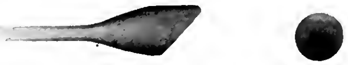

Fig. 17. Right, Roentgenogram of Target of Tube shown in Fig. 16; Left, Broadside View of Target for Comparison

Target placed at Right Angles to the Length-Axis of the Tube

In this method no attempt is made to influence the production of roentgen rays on the surface of the target. The target is merely inserted in the side of the bulb as shown in Fig. 16, instead of in the usual position, and the rays are then taken from the end instead of the side of the target. As a result, the rays from the body and stem of the target do not affect the roentgenogram, as they are intercepted by the face. This is shown in the roentgenogram, Fig. 17, in which the broadside view of the target is also given for comparison. In this simple form this method would be very effective for work calling for a narrow angle of rays; it would not be effective when the angle is wide enough so that the face of the target no longer intercepts the rays coming from the body and stem.

Diaphragm Within the Tube, Parallel to the Target and Insulated from It

This construction is illustrated in Fig. 18. The diaphragm is made of some metal opaque to the roentgen rays, such as molybdenum or tungsten. It may be attached to the cathode, or it may be supported by the glass of the anode arm. In either case the diaphragm will be at cathode potential when the tube is operating, and hence will not be bombarded by the reflected cathode beam. Therefore, it will not of itself be a source of roentgen rays. Fig. 19 shows two roentgenograms of such a target. The lower one is a face view. The diaphragm itself does not show at all in this view, indicating that it undergoes no cathode ray bombardment. The body and stem of the target show through the diaphragm a little, owing to the fact that it consisted of molybdenum only 0.010 in. thick. The upper roentgenogram was made after rotating the tube through an angle of about 120 degrees. It shows that from the inner surface of the

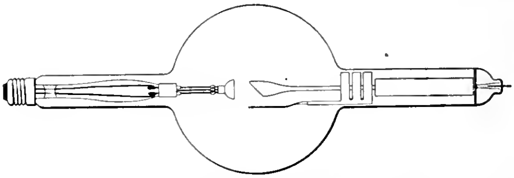

Fig. 18. Tube having Diaphragm Parallel to Target and Insulated from it

Fig. 19. Two Roentgenograms of Target of Tube shown in Fig. 18

diaphragm there is a small amount of roentgen radiation, but this is seen to take place only from that portion of the end of the diaphragm which is in the path of the roentgen rays from the focal spot, and is hence secondary roentgen radiation. The roentgenogram shows that the molybdenum piece not only serves as a diaphragm, but that, by being at cathode potential as it is, it causes some of the reflected cathode ray bombardment to be transferred by electrostatic repulsion from the front to the back of the anode.

Limitations of the Various Methods

Each of these methods, as applied to the present standard tube, interferes in some way with its general usefulness. The hood, to be very effective, should have a small window for the emergence of the roentgen rays, and this limits the size of plate which can be covered with the tube. The same consideration applies, although with less force, to the internal diaphragm which is insulated from the anode.

The placing of the target at right angles to the length axis of the tube makes the tube awkward to handle. In the simple form it is, furthermore, effective in only the narrow central cone of rays. The tube can, of course, be used to cover a wide angle, but it is only the central portion of the resulting roentgenograph which can profit appreciably by the method.

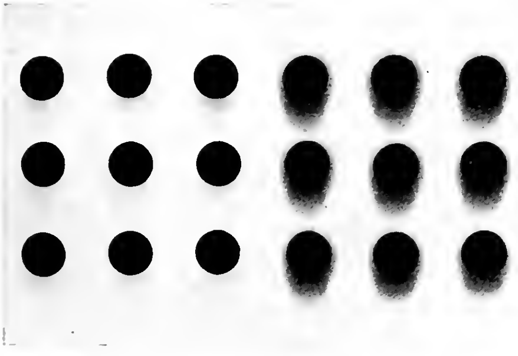

Fig. 21. Left, Roentgenogram through Holes in Lead Plate with Hooded Target (Fig. 8); Right, Standard Tube

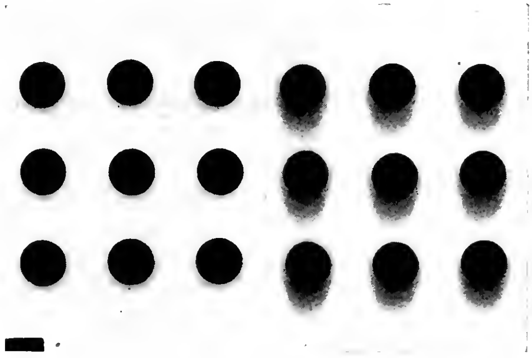

Fig. 22. Left, Tube with Target placed at Right Angles to Length-Axis (Fig. 16); Right, Standard Tube

The placing of the cathode very close to the anode (as close as 2.5 mm., for example) limits the potential which can be used on the tube, at least with present exhaust methods. It would, furthermore, make it necessary to take the roentgen rays out through the cathode structure. The placing of the cathode too close to the anode would also make it difficult to maintain a constant filament temperature, that is, if the target was allowed to become incandescent.

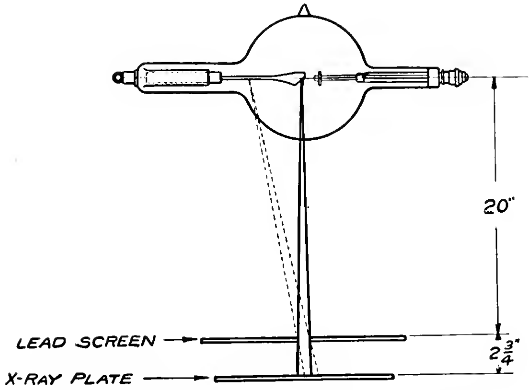

Fig. 20. Diagram showing Arrangement of Apparatus for Determining Effectiveness of Different Methods

The use of a metal of low atomic weight for the surface of the entire target (exclusive of that needed for the focal spot) and stem, is practicable only in case the target is not to be allowed to become very hot, for the reason that there is no metal of low atomic weight which is sufficiently refractory. (Among the non-metallic elements, carbon might possibly be used, but it would render the exhaust more difficult, and at high temperature it furthermore alloys readily with tungsten).

Relative Test of Effectiveness of the Various Methods

Of course the pinhole-camera roentgenograms themselves give some idea of the effectiveness of the various methods. Nevertheless it is difficult to say from an inspection of them which method would give a tube that would make of a given object the best roentgenogram. For this reason a test method, which has been described before* and which is illustrated in Fig. 20, was resorted to. The test object is a lead plate with nine small round holes in it, and is placed at a distance of 2¾ in. from the photographic plate. The tube is placed with its focal spot 20 in. from the X-ray plate. No external diaphragm or cone is used. All exposures are made with the same voltage, current and time, and the same development is used throughout. If all of the roentgen rays came from the focal spot, the radiogram would, in each case, be a series of sharply defined circular areas. Any rays coming from the body and stem of the target tend to produce a halo on one side of each of these circles.

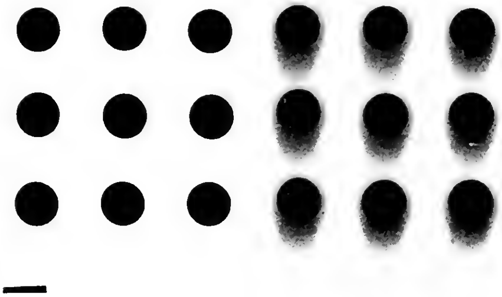

Fig. 23. Left, Tube with Internal Diaphragm (Fig. 18). Right, Standard Tube

The roentgenogram to the right in Fig. 21 was made with the standard tube and that to the left with the tube having a hooded target.

Fig. 22 shows a similar comparison between the standard tube and the one with the target set in to the side of the bulb, as in Fig. 16.

Fig. 23 is a test of the standard tube versus the one with the internal diaphragm, as in Fig. 18.

It will be seen that, according to this test, the tube with the internal diaphragm is the best of those tried. The tube with the copper-backed target was not included. The one with the cathode placed very close to the anode, as in Fig. 13, was not included for the reason that, while from the body and stem of the target it gave the least radiation of any of the tubes, the design of this particular tube was not adapted to the test.

Comparative Test of the Tube with Internal Diaphragm Against the Standard Tube in Medical Roentgenography

The test with the lead plate with the holes was recognized in the beginning as an artificial one, the results of which might be difficult to interpret in terms of medical work. It seemed to be a safe guide, however, as to the relative effectiveness of the different methods.

Having determined in this manner that, of the various experimental tubes made, the one with the internal diaphragm should be looked to for the best definition in roentgenography, the next problem was to show by actual tests whether roentgenographs of medical subjects made with the internally diaphragmed tube were appreciably better than those made with the standard tube.

A pair of tubes was chosen, one with and the other without the diaphragm, with the same size of focal spot (as determined by the pinhole camera method).

The difference found in the pairs of plates made with these tubes of various parts of the body, was so small that it proved very difficult to show beyond reasonable doubt that there was really *any* perceptible difference. Failure to get absolute immobilization of the part in question with either roentgenogram was enough to bring a decision in favor of the other plate. It was finally found that whatever difference there is could better be shown by roentgenograms of a dried skull. This test appears to be more searching than that with a live subject, for the reason that the smaller amount of secondary radiation from the dried skull gives better definition and hence puts the observer in a favorable position to notice differences ascribable to the cause in question. To further this same end, a very small size of focal spot was chosen for the test. The most important thing of all was to use exactly the same voltage on both tubes. This was accomplished by the use of auto-transformer control of the high-voltage transformer and by the use of a stabilizer in the filament circuit.

The difference between such a pair of plates is so small that it at first escaped detection. It would be lost in reproduction. Such a pair of plates has been submitted to quite a number of prominent roentgenolo-

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* W. D. Coolidge, Am. Journal of Roentgenology, Vol. II, p. 885 (1915).

gists, and some of these have chosen the right plate and some the wrong one as the work of the tube with the internal diaphragm.

Explanation of the Smallness of the Gain Made in the Quality of the Roentgenogram by Reducing the Effect of the Radiation from the Target outside of the Focal Spot.

The explanation lies in the sensitiveness curve of the photographic plate and in the narrow range of plate densities involved in roentgenograms of the human body. This is easily proved by going back and making further roentgenograms of the lead plate with the holes. If, instead of greatly overexposing the area of the plate under the holes, so as to bring out the halos strongly, the exposure is so timed as to bring the density of this part of the developed plate only to the maximum density found in actual roentgenograms of the human body, it becomes difficult to see the halos. This is illustrated by Figs. 24 and 25. These were made with the pair of tubes in question, one with and one without an internal diaphragm, and with the same technique employed in Figs. 21, 22, and 23, except that the exposure, instead of being 37.5 milliampere seconds, was 10 in Fig. 24 and 1 in Fig. 25.

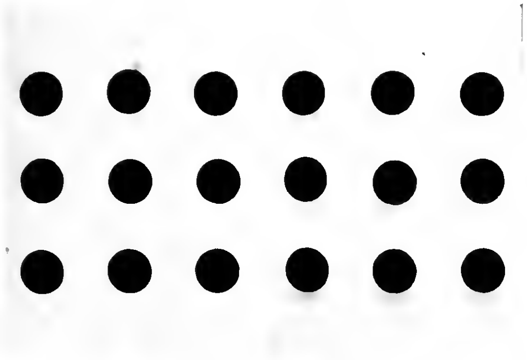

Fig. 24. Left, Tube with Internal Diaphragm. Right, Standard Tube. Exposure, 10 Milliampere Seconds

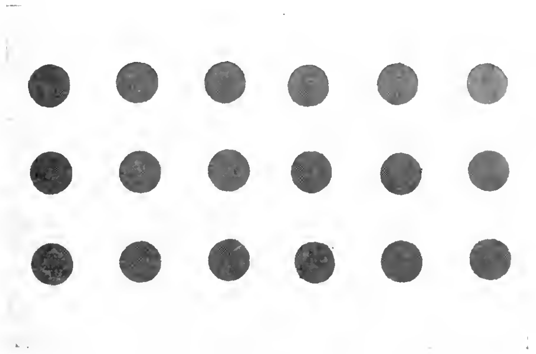

Fig. 25. Left, Tube with Internal Diaphragm. Right, Shortened Tube. Exposure, 1 Milliampere Second

Conclusions Concerning the Importance of the Role Played by the Rays from the Target, Outside of the Focal Spot, in Medical Diagnosis

With the present roentgenographic technique, the part played by these rays seems to the writers to be too small to warrant the use of any one of the methods described for minimizing it, that is, with the present standard type of tube.

In fluoroscopy, comparative tests have not yet been made between the standard and the internally diaphragmed tube; but it seems most probable that the situation is not essentially different here from what it is in roentgenography.

INDUSTRIAL CONTROL

Part VII

DESIGN OF MAGNETIC CONTROL APPLIANCES

By C. B. Bradish

Industrial Control Department, General Electric Company

The preceding articles of this series on Industrial Control have described the applications of magnetic control to both standard and special electric drive and have demonstrated the benefits arising from the employment of this type of control. Since the rapid and extensive adoption of magnetic control has been made possible by the improved design and construction of the control appliances, particular interest is attached to the following article which is descriptive of the most essential of these appliances—contactors and relays—and of their important features.—Editor.

Contactors

For industrial applications, magnetic contactors may be divided into five distinct classes, but these classes have many characteristics in common and the same general considerations apply to all.

I. Direct-current low-voltage, shunt, air-break contactors, up to 600 volts.
II. Alternating-current, low-voltage, shunt, air-break contactors, up to 600 volts.
III. Direct-current, low-voltage, series contactors, up to 600 volts.
IV. Alternating-current, high-voltage, shunt, air-break contactors, up to 2300 volts.
V. Alternating-current, high-voltage, shunt, oil-immersed contactors, up to 6600 volts.

Detail Construction

To perform successfully, a contactor must be of rugged construction and snappy in its action. To obtain this quick action on direct-current contactors some manufacturers make the moving parts comparatively light; but this construction tends to decrease the life of the contactor. Others use a coil of lower voltage and cut a resistor in series with the coil by means of an interlock when the contactor closes; but this arrangement adds two sources of trouble, one in the interlock which may fail to function properly and the other in the resistor which may burn out.

For practically all equipments, a contactor can be designed with a continuously rated coil* and still be rugged and snappy. For extremely rapid intermittent direct-current service, faster operation can be obtained by using a lower voltage coil with the standard contactor. This may be of importance in some steel mill operations where it is common practice to operate the controller as many as thirty times in twenty-five seconds. By using a lower voltage coil the inductance is decreased and this, in addition to the increased pull, considerably lessens the time of closing.

This difficulty in obtaining extremely rapid action is not experienced with alternating-current contactors, for the coils are necessarily of low inductance. A further advantage is illustrated by the curves in Fig. 1. Curve *A* shows the pull on the armature at different air gaps for a sixty-cycle alternating-current coil. Curve *B* shows the pull on the same armature with a direct-current coil. In each case the coils were designed for continuous duty with the same temperature rise, and each coil had approximately six hundred ampere-turns with the contactor closed. The area under each curve represents the work expended on the armature, and clearly explains the more rapid operation of the contactor with the alternating-current coil, even if the time-lag of building up the flux in the direct-current magnet is ignored.

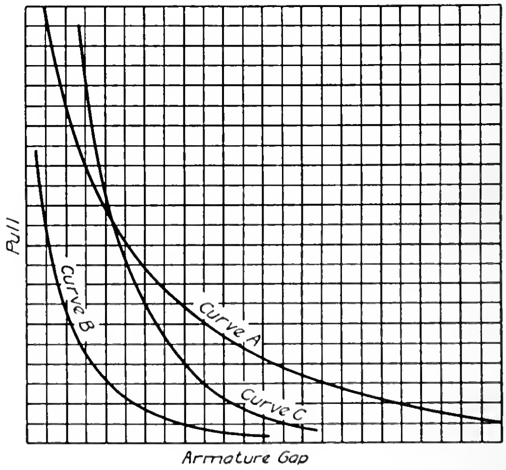

Fig. 1. Curve showing Variation of Pull on Armature of Solenoid at Different Air Gaps, for Alternating Current and Direct Current

This time-lag is greatly increased by an actual counter electromotive force generated

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* A coil is termed "continuously rated" when it can carry its operating current continuously without overheating.

in the coil, due to the increase in the number of lines of force as the contactor closes. Eddy currents also serve to increase this lag, as shown by the fact that a direct-current contactor with a laminated structure is faster than one with a solid frame.

Curve *C* shows the effect of doubling the strength of the direct-current coil; that is, making it twelve hundred ampere-turns. The area under this curve more nearly approximates that under Curve *A*, and shows the necessity for increasing the ampere-turns on the direct-current coil to obtain the same amount of work. This increase in its strength still further increases the inductance of the coil and the time-lag of the contactor. The curves also indicate that the air-gap of a direct-current contactor must be small to obtain a positive "pick-up."

To obtain the necessary travel of the contact tip, the tip must be located on a longer lever than the pole face of the armature; therefore the tip is mounted above the coil and core. The alternating-current magnet has a high "pick-up" value even with a large gap, therefore the tips are mounted on shorter arms and the magnet is given a longer travel. Because of the longer contact arm on the direct-current contactor, the coil must give a stronger pull for the same contact pressure on the tips. However, when the direct-current contactor is closed, this pull is more than sufficient, and the exciting current in the coil can be cut down one-half without affecting the pressure.

An increase of contact pressure decreases the contact drop. The most economical point determines the final pressure on the tip. A reasonable amount of wear must be allowed on the tips, this being called the "wipe." With new tips, the wipe is at a maximum and this is the condition which determines the pull to be obtained from the coil. A contactor should pick up at eighty per cent of normal voltage when the coil is hot, which corresponds in a direct-current contactor to about sixty-three per cent when cold. The resistance of the alternating-current coil is low in comparison to the reactance, consequently even a considerable change in the resistance has but a small effect on the total inductance. For this reason, the pick-up voltage of an alternating-current contactor is practically the same whether its coil is cold or hot.

In considering the matter of design, the direct-current contactor will be taken as an example.

If P = pull in lb. necessary to close the contactor in the wipe position, the flux ϕ ($=AB$), necessary to obtain this pull, is obtained from the formula:

$$P_s = \frac{B^2}{8\pi}, \quad \text{where } P_s = \text{dynes per sq. cm. and } B = \text{lines per sq. cm.}$$

Reducing this to the English system of units:

$$P_i = \frac{B^2}{73{,}134{,}000}, \quad \text{where } P_i = \text{pounds per sq. in. and } B = \text{lines per sq. in.}$$

Then the total pull:

$$P = A \times P_i = \frac{A \times B^2}{73{,}134{,}000}$$

Then

$$B = \sqrt{\frac{73{,}134{,}000 \times P}{A}}$$

And

$$\phi = AB = \sqrt{73{,}134{,}000 \times P \times A}$$

A cross-section for the core which will not give a density beyond the knee of the saturation curve is chosen, but it should be as small as is consistent, for this also determines the diameter of the coil.

If F_c = magnetomotive force in ampere-turns necessary to force the useful or air-gap flux through the core.
F_g = m.m.f. to force this flux through the air-gap.
F_a = m.m.f. to force this flux through the armature
F_f = m.m.f. to force this flux through the frame

Then the total m.m.f.

$$F_t = F_c + F_g + F_a + F_f$$

This does not take into account the leakage factor. If we call this factor *L*, which is the ratio of the total flux in the frame to the flux in the gap, the formula becomes

$$F_t = F_g + F_a + (F_f + F_c)L$$

This formula gives approximate results only, but they are on the safe side since there is a loss of flux between the core and the lower part of the frame running parallel to it. This leakage factor can be determined theoretically and will be called *Lt*, or the ratio of average flux in the core to flux in the gap. If we divide the frame into lower F_l and back F_b sections, the formula will then read:

$$F_t = F_g + F_a + LF_b + (F_l + F_c)Lt$$

In determining these magnetomotive forces, certain cross-sections in the different parts of the circuit must be assumed with consideration for mechanical strength and manufacturing advantages, with the exception of the core as previously mentioned.

If R = reluctance of air-gap
r_g = reluctivity of air-gap
l_g = length of air-gap in inches
Then:

$$F_g = \phi \times R = A \times B \times r_g \times \frac{l_g}{A} = 0.3132\ B \times l_g$$

In the same manner the other forces can be determined if the reluctivity r is known for the materials used at the density assumed, or from B-H curves, with H plotted in ampere-turns per inch, the forces are easily determined from the following:

If

$$F = \phi \times R = \phi \times r \times \frac{l}{A}$$

and

$$r = \frac{H}{B}$$

Then

$$F = A \times B \times \frac{H}{B} \times \frac{l}{A} = H \times l$$

After determining the ampere-turns necessary, the coil is designed which will have not over one watt loss per square inch of radiating surface. In direct-current coils the entire loss appears as I^2R loss in the winding. In considering alternating-current coils, the hysteresis and eddy current losses in the magnet are also to be considered, since these losses are furnished from the coil. It is not possible to cut in resistance with alternating-current contactors, as the addition of a comparatively small amount in series with the coil tends to make the contactor noisy. Also, the high inrush current in the coil, due to the low reactance when the contactor is open, prohibits the use of resistance in the circuit on "pick-up."

Solid copper tips have proved to be the most satisfactory as they insure good contact and long life. They are so shaped and supported that there is a "wiping" or rolling action as the contactor closes. The contact pressure is obtained through the compression of a spring which actuates the tip. Because of this rolling action, pitting of the contact surface on which the current is made and broken does not affect the surface on which the current is carried when the contact is dead. This insures low contact resistance and correspondingly less heat. On contactors for more than 1000 amperes the current is carried by laminated copper brushes, while the secondary arcing tips are of solid copper. The voltage required to close the contactor when the tips are touching, designated as the "wipe" voltage, should be considerably below the pick-up vol age to insure a positive closing of the contactor, and, to a great extent, to prevent welding of the tips. A high final pressure on the tips tends to lower the heating as well as to give a strong positive "kick-off" when the contactor opens.

The arc chutes are made of a moulded compound and are supported so that they can be swung up and back to give easy access to the renewable tips. The blowout coils are wound with bar copper in the larger sizes and with insulated wire in the smaller sizes. The direct-current operating coils are wound with enamelled wire on fiber spool bodies with brass centers and are given a water-proof impregnation treatment after winding. For alternating-current coils enamelled wire covered with silk is used, to provide a better insulation against chafing.

Types

Low-voltage Direct-current Contactors; A unit of this type is shown in Fig. 2. All are of single-pole construction and have the moving contact mounted on the armature above the core, except in the 75-ampere size, for which capacity a double-pole contactor has also been designed having moving tips insulated

Fig. 2. 600-Volt, 339-Amp. Direct-current Contactor with Series Current Limit Interlock

from the armature and having two stationary contact posts with blowouts. The frame and armature on all the direct-current contactors, with the exception of the two 20, 40 and 75-ampere sizes, are iron castings. On the two smallest noted, they are made of punchings and cold rolled steel, while the frame of the 75-ampere contactor is made of angle iron. The armature carries the moving contact and rotates on a heavy brass pin supported by the frame. The current is carried from the tip to the frame by a flexible copper shunt; and in the double-pole type from the insulated tips to studs on the slate by shunts, the frame being dead. These contactors are built in 20, 40, 75, 150, 300, 500, 900 and 1500-ampere sizes, single-pole, with the exception of the 75-ampere contactor, which is also double-pole. The 3000-ampere contactor is of special design having toggle joints, heavy laminated brushes, and solid arcing tips. To obtain a positive pick-up the coil is "soaked" and resistance is cut in series by an interlock. This contactor is not suitable for heavy duty.

Low-voltage Alternating-current Contactor: Contactors of this type are made with one, two, three or four poles, Fig. 3 illustrating the two-pole type. For any given ampere rating the different contactors use the same magnet and coil, with the exception of the four-pole contactors, which are used for accelerating squirrel cage induction motors (these are energized for only a very short time and use a lower voltage coil). The frame and armature are made of thin steel laminations riveted to center ribs which form part of the main castings. The frame is U-shaped and the armature closes the magnetic circuit when the contactor is closed. A loop of copper wire passes across the upper face of the frame and back through the slate, the ends being connected by a german silver shunt. This loop serves to eliminate the noise in the contactor, due to the rapid reversal of current in the coil, by setting up a flux out of phase with the main flux. The armature is attached to a hexagonal steel shaft having mica and fibre insulation. This shaft is supported at its ends by two bearings. The moving contact arms are clamped on this insulated shaft with proper spacings between them.

Fig. 3. 600-Volt, 150-Amp., D. P. Alternating-current Contactor

Fig. 4. 600-Volt, 75-Amp. Series Contactor

Contactors of this type are built in 75, 150, 300, 600 and 1500-ampere sizes with one to four poles, having the magnet on either the left or right-hand side to facilitate mechanical interlocking.

Disk type interlocks are used with direct-current contactors of 75 amperes and larger and with alternating-current contactors of 150 amperes and larger, and are operated by the movement of the armature. The smaller contactors use specially designed interlocks.

Series Direct-current Contactor: Contactors of this type are built in 75, 150, 300, and 500-ampere sizes, Fig. 4 showing the 75-ampere unit. They have solid copper tips, and are without arc chutes. The smaller coils are wire wound and the larger ones bar wound. These contactors are designed to "lock-out" on current above the calibration point and to close on any value of current between this point and one-third the continuous rating of the coil. They will hold "in" on ten per cent of the normal rating of the coil. The last accelerating contactor on the great majority of starters has a shunt holding coil added which is energized by an interlock, thus holding this contactor closed for light loads or pump-backs. A special form has also been developed in the larger sizes with an auxiliary contact, provided with a blowout, for connecting in the motor field resistor after the armature starting resistor has been cut out.

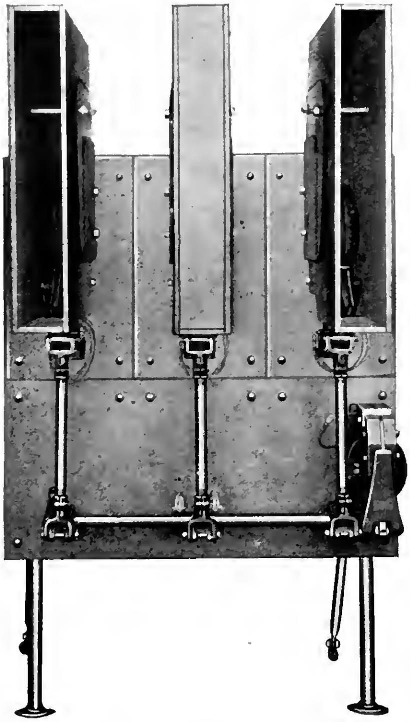
Fig. 5. 2300-Volt, 500-Amp. Air-break Contactor

Forms have also been developed with increased spring pressure for use in intermittent duties, and where plugging is a regular occurrence.

High-voltage Air-break Alternating-current Contactor: Units of this type are designed for use on circuits up to 2300 volts, and are made either double or triple-pole; the latter is more in demand and is illustrated in Fig. 5. In these contactors, the size of the arc in rupturing the current is the main consideration; consequently long arcing horns, large arc chutes, and powerful blowouts are provided. The stationary contacts are mounted on marble bases, with the arcing horn running back over and protecting the blowout coil. The moving contact is operated through a long insulated rod connected to a shaft on which the armature of the operating magnet is mounted. The front arcing horn is supported from the base and is connected with the moving tip through a flexible shunt. The tip in opening drops down past this horn to which it transfers the arc. By keeping the horn stationary and separate from the moving tips and thus decreasing the weight of the moving element, the objectionable arcing on "make" is eliminated.

The arc chutes are made of a heat resisting material; and the two outside chutes are closed on the top and open in front, while the middle chute is closed in the front and open on the top. This is to prevent the arcs from touching and causing a short-circuit when the contactor opens on overloads. The operating magnet and coils are the same as used on the low-voltage contactors.

These contactors, rated at from 50 to 500 amperes, are of the same general construction, the capacity depending upon the size of the blowout coil. For reversing service they can be mechanically interlocked. For this duty it is the practice to use a potential interlocking device in addition, which prevents either contactor closing until the arc has been broken on the tips of the other. This is accomplished by connecting a potential transformer across the tips.

Oil-immersed Contactors: This class of contactors is used on high-voltage alternating-current circuits from 2300 volts to 6600 volts. For special work in mines and similar places, some small low-voltage direct-current starters have been immersed in oil tanks, but these are complete panels rather than contactors and will not be considered in this article.

Oil-immersed contactors are of two types:

I. Standard air-brake, two and three-pole contactors, supported in oil tanks with porcelain bushings in the cases for entrance of the leads.

II. Contactors with contacts only in oil and with magnet on the cover of the tank.

The first type of contactor is satisfactory for infrequent starting duty on alternating-current lines up to 2300 volts, and for currents of 150, 300, 600 and 1500 amperes. Two contactors are frequently mounted side by side in oil, and mechanically interlocked for reversing service. They are not suitable, however, for frequent duty, especially jogging or quick reversals. The standard line of 2300-volt automatic compensators use two contactors mechanically interlocked in oil, one a four-pole for starting and the other a two-pole for running. These contactors are mounted on a marble base supported from the top of the tank.

The second type of contactor is shown in Fig. 6 and has its contacts mounted on a shaft in oil, but the operating magnet is located outside on the cover of the tank. The contacts are closed through a steel push rod connecting the magnet armature to the shaft. This type has been developed especially for reversing contactors, since it greatly reduces the size and weight of the tank and increases the ease of handling. With the magnet outside the tank, inspection and renewals of coils or interlocks are simplified. This contactor is designed for infrequent starting or reversing on 2300 to 4000-volt alternating-current circuits. The reversing type of contactor is made in 150, 300, and 500-ampere sizes.

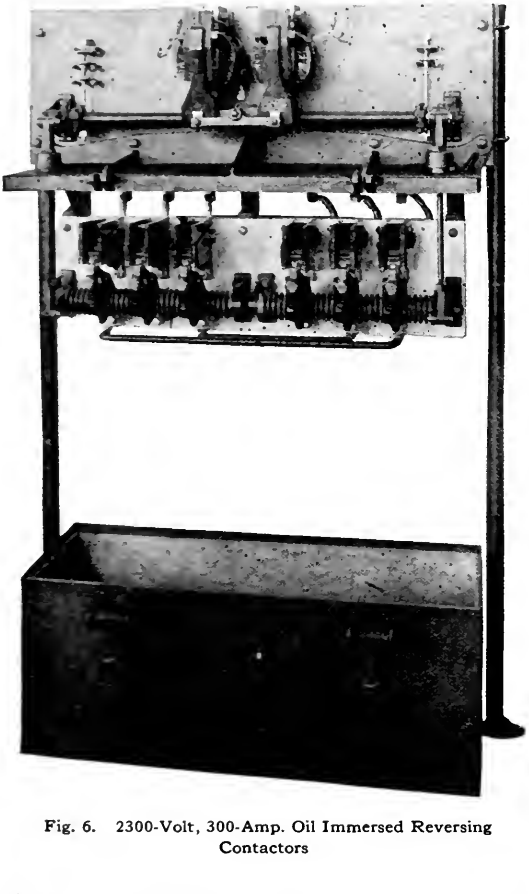

Fig. 6. 2300-Volt, 300-Amp. Oil Immersed Reversing Contactors

For higher voltages, from 4000 to 6600, it is preferable to use two breaks in series with liberal spacing. A three-phase circuit for non-reversing service could thus be handled by two triple-pole contactors.

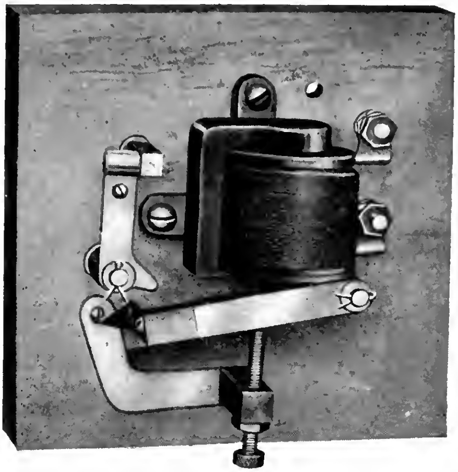

Fig. 7. Instantaneous Overload Gravity Reset Relay

The operating coils on these high-voltage contactors are usually wound for 220 volts and a step-down transformer is used for the control circuits. However, any voltage under 600 is suitable for operating the contactors.

In using any of these oil-immersed contactors the conditions should be positively known to be within the limits of the contactor. Also, they should never operate oftener than fifteen times an hour.

Relays

Relays are of the series or shunt type, or of a combination of both, and are either instantaneous or time-limit. In general, they are used to break or make control circuits when conditions in the main lines become dangerous or reach certain definite values. They must be of simple construction and rugged enough to withstand severe duty under heavy overloads or short circuits, or under continuous service. There must be no delicate parts to fail, due to careless handling. They should be made "fool-proof" as far as possible.

Gravity-reset Instantaneous Overload Relay: The unit shown in Fig. 7 is of the simplest type. The contacts carrying the control current have a good positive contact and in closing "wipe" over the surface to keep a bright clean connection. The striking lever arm sets firmly in its normal position until the current has reached the tripping value, when it picks up and opens the tips in a strong and positive manner. The operating coil is wire-wound in the smaller sizes and bar-wound in the larger sizes. The control circuit is insulated from the frame and coil, since the coil may be of opposite polarity to the control circuit. This relay has a wide calibration range and all delicate adjustments are eliminated. The coil will carry its rated current continuously without overheating and momentary peaks without damage.

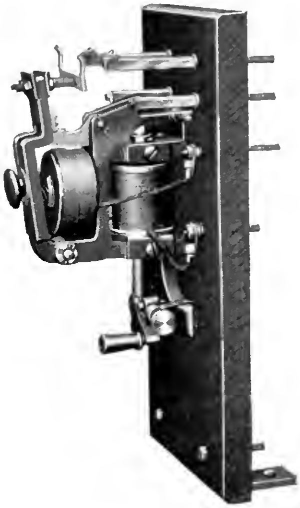

Fig. 8. Instantaneous Overload Electrical Reset Relay

Electrically-reset Overload Relay: The unit shown in Fig. 8 has both a series and a shunt coil, the former for tripping the relay and the latter for resetting it electrically from the master switch. The control tips make positive contact until the plunger lifts on overload, when the inertia of the moving plunger assists in tripping the levers. The resetting coil is energized only momentarily and the relay breaks this circuit in resetting. It is advantageous to keep the control circuit and coils insulated from the frame, as this enables relays to be used in both sides of the line, or in two different phases, without danger of breakdown between coil and frame.

Hand-reset Overload Relay: This type is a modification of the electrically-reset relay, the shunt reset coil being omitted and the resetting being performed by hand. This necessitates that the operator shall return to the panel before again starting up the equipment. The three relays just described are designed for both alternating-current and direct-current circuits.

Inverse Time-limit Overload Relay: A unit of this type is shown in Fig. 9. It is made in both hand and gravity reset types. An oil dash-pot is used to obtain the time interval, the plunger operating a toggle on the top of the frame to open the control circuits. Punched sheet steel covers are provided to keep dust from the contacts and dash-pot, and also to prevent accidental contact with the live parts of the relay. These relays are used on alternating-current circuits, especially where high inrushes for short intervals take place, as in starting squirrel-cage motors, etc.

Current-limit Relay: Fig. 10 illustrates a relay of this character having both a series and a shunt coil and used for alternating-current motor acceleration. The series coil carries the primary current direct, or through current transformers. The shunt coil is connected in series with the contactor coil, thus keeping the contactor open until the plunger and disk held up by the series coil fall and short circuit the shunt coil, thereby allowing the contactor to close. In using this relay the series coil should have the inrush current of the motor pass through it before the shunt coil is energized, in order to prevent the plunger falling too soon. With two of these relays working alternately, any

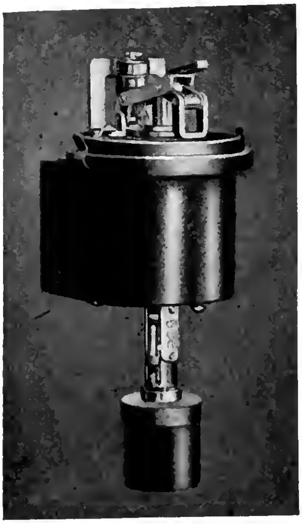

Fig. 9. Inverse Time-limit Overload Relay. Covers Removed

number of accelerating contactors can be closed on current limit.

A modification of this relay with two extra contacts is used for current-limit acceleration on automatic compensators.

D-C. Current-limit Relay: This relay is used in connection with shunt-type direct-current contactors and is mechanically operated from the armature of the contactor, as shown in Fig. 2. The relay has a series coil with a tap in the middle connected to the contactor frame. The armature current flows through the full coil until the contactor closes, thus holding up the plunger. The contactor in closing shunts out half of the coil and the plunger drops at the proper value of current flowing through the half coil. When the contactor opens, the relay is picked up mechanically. Each accelerating contactor requires a separate relay.

Time-limit Accelerating Relay: A relay of the shunt type with oil dash-pot, as shown in Fig. 11, is often used on automatic compensators, especially when two motors are to be started either separately or together. It is also used on furnace control panels.

Fig. 10. Current Limit Alternating-current Relay

Air Dash-pot Relay: A relay of this type, operated mechanically from the 75-ampere alternating-current contactor, is used for time-limit acceleration on a special predetermined-speed printing press panel. This relay has a range of from three to seven seconds in closing.

Step-back Relays: Heavy construction and independently adjustable pick-up and drop-out settings are features of this class of relay. One type is used for direct-current and another type for alternating-current shown in Fig. 12. These appliances open the accelerating-contactor coil circuits only when a heavy overload comes on the motor, leaving it still

Fig. 11. Time-limit Shunt Relay

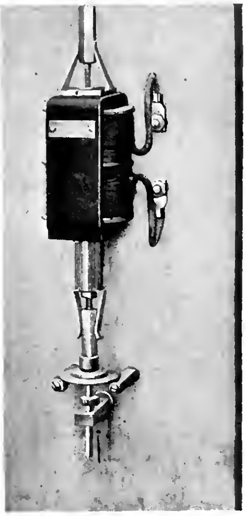

Fig. 12. Alternating-current Step-back Relay

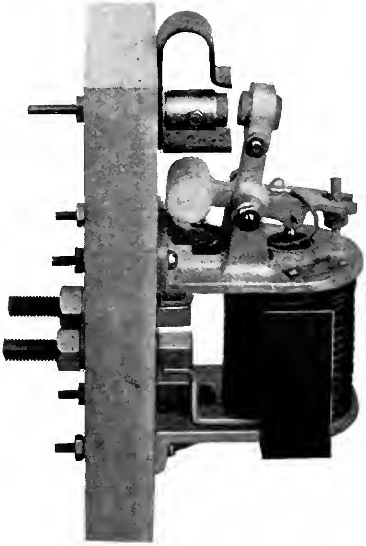

Fig. 13. Direct-current Field Accelerating Relay

connected to the line with all of the starting resistor in circuit.

Field Protective Relay: This relay has its operating coil connected in the shunt-field circuit and is used to open the control circuits upon loss of the shunt field. A copper damper is incorporated when the motor is heavily compounded, since the shunt field is greatly reduced on a sudden strengthening of the series field, which condition takes place during starting.

Field Accelerating Relay: The device shown in Fig. 13 is used with adjustable speed motors for accelerating the motor from its basic speed to some higher speed, determined by the setting of the field resistor. The operating coil is connected in the armature circuit and closes the contact tips on a definite rise in current. These tips short circuit the field resistor and thus reduce the current demand by increasing the counter electro-motive force

TABLE I

CONTACTORS: CLASS I, LOW-VOLTAGE D-C. SHUNT

Amperes Continuous	Maximum Voltage	Number of Poles	Identification Symbol
3000	250	1	171
1500	600	1	175
900	600	1	184
500	600	1	186
300	600	1	185
150	600	1	225
75	600	1	324
75	250	2	325
40	250	1	378
20	250	1	377

TABLE II

CONTACTORS: CLASS II. LOW-VOLTAGE A-C. SHUNT

Amperes Continuous	Maximum Voltage	Number of Poles	Identification Symbol
1500	600	1	194
1500	600	2	230
1500	600	3	307
600	600	1	338
600	600	2	199
600	600	3	224
300	600	1	337
300	600	2	197
300	600	3	223
300	600	4	228
150	600	1	336
150	600	2	198
150	600	3	222
150	600	4	227
75	600	2	302
75	600	3	305
75	600	4	306

TABLE III

CONTACTORS: CLASS III. LOW-VOLTAGE D-C. SERIES

Amperes Continuous	Maximum Voltage	Number of Poles	Identification Symbol
75	600	1	233
100 int.	600	1	393
150	600	1	234
300 int.	600	1	394
300	600	1	235
400 int.	600	1	395
500	600	1	236
600 int.	600	1	396

TABLE IV

CONTACTORS: CLASS IV. HIGH-VOLTAGE A-C. AIR-BREAK

Amperes Continuous	Maximum Voltage	Number of Poles	Identification Symbol
50–150	2300	2–T-P.	374
250–500	2300	2 and 3	202

TABLE V

CONTACTORS: CLASS V. HIGH-VOLTAGE A-C. OIL-IMMERSED

Amperes Continuous	Maximum Voltage	Number of Poles	Identification Sumbol
150	2300	2-T.P.	342-B
300	2300	2-D.P.	326-A
300	2300	2-T.P.	326-B&D
300	4000	2-T.P.	326-C&E
500	2300	2-T.P.	327-B
1500	2300	2-D.P.	328-A
1500	2300	2-T.P.	328-B

TABLE VI

RELAYS: A-C. OR D-C.

Maximum Voltage	Service	Reset	Identification Symbol
600	I.T.L. Overload	Gravity	797-B
600	Inst. Overload	Gravity	798-A
600	Inst. Overload	Electrical	784-D
600	Inst. Overload	Hand	784-E
600	I.T.L. Overload	Hand	797-A

TABLE VII

RELAYS: A-C. OR D-C.

Maximum Voltage	Service	Identification Symbol
600	Current limit—a-c.	723-A
600	C.L.—a-c. auto. Compensators	723-H
600	Time limit—oil dash-pot	778
600	Step-back—a-c.	783
600	Step-back—d-c.	763
600	Field protective relays for compound motors	376
600	Field accelerating	785
600	Field accelerating	766

of the motor armature. As the current decreases the tips open again. This vibrating action continues until the motor has attained the desired speed. The control tips are of carbon to insure long life and improve operation.

All of these relays handle control circuits of only 600 volts or less.

There have been developed many contactors and relays for special services, which are in general modifications of the type just described.

Tables I to VII list standard contactors and relays according to the classification used in this article and give numerical data descriptive of these appliances.

ELECTRICAL MACHINERY TESTS AND SPECIFICATIONS BASED ON MODERN STANDARDS

By H. M. Hobart, M. Inst. C. E.

General Electric Company

The mere drafting and circulating of Standardization Rules constituting a radical departure from former practice are insufficient to bring about general use of the contemplated modifications. It is necessary to have a wide and thorough discussion in order that there shall be a clear appreciation of the reasons for and the consequences of the alterations. Furthermore, in working out so comprehensive a proposition as that represented by the Standardization Rules of the American Institute of Electrical Engineers, provision has to be made for a large number of details, whose importance, if not especially emphasized, is liable to be overlooked in the practical application of the Rules to concrete cases. There are many sections in the rules, which at first glance would seem of minor importance, but which, nevertheless, set forth requirements which cannot be disregarded advisedly on the occasions of acceptance tests and in the drafting of specifications. It is believed that this paper, which was read at the Toronto Section Meeting of the A.I.E.E., will be found very instructive in this regard.—Editor.

Introduction

The author recently has had occasion to carry out a series of very interesting acceptance tests upon some large waterwheel-driven generators. Since it was the purpose to make the tests with exceptional care, it seemed to be an admirable occasion to subject the American Standardization Rules to a thorough test. Consequently, special endeavors were made to conform with the requirements set forth in the American rules. Various points arose in which this practical process of putting the rules to the test suggested the desirability of slight modifications to increase their definiteness.

In the original drafting of a specification, the feasibility of determining by simple tests that the requirements of the specification have been fulfilled should always be kept prominently in mind. Indeed, the close association between a consideration of the terms of the specification and a consideration of the general subject of the carrying out of acceptance tests is so obvious that it is unnecessary to further justify the predominance given in this article to the acceptance-test aspects of the subject.

As regards electrical machinery, the British Standardization Rules issued by The Engineering Standards Committee in Report No. 72 and the October, 1916, edition of the Standardization Rules of the American Institute of Electrical Engineers are in such close agreement that machinery built and rated to conform with the one set of rules will usually also conform with the other set of rules. The slight quantitative differences between the two sets of rules practically always will be covered by the margin reserved by manufacturers. This general statement of fact is made as a matter of interest, but of course it is always important to make certain that the Standardization Rules according to which the machinery is specified in any particular case agree in all particulars. An appendix to this article contains in tabular form a statement showing the slight differences in the temperature limits in the British and American Standardization Rules. The heating and temperature sections of the 1916 edition of the Italian rules are also in close agreement with the corresponding sections of the British and American rules.*

The British rules do not yet cover quite as many subjects as the American and Italian rules, which already contain sections relating to efficiency and to regulation in addition to those covered by all three sets of rules. The limitations of this article will not permit of a discussion of these two latter subjects nor of the subject of dielectric tests, notwithstanding their interest and importance. The article is further limited chiefly to points relating to rotating machinery, the important

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* "Standards for the Ordering and Acceptance of Electrical Machines" issued by the Italian Electrotechnical Association; Central Offices; 10 Via S. Paolo, Milan.

subject of stationary transformers being excluded since its consideration would have too greatly increased the length of the article.

Temperature Standards

So far as relates to heating and temperature, the plan underlying all modern standardization rules for electrical machinery consists in establishing approved upper limits of temperature. These limits are such as to permit of continuous subjection thereto. While as an actual fact these limiting temperatures could be exceeded safely for short intervals, this is not permitted by the rules. The approved upper limits have been determined upon with a view to providing adequate factors of safety. Having determined upon approved values for the upper temperature limits, the next step consists in adopting a reference value for the ambient temperature. The difference between the approved upper limits and the ambient temperature of reference constitutes the limiting temperature rise. The *rating* is obviously a function of the thus-deduced temperature rise.

Ambient Temperature of Reference

In the British, the American, and the Italian rules the ambient temperature of reference is 40 deg.* This value was adopted because it is a temperature approached in all parts of the temperate zone at some time during the year.

In none of these three sets of rules is there, as yet, any provision for machinery for tropical countries. The author would suggest 55 deg. as a suitable ambient temperature of reference for tropical ratings. The suggestion is not based on any contention that electrical machinery is liable to be installed in locations where an ambient temperature of 55 deg. would be at all likely to occur, but for the three following reasons:

First, that it is desirable to employ a value which will ensure a margin of a few degrees; *second*, that the ambient temperature of reference for tropical ratings should not exceed that for temperate ratings by less than 15 deg. (a less difference would lead to ratings which would be so nearly the same for the two cases that the difference hardly would be worth taking into account); *third*, that the value of 40 deg. is, strictly speaking, rather too low for the temperate zone. While its occurrence is by no means usual, it is so often approached within a few degrees that it cannot be said to provide much margin when employed as a standard reference value. Since 40 deg. is now firmly established for the temperate zone, the consistent value for a basis for tropical ratings is 55 deg.

Practical experience has demonstrated that ratings for electrical machinery destined for use in tropical countries should be distinctly lower than ratings which have proven satisfactory for the temperature zone.

The ambient temperature of reference of 40 deg. for all countries in the temperate zone was adopted only after very careful investigations. While there are many localities where an outdoor shade temperature of 40 deg. is never attained at any time in the year, nevertheless there are in the temperate zone very few localities where an outdoor shade temperature of 35 deg. is not sometimes closely approached. It was decided that 35 deg. did not afford sufficient margin. The following data bear out the correctness of this decision.

The temperatures in Table I have been taken from the report of the Chief of the Weather Bureau and are the maximum recorded in any station in the designated states during the year 1908.

TABLE I

Max. Temp. in Year 1908	States
42 deg.	Kansas, Nebraska, New Mexico, Oklahoma
43 deg.	Montana, Idaho, Oregon, South Dakota, Utah, Wyoming
44 deg.	Washington
46 deg.	Texas
47 deg.	Nevada
49 deg.	California
52 deg.	Arizona

In America, meteorological observations are often made by amateur volunteers and it is possible that some of these higher values may not have been adequately verified.

From "Symons Meteorological Magazine" for 1912 the temperatures at twenty places in the British Empire have been compiled in Table II. The records consulted were compiled from 30 places in the British Empire. For the remaining ten places 32.5 deg. was not reached at any time during the year 1911.

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* Throughout the paper, all temperatures are given in the centigrade scale.

TABLE II

NUMBER OF MONTHS DURING 1911 IN WHICH THE MAXIMUM SHADE TEMPERATURE EQUALLED OR EXCEEDED

	32.5 deg.	35 deg.	37.5 deg.	40 deg.
London	3	1	0	0
Malta	1	0	0	0
Lagos	4	0	0	0
Cape Town	3	3	1	0
Durban (Natal)	3	1	0	0
Calcutta	9	4	2	0
Bombay	9	0	0	0
Madras	8	8	6	3
Colombo (Ceylon)	4	0	0	0
Hongkong	3	0	0	0
Sidney	3	2	2	0
Melbourne	4	3	3	2
Adelaide	6	6	5	2
Perth	4	4	3	2
Coolgardie	6	6	6	5
Hobart (Tasmania)	2	2	1	0
Jamaica (Kingston)	9	3	0	0
Toronto	1	0	0	0
Fredericton	1	1	0	0
Bloemfontein	5	2	0	0

It is of importance to emphasize that it is not essential to be able to reconcile the ambient temperature of reference with the maximum temperature occurring in the locality where the machinery is to operate. The greater the amount by which the ambient temperature of reference exceeds the temperature where the machinery is operated, the greater is the factor of safety. The shade temperatures set forth in meteorological records are usually taken where there is no local source of generation of heat and where air circulates freely. Electrical machinery in operation is itself a source of heat and increases the temperature of the surrounding air. Furthermore electrical machinery is often located in places where the circulation of air is very much restricted. Consequently, the ambient temperatures near electrical machinery will generally considerably exceed the shade temperatures recorded by meteorological stations. Indeed there is no proof that the actual ambient temperatures in the neighborhood of electrical machinery are related at all closely to the official temperatures issued from meteorological stations. It is evident from the tables which have been given that, strictly speaking, even 40 deg. is too low for the reference temperature on the basis that it is to be a value that shall *never* be even *slightly* exceeded. The reference value adopted must rest upon an assumption and it is important that the assumption shall be conservative. In the rules of the Verband Deutscher Elektrotechniker the ambient temperature of reference is 35 deg. The precise statement in this respect as set forth in the V. D. E. rules is as follows:

"It is assumed that the temperature of the surrounding air will not exceed 35 deg."

In the British, American and Italian rules, it is assumed that the temperature of the surrounding air will not exceed 40 degs. It is probable that in the neighborhood of electrical machinery, *i. e.*, at a distance of 1 to 2 meters from the machine as set forth in Section 314 of the American rules), the temperature of the air at some time during the year exceeds 35 deg. in the majority of cases and there is often a considerable probability that the ambient temperature near electrical machinery will occasionally rise a few degrees above 40 deg. But by the adoption of the 40 deg. as the ambient temperature of reference there will, for almost all installations of electrical machinery in the temperate zone, probably be a margin of a few degrees during 99 per cent of the year. For such an indefinite state of affairs, it is reasonable to adopt a value which offers some probability that there will be such a margin. It is not possible to predict the maximum ambient temperature in the neighborhood of an electrical machine within several degrees even when the machine is not running, and the value to which the ambient temperature is likely to attain when the machine is in operation is still more indefinite. The records of the official shade temperature for any given locality are of little or no service. Indeed the temperatures maintained within buildings are apt to be fully as high in cold climates as in warm climates. In view of the indefiniteness inherent to the subject, and of the importance of taking a conservative value, it would appear that the reference value of 40 deg. for the ambient temperature in regions in temperate climates is certainly not too high and reasonably might be criticized as too low. From whatever way the matter is approached there is obviously a 5-degree-greater factor of safety, (in other words, a more conservatively rated machine), when the rating is based on an ambient temperature of reference of 40 deg., as in the British, Italian and American rules, than by basing it on 35 deg.

A distinct commercial value is attached to the provision of means for maintaining at a reasonably low temperature the premises in which electrical machinery is operated. If a temperature of 30 deg. on these premises is never exceeded at any time during the year, then the maximum temperature ever occasioned in the electrical machinery when operating at its rated load is 10 deg. below the approved limits and the margin of safety is very much greater.

Ambient Temperature During Acceptance Tests

In determining the ambient temperature on the occasion of acceptance tests in the case of rotating machines cooled by forced draft, it is provided in Section 311 of the American rules that "a conventional weighted mean should be employed, a weight of *four* being given to the temperature of the circulating air supplied through ducts and a weight of *one* to the surrounding room air." Thus, for example, if on the occasion of an acceptance test the circulating air is taken from outside the building and has a temperature of 14 deg. at the intake of the machine, while the temperature of the air in the room is 24 deg., the ambient temperature, from which the temperature rise is determined, should be taken as:

$$\frac{4\times14+1\times24}{5}=16 \text{ deg.}$$

If the temperature of the machine at the end of the heat run is 70 deg., then we have:

Temperature rise *in accordance with the American rules* = 70 — 16 = 54 deg.
Temperature rise *above room temperature* = 70 — 24 = 46 deg.
Temperature rise *above inlet temperature* = 70 — 14 = 56 deg.

While, strictly speaking, the weights given for the two air temperatures should depend upon the characteristics of the particular machine under test, the correction is of such moderate amount that it has been desirable in the interests of simplicity and definiteness to standardize the weighting of the two temperatures.

It is further to be noted (from Sections 314 and 315 of the American rules) that the room temperature is to be taken as the mean of "several thermometers placed at different points around and half way up the machine, at a distance of one to two meters," and that the value to be employed shall be the mean of the readings of these thermometers taken at equal intervals of time during the last quarter of the duration of the test.

The temperature of a large machine will not at all promptly follow the changes which are always taking place in the temperature of the premises where a heat run is being made. Consequently, if no appropriate provision be made, a greater temperature rise will usually be recorded if the heat run concludes shortly after midnight, when the air temperature in a large factory building is usually falling, than if the heat run is concluded in the middle of the forenoon, when the air temperature of such a building is usually rising. Errors from this source are avoided by complying with the requirement in Section 316 that "the thermometer for determining the ambient temperature shall be immersed in a suitable liquid, such as oil, in a suitable heavy metal cup." With a falling room temperature a mercury thermometer exposed to the room air might read at least a couple of degrees lower than an identical thermometer with its bulb immersed in oil in one of these metal cups.

To those who have not had extensive experience in testing large generators, these various precautions may seem trivial. As a matter of fact they ensure immunity from errors which may easily amount to several degrees difference in the result obtained for the temperature rise.

The British, Italian and American rules are now in agreement in providing that for rotating machinery no correction is to be made in the temperature rise on account of the particular value of the ambient temperature on the occasion of the test. The British and American rules simply suggest (Section 320 of the American rules) that "tests should be conducted at ambient temperatures not lower than 15 deg." The corresponding Italian rule is as follows:

> "For ambient temperature lower than 40 deg. during the tests, no correction shall be applied to the results of the measurements so long as the temperature does not fall below 10 deg.; however it is not convenient that tests should be carried out at temperatures below 10 deg."

This plan of omitting any corrections is a decided improvement over the old plan of applying to the observed temperature rise a correction which was a function of the ambient temperature at the time of the test. Careful tests have shown that the temperature rise of the average machine is not very dependent upon the temperature at the time of the test and that the reliability of the result cannot be increased by means of any simple corrections. Elaborate tests have been made with the object of clearing up this matter by making heat runs in a room maintained successively at low and high temperatures. The rise with low room temperatures averaged as great as the rise with high room temperatures, the inverse change in core and copper loss with change in temperature combined with the very rapid increase in radiation at high temperatures tending to render the result independent of the room temperature.

Another progressive ruling which is identical in the British and American rules is that relating to the duration of heat runs. It is to the effect that:

> "The temperature test shall be continued until sufficient evidence is available to show that the maximum temperature and temperature rise would not exceed the requirements of the rules, if the test were prolonged until a steady final temperature were reached."

For conditions where the temperature of a part cannot be obtained until the machine is shut down (for example, the resistance of the stator windings of a polyphase generator) the rules make the following provision:

> "Whenever a sufficient time has elapsed between the instant of shut-down and the time of the final temperature measurement, to permit the temperature to fall, suitable corrections shall be applied, so as to obtain as nearly as practicable the temperature at the instant of shut-down. This can sometimes be approximately effected by plotting a curve, with temperature readings as ordinates and time as abscissas, and extrapolating back to the instant of shut-down. In other instances, acceptable correction factors can be applied."

As to these *acceptable correction factors*, it may be said that from the many test results available on the records of manufacturers, it will be known generally that, for a particular type of machine, the cooling of the hottest-spot will be approximately at some particular rate per minute for the average of the first three or four minutes after shut-down. At the time of the acceptance tests, both parties to the transaction usually will readily arrive at a satisfactory agreement that for any particular machine under test a certain number of degrees shall be added to the temperature determined by resistance measurements made within a given number of minutes of shut-down. It rarely would be worth while to encumber the specifications and guarantees with a clause setting forth the amount of this correction, but it is simple enough to do so when it is considered that it is of sufficient consequence to have the amount definitely stipulated.

Embedded Temperature Detectors

The American rules (Section 355) require that for the purposes of acceptance tests the temperatures of the stators of large generators shall be determined by means of embedded temperature detectors, several of which shall be employed. These are to be so located as to disclose as nearly as possible the temperature of the hottest spot existing anywhere in the machine. These embedded temperature detectors consist of thermocouples or resistance coils. An extensively employed design of embedded temperature detector of the resistance type has a length of about 10 in. (25.4 cm.), and, at a temperature of 25 deg., its resistance is just 10 ohms. In Fig. 1 are shown sections through slots for two types of slot windings usually designated two-layer and single-layer windings respectively. It is required in Sections 353 and 354 of the American rules that "a liberal number" of temperature detectors shall be placed in the locations designated in Fig. 1 as *A* and *B*, for two-layer windings, and *B* and *C* for one-layer windings.

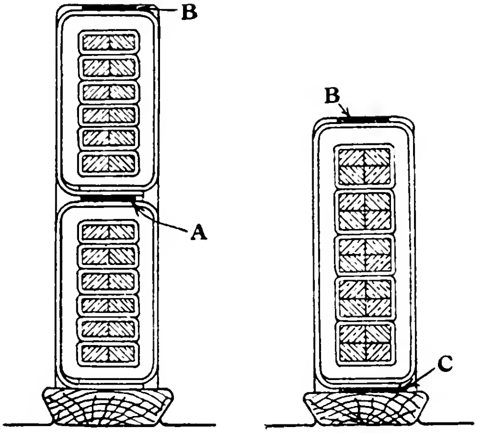

Fig. 1. Location of Temperature Detectors in Single and Two-layer Windings as Required by A.I.E.E. Standardization Rules

Hottest-Spot Temperature

The rules stipulate that for machines with two-layer windings the hottest-spot temperature shall be considered to be 5 deg. greater than the highest reading obtained by any of the embedded temperature detectors; and that in single-layer windings the hottest spot temperature shall be that obtained by adding to the highest reading 10 deg., plus 1 deg.

per 1000 volts above 5000 volts of terminal pressure.

These corrections are brought together in Table III.

For two-layer windings.	Add 5 degrees to the highest reading.
For single-layer windings for 5000 volts or less.	Add 10 degrees to the highest reading.
For single-layer windings for more than 5000 volts.	Add to the highest reading 10 deg., plus 1 deg. for every kilovolt by which the voltage between the terminals of the machine exceeds 5 kv.

Thus for a three-phase machine with an 11,000-volt single-layer winding, the correction to be added to the maximum observable temperature in estimating the hottest-spot temperature is 16 deg.

With rare exceptions the hottest-spot results derived from the indications of the embedded temperature detectors are the most satisfactory. It is, however, quite possible that the temperature rise derived from measurements of the resistance of the stator windings at the conclusion of the heat runs may be greater than the temperature rise determined from the embedded detectors. Consequently it is provided in Section 352 of the American rules that when the embedded-detector method is used, the results shall, *when required*, be checked by the results obtained from measurements of the resistance of the stator windings, and "the hottest-spot shall then be taken to be the highest value by either method, the required correction factors being applied in each case." By correction factor is meant the number of degrees which shall be added to the observed temperature to obtain the hottest-spot temperature. For the resistance method the correction factor is 10 deg.

As regards the so-called correction factors* established in the American rules, it would appear that the hottest-spot temperature determined by adding to the observable temperature the stipulated correction factor shall constitute the criterion and that a machine could not be rejected on the ground that other evidence demonstrated that a still-greater temperature existed at some point of the winding. For example, for purely research purposes it would be practicable to locate temperature detectors actually against the copper of a high-pressure winding. In some special cases such temperature detectors might disclose temperatures exceeding those obtained by adding the conventional correction factors to the observable temperatures. Since the conventional correction factors have been established with every intention that they shall be liberal and since definiteness in contracts is essential, the hottest-spot temperatures obtained by complying with the methods approved in the American rules should be taken as final, irrespective of evidence of the existence of higher temperatures. It is believed that it would be only in exceedingly rare instances that higher temperatures could be found and that they would exceed the conventional hottest-spot temperatures by immaterial amounts. However, in so far as the rules on this point may be obscure in the least, it would seem to be very important to make their intention unmistakably evident.

The use of embedded temperature detectors has been demonstrated to be of great advantage. When only required for the acceptance tests the leads from the detectors may, at the conclusion of the tests, be cut off, and the detectors abandoned. But it is of decided advantage, in the service operation of large generators, to be able, at any time, to ascertain the internal temperatures from the direct readings of switchboard instruments. This practice is now very customary.

It has been mentioned that the hottest-spot temperatures indicated by embedded detectors may in rare instances be less than the hottest-spot temperatures indicated by measurements of the resistance of the stator winding of a generator. Moreover, since the resistance measurements of a winding only disclose *average* temperatures, occasions will arise where a suitably-located surface thermometer may indicate a temperature in excess of that indicated by the resistance measurements. A liberal number of surface thermometers ought, therefore, also to be employed when making heat runs. The author is of the opinion that one of the chief advantages of embedded temperature detectors of the resistance type relates to the ability to employ a resistance of a magnitude which can be measured readily with accuracy, and to the reliability with which its resistance at any time can be taken to indicate a definite temperature. The temperature rise obtained from the increase in the resistance of an armature or field winding would be of distinctly greater value were it practicable to know

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* These are not factors. Some better designation should be substituted.

accurately the temperature of the winding on the occasion of the measurement of the cold resistance. It is rarely practicable to incur the delay before commencing a heat run which would be necessary to ensure that an armature or field winding is within a couple of degrees of the surrounding temperature. Often when it is assumed that the winding's temperature is substantially identical with that of the surrounding air, there is actually a difference of over five degrees and consequently the measured cold resistance is associated with a temperature over five degrees different from its actual temperature, and a corresponding error is incurred in deducing from its hot resistance the temperature of the winding at the end of the heat run.

Some such plan as that set forth in the following clause, if the conditions of practise should permit of its adoption, would provide a way out of the difficulty and much increase the value of temperature determinations by measurements of the resistance of the main windings:

> "In order to avoid protracted delays in the testing of a machine, in bringing the temperature of its windings into accord with the ambient temperatures, the resistance of the windings of a machine, reduced to 40 deg., should be made a matter of factory record for all machines subject to temperature measurement by resistance under these rules."

In general, the author's opinion in this matter is that the methods of obtaining temperatures by surface thermometers and by measurements of the resistances of the main windings should not be discarded in favor of the newer method by embedded temperature detectors, but should continue to be employed *in addition thereto.* Indeed the careful tests made on a large machine, which are described later, showed, as may be seen from Table XII, that in two out of the three heat runs the temperature rise of the hottest spot as deduced from measurements of the resistance of the stator windings was greater than the temperature rise of the hottest spot deduced from the readings of temperature detectors, and that in the third heat run the temperature rise of the hottest spot was the same by both methods. Furthermore the readings of mercury thermometers placed against appropriate parts of the surface of the rotor winding disclosed higher temperatures than were obtained by means of measurements of the resistance of the rotor winding. The results in these tests were especially reliable since the cold resistances were measured with the greatest care after the machine had been standing idle for two days, so that its windings at the time of measuring their resistances before beginning the heat run should be at the same temperature as the surrounding air.

A recommendation to take advantage of all three methods (Method I, surface thermometers; Method II, main winding resistance measurements; and Method III, embedded detectors) might at first sight be condemned as impracticable on all except large, valuable machines, since the expense of making such thorough tests would be prohibitive. Were it necessary to make these measurements on each and every machine, such a criticism would be well founded. The author holds the opinion which, in another publication, he has expressed as follows:

> "Although the rules contain no explicit statement to that effect, it may doubtless be understood that it is not intended that a test by the prescribed method need necessarily be made upon every individual machine comprised in a transaction. The simplest method, as above explained, is usually Method I, and in the interest of avoiding needless expense, it should often be practicable to arrange for a judicious employment of Method I for most of the machines of a given size, employing Method II or III, as the case may be, on a few of the machines, and thereby arriving at a fact or by which the results obtained by Method I require to be multiplied in order to arrive at the results which *would have been obtained* on those particular machines had Methods II and III been employed. In other words, it should not be concluded that the less simple measurements will necessarily be made on every machine, but rather that conclusive evidence shall be provided to insure that *had the measurements been made* the temperature would have been within the required limits."

Further Consideration of the Hottest-Spot Temperature. The American rules lay emphasis on the hottest-spot temperature. Limiting approved values for the hottest-spot temperatures are set forth. The limiting values depend chiefly upon the class of insulating material employed. Insulating materials are divided into three classes, *A*, *B*, and *C*. These classes are defined in the American and British rules as presented in Table IV.

No limit is placed upon the temperature of Class C insulation. The permissible temperatures and temperature rises of electrical machinery at present are based chiefly upon the characteristics of Class A and Class B insulations. The British and American rules agree in adopting 105 deg. and 125 deg. for the limiting hottest-spot temperatures for these two classes of insulations. Based on extensive tests, it is the opinion of many engineers that 105 deg. for Class A insulations and 150 deg. for Class B insulations are both thoroughly conservative limits, when all the designing and manufacturing processes are carried out with due regard for numerous important details. But, failing the availability and application of skill and experience, even much lower temperature limits for Class A and Class B insulations will not ensure a satisfactory product. It is difficult to see how any Standardization rules can afford the necessary assurance in this respect. The successful withstanding of acceptance tests does not necessarily constitute evidence that the insulations will endure the stipulated temperatures (and other deteriorating influences which vary from instance to instance), for a satisfactory term of years. Fortunately the manufacturer's interest in the success and reputation of his product usually affords the required assurance. Indeed there is usually a strong tendency on the part of the manufacturer to refrain from taking advantage of temperature limits of established practicability until years of study by tests on samples and on experimental machines have established beyond all reasonable doubt the appropriateness of the higher limits. It is, however, important to the industry to take advantage of higher limiting temperatures as soon as a reasonable amount of experience is gained, since this permits of reduced capital costs for machinery and rarely affects predudicially the working costs except where the action is premature. The adoption of new limits by bodies of the standing of the American and British Standard Committees is ample proof that the evidence in the case has been carefully sifted and that the time is ripe for the modification. While the temperature limits for Class A and Class B insulations can both be safely exceeded for short periods, it is in the interests of reserving reasonable factors of safety to establish them (as is expressly emphasized in the American and British rules) as limits which shall *never* be exceeded. In the American and British rules the limit at present standardized for Class B insulations is 125 deg. but there is a well-developed opinion in America that, since there is now a great deal of experience on which to base the action, the limit for Class B insulations could with advantage be raised to 150 deg.

TABLE IV

Class of insulation	Description of insulating material
A	Cotton, silk, paper and similar materials when so treated or impregnated as to increase the thermal limit, or material permanently immersed in oil; also enamelled wire.*
B	Mica, asbestos and other materials capable of resisting high temperatures, in which any Class A material or binder is used for structural purposes only, and may be destroyed without impairing† the insulating or mechanical qualities of the insulation.
C	Fireproof and refractory materials, such as pure mica, porcelain, quartz, etc.

*For cotton, silk, paper and similar material, when not treated, impregnated or immersed in oil, the highest temperatures shall be 10 deg. lower than the limits given above for Class A.

†The word impair is here used in the sense of causing any change which would disqualify the insulation for continuous service.

Intensified Aging of Insulations

Reference has been made to the impossibility of framing rules to ensure that the insulations employed have satisfactory longevity. Naturally, however, the aging of insulating materials is a matter of great importance to the manufacturer. The point of most importance to decide is that of the temperature which can be withstood for 10 to 20 years by an insulating material. It would naturally be supposed that subjection to super-temperatures for brief periods would permit of forming an opinion regarding the life corresponding to lower temperatures. To a certain extent brief tests for short periods at super-temperatures are useful, but conclusions drawn therefrom must, at the present state of affairs, be regarded as only of the nature of very rough evidence. For some Class A insulations, values of the order shown in Table V are indicated.

TABLE V

Temperatures which can be withstood successfully, not only electrically but physically, by approved Class A insulations:

For seconds	250 degrees
For minutes	200 degrees
For hours	170 degrees
For days	150 degrees
For weeks	130 degrees
For months	115 degrees
For years	105 degrees

A very slight modification in the composition or construction of the insulation, however, might completely disqualify it for withstanding any considerable super-temperatures, even for brief periods. Tests on various approved Class B insulations lead to values which, while quantitatively higher by a matter of some 50 deg., are qualitatively very similar.

Reasonable factors of safety must, however, be reserved. This is realized by the American, British and German Standards Committees and no recognition whatsoever is extended to the ability of insulations to successfully withstand super-temperatures for brief periods. Thus in the American rules we have Section 305 A, to the following effect:

> Section 305 A. Whatever may be the ambient temperature when the machine is in service, the limits of the maximum observable temperature and of temperature rise specified in the rules should not be exceeded in service; for, if the maximum temperature be exceeded, the insulation may be endangered, and if the rise be exceeded the excess load may lead to injury, by exceeding limits other than those of temperature; such as commutation, stalling load and mechanical strength. For similar reasons, load in excess of the rating should not be taken from a machine.

It is thus clear that in the interest of securing a liberal margin of safety we must forego rigorously the temptation to expose the insulation of machinery, even for brief periods, to temperatures in excess of the limits approved in the American rules.

This practice is in striking contrast to that underlying the older Standardization rules which authorized higher temperatures for short periods. Probably the credit for the modern departure belongs to the German Standards Committee, which, for some years, has employed the plan of permitting overloads with the same temperature limits as for the rated load. Table VI presents clauses from the German standardization rules.

TABLE VI

Overloading. With the limitation that the overloads only are carried for so short a time, or only occur under such temperature conditions of the machines and transformers that the highest permissible temperatures are not thereby exceeded, machines and transformers must be capable of carrying the following overloads:

Generators Motors Synchronous converters and motor-generators Transformers	25 per cent during one-half hour
Motors Synchronous converters and motor-generators Transformers	40 per cent for 3 minutes

Section 305 A of the American rules, however, contains the restriction that "loads in excess of the rating shall not be taken from the machine," lest limits other than those of temperature, such as commutation, stalling load and mechanical strength should be exceeded.

Nevertheless the American rules provide for the case where a machine is required to carry very heavy loads for brief periods. Such a case is met by giving a machine more than one rating. Thus amongst the machinery recently supplied to the Chicago, Milwaukee and St. Paul Railway are some couple of dozen 2000-kw. motor-generator sets for use in substations. These sets have the following three ratings:

Continuous rating	2000 kilowatts
Two-hour rating	3000 "
Five-minute rating	6000 "

The mechanical strength and the commutating requirements for the five-minute rating are far in excess of those for the continuous rating. But the temperature attained with the continuous rating exceeds that attained with the five-minute rating.

This plan may be employed whenever it is necessary to provide for peaks of load, as in the case, for instance, of crane motors. Knowing the typical duty cycle, we may prescribe a short-time rating sufficient to ensure that the motor shall have ample mechanical strength as well as sufficient margin in the matter of commutation, and that it shall not stall with the greatest load which it ever will be called upon to carry. Knowing also the average load, we may prescribe a continuous rating which will ensure that approved temperatures shall never be exceeded. Two ratings should usually suffice, a continuous rating to ensure the non-exceeding of approved temperatures and a short-time rating to ensure the required capacity for the intermittently occurring peaks of load as regards commutation, stalling load and mechanical strength.

While we owe the conception of modern ratings to the German Standards Committee, as already stated, the way in which the American Committee has fitted the conception to the requirements of practice would appear to be distinctly excellent.

Low-Temperature Circulating Air

For small machines built in large quantities for stock, the ultimate destination is unknown. In normal times a motor driving a printing press in Bombay or Pekin or Moscow is about equally likely to have been built in Berlin or Manchester or Milan or Schenectady. Even if the ultimate destination may be ascertained it is not practicable to countenance departures from the strict letter of the Standardization Rules in the case of small machinery.

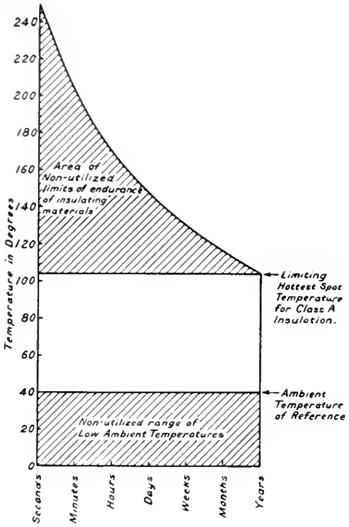


Fig. 2. Chart Showing Temperature Limits for Insulation as Established by American and British Standardization Rules

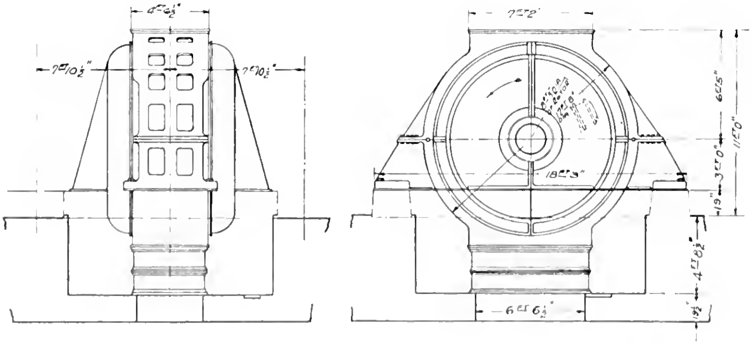


Fig. 3. 12-Pole, 8750-Kv-a., 6600-Volt, 500-R.P.M., 3-Phase Generator. Curves of Figs. 4 to 10 were Derived from Tests made on this Machine

But for large machines worth many thousands of dollars apiece and operated under skilled supervision, it would be wasteful to forego any economic advantage compatible with sound engineering practice. As a concrete case let us assume that a large operating company is purchasing a 20,000-kv-a. generator which will be cooled by circulating through it every minute 50,000 cu. ft. (1416.4 cu. m.) of air taken from outside the building. In the summer, on days when the humidity is high, the circulating air's temperature, even after passing through the air washer, may sometimes be nearly 40 deg. But the nature of the load may be such that the station's peak in summer is half of its mid-winter peak, or even much less. It may be practicable to rely on 15-deg. circulating air for the mid-winter peak. For the limiting temperature for Class A insulation (105 deg.), this represents 90 deg. rise as against 65 deg. rise in the summer. By temperature coils in location A of Fig. 1, the observable rises are:

Summer—(105—5—40) = 60 deg.
Winter— (105—5—15) = 85 deg.

Consequently, if the machine has ample margin as regards mechanical strength and if the prime mover is adequate, advantage ought to be taken of its increased capacity in winter, which would be of the order of 25 or 30 per cent.

Three such 20,000-kv-a. machines, operated on the basis of loading them up to their capacity as indicated by embedded temperature detectors, would do the work of four machines operated in strict accordance with Section 305 A of the American rules, and the saving in the capital component of the total cost of manufacturing electricity would be quite appreciable.

Such a case would be met by some such clause as follows:

"Contractors will be required to guarantee that the machine shall be in all respects in strict accordance with the (October, 1916) American rules with the following exception:

Exception. The machine shall have ample mechanical strength and shall be in all other respects adequate to carry the increased load which with a circulating-air temperature of 15 deg. may be carried without occasioning hottest-spot temperatures in excess of those set forth in the American rules as approved for the class of insulation employed. The embedded-temperature-detector method supplemented by measurements of the resistances of the main windings and by surface thermometer measurements shall be employed for determining the temperature attained.

Margin of Safety

Adherence to the recommendations in the American and British Standardization Rules ensure very liberal margins of safety. This is apparent from Fig. 2 in which the shaded areas indicate respectively for machines with Class A insulation the temperature ranges above the permitted hottest-spot temperature of 105 deg. which are available but which are not allowed, and the temperatures below the reference ambient temperature which are liable to exist in most locations during nearly all seasons of the year. The unshaded area represents the temperature range, utilization of which is approved in the American rules. There is no disposition to suggest encroachment upon these liberal margins of safety; they are simply in accordance with the best and most valued traditions of the engineering profession.

Equivalent Tests

We now arrive at a matter with which the Standardization Rules do not yet deal, at any rate with any approach to thoroughness. The deficiency relates to indicating the nature of the tests which shall be regarded as satisfactory criteria for determining the temperature rise. Several methods are in vogue, but for testing a single large machine no method in common use is thoroughly satisfactory. Doubtless the matter will be given very careful consideration by the Standards Committees before rules are adopted.

Mention has already been made of an 8750-kv-a. 500-rev. per min., 50-cycle, three-phase generator which was recently tested. This machine was of the design indicated in Fig. 3. Advantage was taken of the opportunity to employ for the heat test a method which may be termed a cyclic heat run. It appears to be especially well adapted to a machine of the kind tested. The test consisted in operating the machine for alternate 15-minute periods on open circuit with super-normal pressure and on short circuit with super-normal current. The degree of the super-normality was so selected as to occasion in each complete half-hour cycle, as nearly as practicable, the conversion into heat of the same amount of energy in each part of the machine as would be occasioned in each part were the machine to deliver the actual load which it was the object of the test to investigate. The pressure of the machine was 6600 volts between terminals, (3800 volts per phase) and heat tests were required at each of the three different loads set forth in Table VII.

TABLE VII

Designation of heat run	Kilovolt amperes	Power factor	Current per phase	Terminal pressure
I	7,000	1.00	614 amp.	6600 volts
II	8,750	0.80	766 amp.	6600 volts
III	10,937	0.80	960 amp.	6600 volts

For each of the three heat runs it was desired to provide heating conditions equivalent to the loads in Table VII. This was accomplished by cyclic tests under the conditions named in Table VIII.

TABLE VIII

Designation of heat run	I	II	III
For the short-circuit periods			
Rotor excitation (amperes)	119	148	185
75-deg. rotor I^2R loss (kw.)	5.1	7.9	12.4
Stator current (amperes)	854	1070	1344
75-deg. stator I^2R loss (kw.)	24.0	37.8	60.0
Stray load loss (kw.)	18.0	25.5	42.3
For the open-circuit periods			
Rotor excitation (amperes)	327	327	324
75-deg. rotor I^2R loss (kw.)	38.5	38.5	38.0
Terminal pressure (volts) . .	8420	8420	8350
Core loss (kw.)	270	270	260

Before these values were determined upon, curves of no-load excitation, short-circuit excitation, core loss and stray load-loss had already been taken. These are reproduced in Figs. 4, 5, and 7. The resistances of the windings had also been measured and reduced to the 75-deg. reference values. The resistances were:

Stator winding per phase. . . . 0.0110 ohm
Rotor winding . . . . 0.360 ohm

The value of the internal windage was estimated to be 30.0 kw.

The extent of the equivalence to the actual losses for the three loads is seen from the data in Table IX.

TABLE IX

	Losses during the: Open-circuit half of the cycle	Losses during the: Short-circuit half of the cycle	Average losses during cyclic test	Losses corresponding to actua load of 7000 kv-a at P.F. = 1.00
Heat Run I				
Stator I^2R	0	24.0	12.0	12.5
Rotor I^2R	38.5	5.1	21.8	17.8
Core loss	270.0	0	135.0	119.0
Stray load loss	0	18.0	9.0	11.5
Internal windage	30.0	30.0	30.0	30.0
Total loss =	......	......	170.8 kw.	190.8 kw.
Heat Run II				=80
Stator I^2R	0	37.8	18.9	19.4
Rotor I^2R	38.5	7.9	23.2	27.9
Core loss	270.0	0	135.0	119.5
Stray load loss	0	25.5	12.8	15.3
Internal windage	30.0	30.0	30.0	30.0
Total loss =	......	......	210.9 kw.	212.1 kw.
Heat Run III				=80
Stator I^2R	0	60.0	30.0	30.5
Rotor I^2R	38.0	12.4	25.2	32.6
Core loss	260.0	0	130.0	120.0
Stray load loss	0	42.3	21.2	21.5
Internal windage	30.0	30.0	30.0	30.0
Total loss =	......	......	236.4 kw.	234.6 kw.

The temperatures of the circulating air were determined at the inlet and outlet from the mean of the readings of several thermometers. The results and the "Loss per Degree Air Rise" are given in Table X.

TABLE X

Designation of heat run	Total loss in machine	Air rise in machine	Loss per degree air rise
I	208 kw.	12.4 deg.	168 kw.
II	220 kw.	13.0 deg.	16.9 kw.
III	236 kw.	15.5 deg.	15.3 kw.
Average value for loss per degree air rise			16.3 kw.

It can fairly be assumed for this particular design that the heat corresponding to 90 per cent of the loss in the machine is carried off by the circulating air, the remaining 10 per cent being dissipated from the surfaces of the machine.

Therefore we have, as carried away by the circulating air:

$$16.3 \times 0.90 = 14.7 \text{ kw. per degree rise.}$$

One kilowatt raises the temperature of 1000 cu. ft. (28.3 cu. m.) of air per minute by 1.78 deg. or:

A temperature rise of 1 deg. will be occasioned by a loss of 1 kilowatt for a circulation of 1780 cu. ft. (50.4 cu. m.) per min.

TABLE XI

Designation of heat run	I	II	III
Total loss in machine	208 kw.	220 kw.	236 kw.
Temperature rises by embedded detectors			
Location–A.	33.0 deg.	36.0 deg.	41.5 deg.
Location–B.	26.3 deg.	28.8 deg.	29.3 deg.
Mean of A & B.	29.7 deg.	32.4 deg.	35.4 deg.
Loss per degree of mean rise	7.00 kw.	6.80 kw.	6.70 kw.
Average for the three heat runs for the loss per deg. of mean rise	6.83 kilowatts		

TABLE XII

Designation of heat run	I	II	III
Kilovolt amperes	7000	8750	10937
Power factor	1.00	0.80	0.80
Terminal pressure (volts)	6600	6600	6600
Current (amperes)	614	766	960
Maximum observed rise by temperature detectors	33.0	36.0	41.5
Observed by temperature detectors			
In location "A"	33.0	36.0	41.5
In location "B"	26.3	28.8	29.3
Mean of A & B	29.7	32.4	35.4
Maximum observed rise of rotor winding	19.0	19.0	20.5
Rise stator winding by resistance	28.0	34.5	42.0
Air rise in machine	12.4	13.0	15.5
Deduced hottest-spot temperature corresponding to ambient temperature of reference	78.0	84.5	92.0

Consequently we have:

Quantity of circulating air = 14.7 × 1780 = 26,200 cu. ft. per min. (742.2 cu. m.).

In Table XI are brought together for the three heat runs the results obtained by the embedded temperature detectors in the locations designated by A and B in Fig. 1, and also the results for the mean of A and B. It is to be noted that by mean rise by embedded detectors is meant the mean of the two maxima, the one being the maximum for location A and the other being the maximum for location B.

The results for these three heat runs by the cyclic method deviate from the average result by less than 2 per cent in the case of the "Loss per Degree Mean Rise by Embedded Detectors" and by only 6 per cent in the case of the "Loss per Degree Air Rise in Machine." These values speak well for the accuracy of the cyclic test.

These and the temperature rises obtained at other parts are brought together in Table XII.

It is interesting to note that in heat runs II and III the hottest-spot temperature corresponds to the observations of the rise of

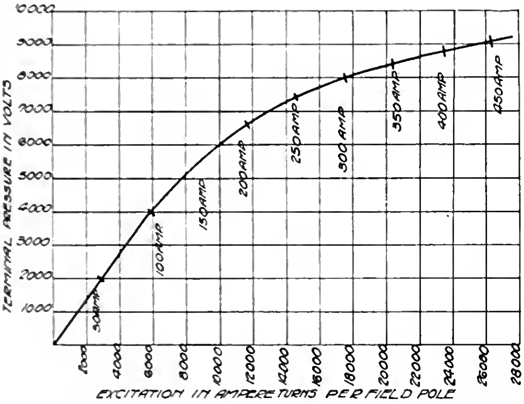


Fig. 4. No Load Saturation Curve of Generator

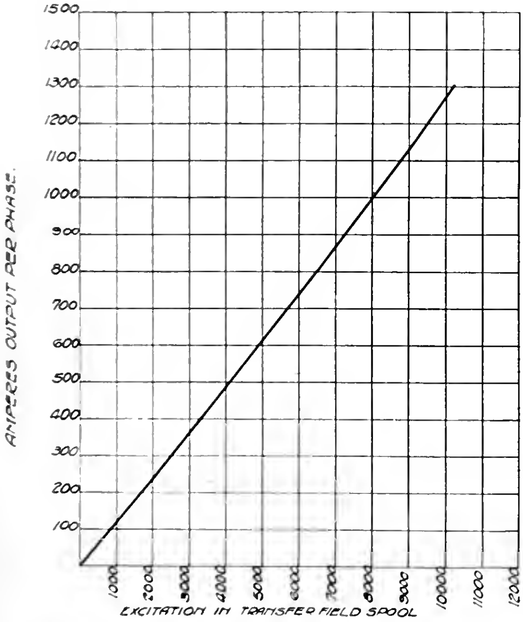


Fig. 5. Short Circuit Excitation Curve of Generator

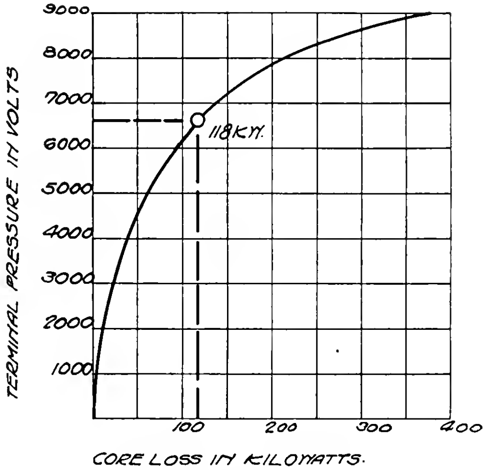


Fig. 6. Core Loss of Generator

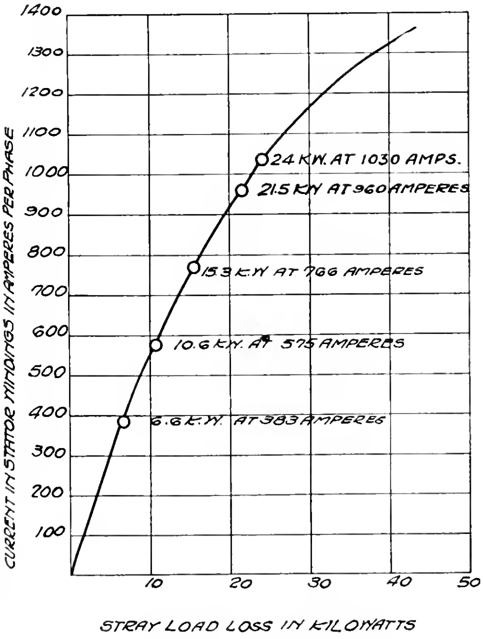


Fig. 7. Stray Load Loss of Generator

the stator winding by resistance and not to the results obtained by the embedded detectors. The reason for this is that the Standardization Rules require 10 deg. to be added to the observable temperature as determined by the resistance method and require 5 deg. to be added to the observable temperature as determined from the highest reading of any of the embedded detectors. Such results may occur in machines so designed that no part of the stator winding is much hotter or cooler than the average temperature of the stator windings.

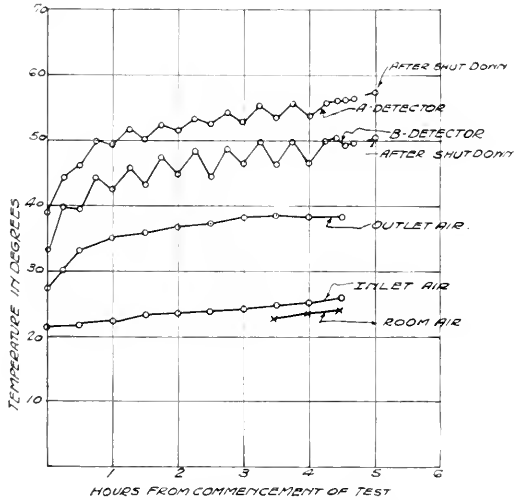


Fig. 8. Temperature-Time Curves for Cyclic Heat Run, Equivalent to 7000 Kv-a. at Unity Power-factor

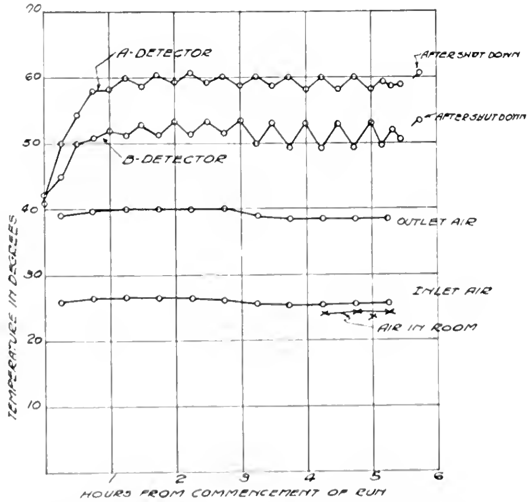


Fig. 9. Temperature-Time Curves for Cyclic Heat Run, Equivalent to 8750 Kv-a. at 0.8 Power-factor

In Figs. 8, 9 and 10 are given curves showing the progress of the heating during the cyclic tests.

It should be understood that this article has been chiefly confined to a discussion of those parts of the temperature sections of the Rules which deal with rotating machinery and that even in this small portion of the Rules there are various matters of interest and importance which have not been considered. On the subject of transformers there are further matters of importance in the temperature sections. The sections on dielectric tests and those on efficiency and regulation present features of at least equal importance as regards both rotating machinery and transformers.

APPENDIX

A comparison of the temperature limits in the American and the British rules for electrical machinery.

In the following collection of Tables the three methods of determining the temperature are designated I, II and III, following the arrangement in the American rules. Briefly these methods are defined in the American rules as given in Table XIII.

Limits of observable temperature for Class A and Class B materials when method III is used.

When Method III is used, the limits set forth in the American and the British Rules

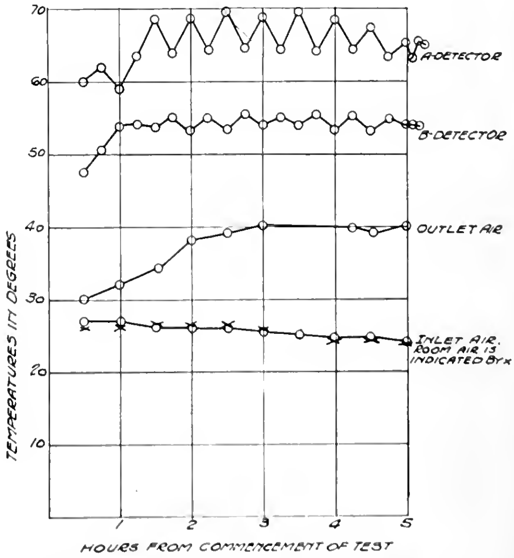


Fig. 10. Temperature Curves for Cyclic Heat Run, Equivalent to 10,937 Kv-a. at 0.8 Power-factor

are identical and are set forth in Table XVI for machines of various voltages.

NOTE: Method III, (Defined and discussed in sections 352 to 350 of the A. I. E. E. Rules) is, in the A. I. E. E. Rules mandatory for all stators of machines (exclusive of induction regulators) with cores having a width of 50 cm. (20 inches) and over, and also for all machines of 5000 volts and over, if of over 500 kv-a., regardless of core width. The method is not mandatory in the British Rules but section 63 of those rules states that: "When so specified with the inquiry, embedded temperature detectors shall be employed in the case of a machine of over 3000 kilowatts if wound for a rated pressure exceeding 3300 volts."

TABLE XIII

Designating number of method	Designating name of method	Description of method
I	Thermometer method	This method consists in the determination of the temperature, by mercury or alcohol thermometers, by resistance thermometers, or by thermo-couples, any of these instruments being applied to the hottest accessible part of the completed machine, as distinguished from the thermo-couples or resistance coils embedded in the machine as described under Method No. III.
II	Resistance method	This method consists in the measurement of the temperature of windings by their increase in resistance, corrected to the instant of shut-down, when necessary. In the application of this method, thermometer measurements shall also be made whenever practicable without disassembling the machine in order to increase the probability of revealing the highest observable temperature. Whichever measurement yields the higher temperature, that temperature shall be taken as the "highest observable" temperature.
III	Embedded temperature detector method	This method consists in the use of thermo-couples or resistance temperature detectors, located as nearly as possible at the estimated hottest spot. When Method No. III is used, it shall, when required, be checked by Method No. II; the hottest spot shall then be taken to be the highest value by either method, the required correction factors being applied in each case.

TABLE XVI

Voltage of Machine	PERMISSIBLE LIMITS OF TEMPERATURE AS MEASURED BY EMBEDDED TEMPERATURE DETECTORS			
	Temperature detectors located between top and bottom coil-sides in two-layer windings		Temperature detectors located between coil-side and core and between coil side and wedge	
	Class A	Class B	Class A	Class B
Not over 5000 volts	100 degrees	120 degrees	95 degrees	115 degrees
Between 5000 & 6000 volts	100 degrees	120 degrees	94 degrees	114 degrees
Between 6000 & 7000 volts	100 degrees	120 degrees	93 degrees	113 degrees
Between 7000 & 8000 volts	100 degrees	120 degrees	92 degrees	112 degrees
Between 8000 & 9000 volts	100 degrees	120 degrees	91 degrees	111 degrees
Between 9000 & 10000 volts	100 degrees	120 degrees	90 degrees	110 degrees
Between 10000 & 11000 volts	100 degrees	120 degrees	89 degrees	109 degrees
Between 11000 & 12000 volts	100 degrees	120 degrees	88 degrees	108 degrees

(Tables XIV and XV are shown on the two following pages.)

TABLE XIV

LIMITS OF OBSERVABLE TEMPERATURE FOR: { "CLASS A" MATERIAL; SHORT-CIRCUITED WINDINGS, TRANSFORMERS, INDUCTION REGULATORS, IRON CORES } WHEN METHODS I AND II ARE EMPLOYED

BROAD DESCRIPTION OF THE PART OF THE MACHINE	BRITISH DESIGNATING NUMBERS OF THE ITEMS (from p. 18 of the British Rules)	DETAIL DESCRIPTION OF THE PART OF THE MACHINE		LIMITS OF OBSERVABLE TEMPERATURE			
				METHOD I		METHOD II	
				BRITISH RULES	A. I. E. E. RULES	BRITISH RULES	A. I. E. E. RULES
Stationary and rotating d-c. field coils	1 and 2	Shunt or separately excited field coils		Method I is not allowed	90 deg.	95 deg.	95 deg.
		Series field coils and compensating and commutating coils		95 deg.	90 deg.	Method II is not allowed	Method II is not allowed
		Bare windings, such as an edgewise strip conductor or cast copper windings.		Makes no specific provision for such windings	100 deg.	Makes no specific provision for such windings	95 deg
Rotating armatures with commutators	4 and 5	Rotating armatures with commutators		90 deg.	90 deg.	Method II is not allowed	95 deg
A-c. windings in slots (of the ratings for which method III is not required)	7 and 8	Stator (induced winding) of synchronous motor or alternator	For 5000 volts and above	95 deg. minus 1½ deg. for each 1000 volts or part thereof by which the rated pressure exceeds 5000 volts Method I is only allowed when method II is inapplicable	90 deg.	95 deg. minus 1½ deg. for each 1000 volts or part thereof by which the rated pressure exceeds 5000 volts	95 deg.
			For less than 5000 volts	90 deg. when method II is practicable. 95 deg. when method II is impracticable	90 deg.	95 deg.	95 deg.
		Stator and rotor of non-synchronousmotor or alternators	For 5000 volts and above	95 deg. minus 1½ deg. for each 1000 volts or part thereof by which the rated pressure exceeds 5000 volts Method I is only allowed when method II is inapplicable	90 deg.	95 deg. minus 1½ deg. for each 1000 volts or part thereof by which the rated pressure exceeds 5000 volts	95 deg.
			For less than 5000 volts	90 deg. when method II is practicable. 95 deg. when method II is impracticable	90 deg.	95 deg.	95 deg
Short - circuited windings	10	Insulated		100 deg.	"The temperature rise may be of any value such as will not occasion mechanical injury to the machine" (see section 388)	Method II is not applicable to short-circuited windings	
	11	Uninsulated		100 deg.			
Air-cooled transformers	14 and 15			Method I is not allowed		95 deg.	95 deg.
Oil-immersed transformer	17	Windings		Method I is not allowed		95 deg.	Oil immersed without water cooling 95 deg. Oil immersed with water cooling 80 deg.
	18	Oil		90 deg.	90 deg.	Method II is not applicable	
Induction regulators				No specific provision for induction regulators in British rules	Method I is not allowed	No specific provision for induction regulators in British rules	Temperature rules for induction regulators same as for transformers
Iron cores	19	For British rules see their sections 42 and 43. For A. I. E. E. rules see section 391					

NOTE.—Both the British and American rules state that for cotton, silk, paper and similar materials when neither impregnated nor immersed in oil, the temperature limits shall be 10 deg. C below the limits fixed for class A materials.

TABLE XV

LIMITS OF OBSERVABLE TEMPERATURE FOR: { "CLASS B" MATERIALS AND FOR COMMUTATORS AND SLIP RINGS } WHEN METHODS I AND II ARE EMPLOYED.

BROAD DESCRIPTION OF THE PART OF THE MACHINE	BRITISH DESIGNATING NUMBERS OF THE ITEMS. (From p. 18 of the British Rules.)	DETAIL DESCRIPTION OF THE PART OF THE MACHINE		LIMITS OF OBSERVABLE TEMPERATURE			
				METHOD I		METHOD II	
				BRITISH RULES	A. I. E. E. RULES	BRITISH RULES	A. I. E. E. RULES
Stationary and rotating d-c. field coils	3	Shunt or separately excited field coils.		Method I is not allowed	110 deg.	115 deg.	115 deg.
		Series field coils and compensating and commutating coils.		115 deg.	110 deg.	Method II is not allowed	Method II is not allowed
		Bare windings, such as an edgewise strip conductor, or cast copper windings		Makes no specific provision for such windings	120 deg.	Makes no specific provision for such windings	115 deg.
Rotating armatures with commutators	6	Rotating armatures with commutators		110 deg.	110 deg.	Method II is not allowed	115 deg.
A-c. windings in slots (of the ratings for which method III is not required	9	Stator (induced winding) of synchronous motor or alternator	For 5000 volts and above	115 deg. minus 1½ deg. for each 1000 volts or part thereof by which the rated pressure exceeds 5000 volts (method I is only allowed when method II is inapplicable)	110 deg.	115 deg. minus 1½ deg. for each 1000 volts or part thereof by which the rated pressure exceeds 5000 volts	115 deg.
			For less than 5000 volts	110 deg. when method II is practicable. 115 deg. when method II is impracticable	110 deg.	115 deg.	115 deg.
		Stator and rotor of non-synchronous motor or alternator	For 5000 volts and above	115 deg. minus 1½ deg. for each 1000 volts or part thereof by which the rated pressure exceeds 5000 volts (method I is only allowed when method II is inapplicable	110 deg.	115 deg .minus 1½ deg. for each 1000 volts or part thereof by which the rated pressure exceeds 5000 volts	115 deg.
			For less than 5000 volts	110 deg. when method II is practicable. 115 deg. when method II is impracticable	110 deg.	115 deg.	115 deg.
Commutators	12			90 deg.	See sections 390 and 347	Method II is not applicable to commutators	
Slip-rings	13			90 deg.	See sections 389 and 347	Method II is not applicable to slip-rings	
Air-cooled transformers	16			Method I is not allowed		115 deg.	115 deg.

TRANSPORTATION OF THE EQUIPMENT FOR A HYDRO-ELECTRIC PLANT FOR AN INLAND SOUTH AMERICAN TOWN

By E. F. Colyer

Foreign Department, General Electric Company

The transportation of power-house equipment over average country roads requires the exercise of considerable ingenuity; but when this task is undertaken over mountainous sections of country, where the roads are nothing more than rough trails that make the use of wheeled vehicles impossible, the problem becomes exceedingly difficult. The heavier parts of the equipment referred to in this article were secured to bamboo poles roped together, and the rack thus constructed was carried on the shoulders of natives, allowing approximately twenty-five pounds per man.—Editor.

Some interesting details in the installation of a small lighting plant for the Municipality of Cuenca, Ecuador, are shown in the photographs reproduced herewith.

Many of the principal towns of the western and northern part of South America are located in the high fertile valleys of the great cordillera of the Andes, which like a backbone to the continent extend north from Patagonia to Venezuela. Even in the torrid zone moderate temperatures are found at an elevation of only a few thousand feet above sea level, and Cuenca, which is about three degrees south of the equator at an altitude of some 8000 feet, is noted for its mild and genial climate. Like other towns of its class, however, the climatic advantage has the corresponding drawback that the town is not readily accessible. Although the third city in Ecuador, it is as yet without rail connection with the seaboard, and from Huigra, the nearest point on the Guayaquil-Quito railway, whence a railroad is projected to Cuenca, a very inadequate road some eighty miles long is at present the principal highway to this relatively important center. Owing to the mountainous nature of much of the country traversed by this road and the con-

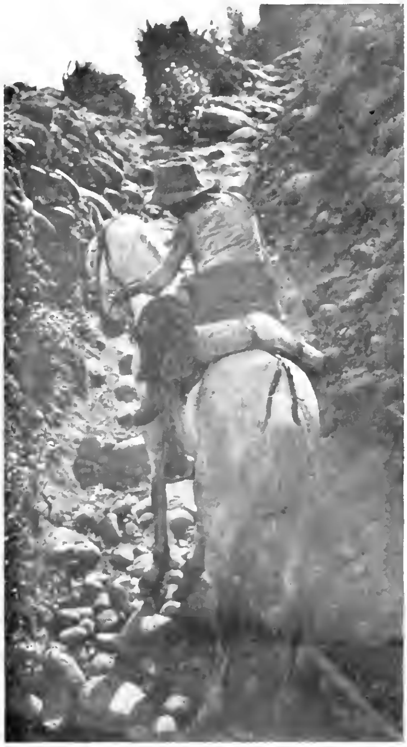


Fig. 1. Showing Character of Roadway over which Equipment was Transported

Fig. 2. Transformer Case Secured to Bamboo Poles which are Carried on the Natives' Shoulders. Packages weighing as much as 1000 pounds are carried in this way

Fig. 3. Nearing Cuenca. Changing from Shoulders to a Six-ox Drag

Fig. 4. Reducing Weight on the Trail

Fig. 5. Transporting Sections of Pipe Line. This method proved a failure

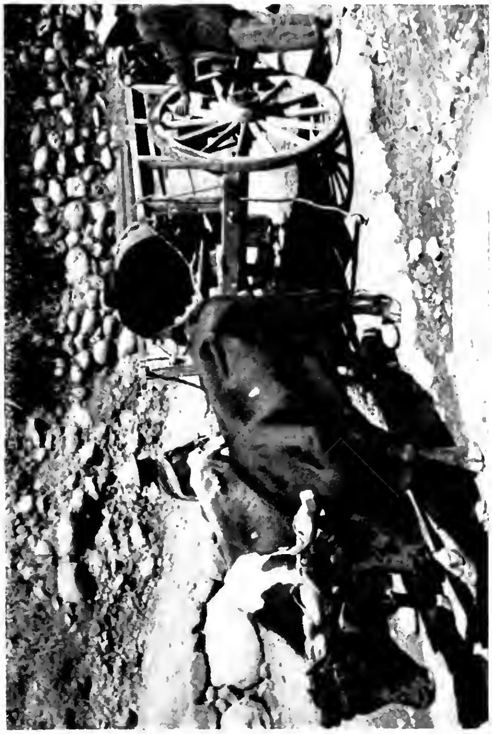


Fig. 6. Transportation by Oxen and Cart over Better Sections of the Route

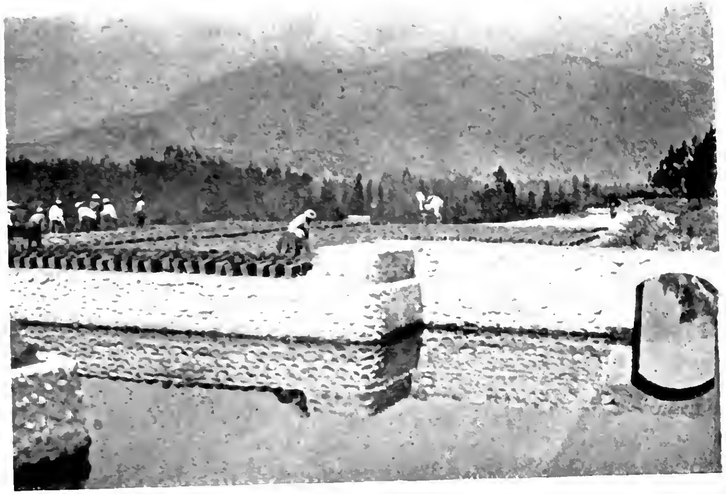


Fig. 7. Forebay

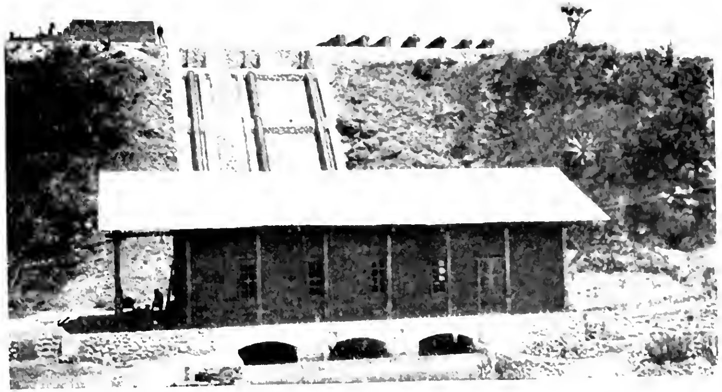


Fig. 8. Power House and Penstocks

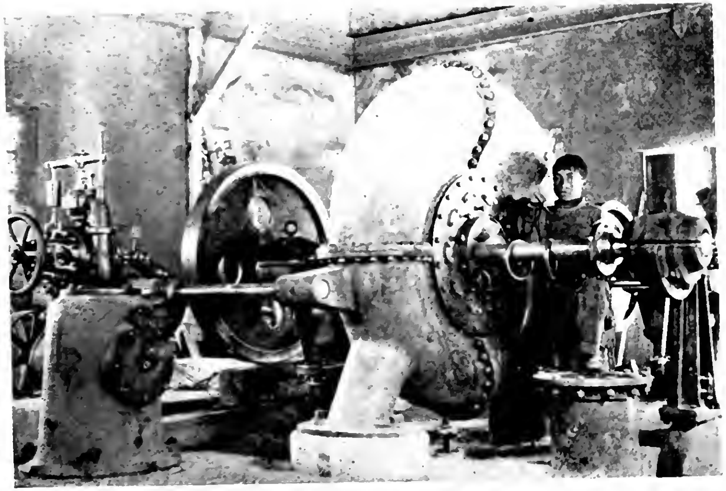


Fig. 9. Hydraulic Turbine

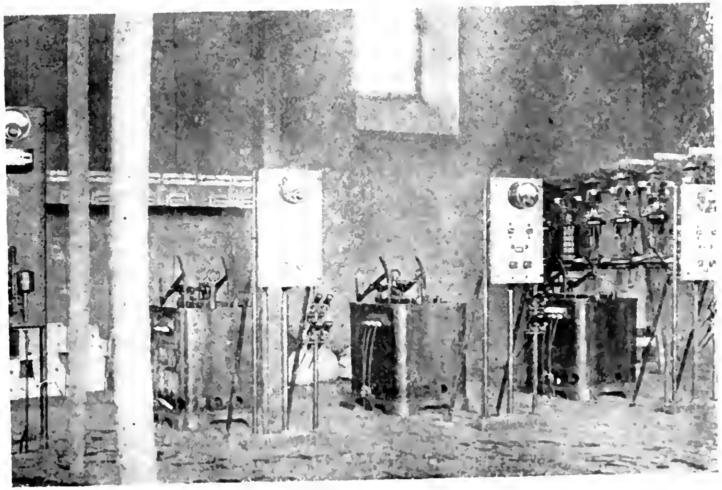


Fig. 10. Interior of Substation

ditions of periodic tropical rainfall, the road is in many parts nothing more than a narrow winding slippery trail, quite impassible to even the roughest form of carts. Over such roads the transportation of heavy machinery presents problems which might well daunt the promoter of a public utility such as a lighting plant; nevertheless, some of the oldest plants in South America are found in just such towns, and public spirited municipalities have frequently undertaken the heavy expense involved in the installation of plants in places where uncertainty as to profit has deterred private capital.

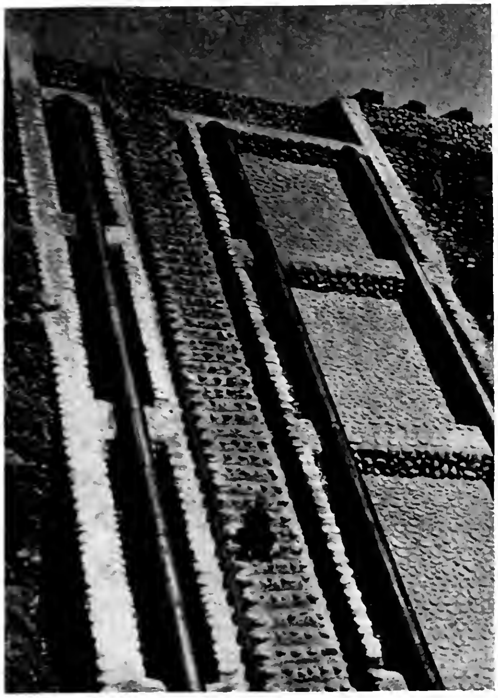


Fig. 11. Near View of Penstocks and Masonry

In spite of the transportation difficulties which were foreseen, and which ultimately proved to be far greater than anticipated, the Municipality of Cuenca decided some three years ago to acquire a plant to furnish both public and private lighting, and in the summer of 1914 placed their order for the equipment. This comprised three 75-kw. 60-cycle, 2300-volt generators, each driven directly by a 135-h.p., 900-r.p.m. Pelton-Francis turbine, with all necessary piping, transmission line, and material for distributing circuits. The power house is at Yanucay near Cuenca, from which point power is transmitted to the substation in the city. In addition to the necessary switchboards, suitable voltage regulators are installed here, as well as four constant-current transformers for the operation of the 100-type W flame series are lamps for street lighting.

In preparing materials for shipment it was stipulated that so far as practicable packages should not exceed 125 lb. in weight to permit of muleback transportation, and that no piece should weigh to exceed 1000 pounds. All of the material—machinery, pipe line, poles and wiring—went forward from New York early in November, 1914, having been disassembled as far as possible and packed to meet the severe conditions of transportation. The Municipality had previously arranged for the selection of a competent engineer to supervise the installation of the plant, and Mr. J. H. Torrens had already arrived in Cuenca, and had begun the work of preparing the two mile ditch and reservoir. After getting these completed and the saddles for pipe line and the power house ready, it was found necessary for him to devote considerable time to helping out with the transportation from the railroad station at Huigra, since it was desired to still further subdivide some of the packages and arrange for their safe carriage. There were 2400 packages in

Fig. 12. Substation

all, of which 150 had ultimately to be carried by Indian porters.

The pipe line proved to be a particularly awkward problem. Each of the 105 pieces weighed 283 pounds. It was at first proposed to transport these by mule back, but the contractor after wrestling with the job for two months, and in that time having succeeded in delivering only ten pieces by mule, was forced to throw up his hands and report that it would be necessary to send men to transport them by "guando" (Quichua for load carried on the shoulders of several people), since as before-mentioned the use of carts was impossible over much of the road.

Fig. 13. Type of Arc Lamp and Pole in Use in Cuenca

In preparing heavy packages for carrying by guando all surplus boxing is removed, and by the use of bamboo poles and cross pieces weights are so distributed that packages up to one thousand pounds in weight are carried on the shoulders of the Indians, the bamboo poles adding approximately another fifty per cent to the weight of the part so transported. Several packages of this weight were included in the shipment, and for each of these pieces seventy men were allotted, and on account of the severe trail conditions the allowance of twenty to twenty-five pounds per man was found none too liberal.

A freight caravan engaged in a transportation job of this nature cuts a rather imposing figure. On the parts of the trail where oxen may be used it will be preceded by a trumpeter known as a "bosinero" who is equipped with a long horn with which he enlivens the trip with martial airs, the music also serving as a warning to others on the trail of the approach of the party. A small army of men will often be used in carrying the heavy packages. When the guandos for Cuenca were ready the Governor of the Province went to the railroad personally with about three thousand Indians, all divided into companies with their captains, and carried off practically all the heavy pieces, with much shouting and enthusiasm. For the trip each man received eight sucres—about four dollars—with food, pisco and chicha (the native beverages).

It is under such difficult conditions that the tools of modern progress are being acquired by our southern neighbors. Owing to the scarcity of local capital which commands from twelve to twenty-four per cent per annum, only the most profitable projects can be undertaken, and these cannot in the nature of things be large as measured by our standards. Much time is required in their construction, and to one unfamiliar with the conditions it might appear that nearly two years for the transport and installation of a plant of this character was excessive. The matter, however, presents an entirely different aspect when the obstacles to be overcome are taken into account.

Fig. 14. Special Illumination of Public Buildings

The lighting service of the Cuenca plant was successfully inaugurated on August 9 last, and from the illustrations it is evident that the Cuencanos have not spared any effort or expense in obtaining a plant of which they may be proud.

PORTABLE ELECTRIC MINE LAMPS

By F. T. Forster

Pittsfield Works, General Electric Company

The introduction of the following article contains a brief review of the development of portable mine lamps from the pitch torch, through the Davey safety lamp, to the modern electric lamp. Following this is a summary and explanation of the requirements which a portable electric lamp must fill to be acceptable to the Bureau of Mines. The remainder of the article is devoted to a description of the light and electrical characteristics, and the construction, safety features, and maintenance of a portable electric lamp which has been accepted by the Bureau of Mines and declared permissible for use in gaseous mines.—Editor.

The problem of producing a satisfactory portable mine lamp is as old as mining itself. The pitch torch, with its smoking flame, the candle, and the open-flame oil lamp have each served in turn to guide and aid the miner in his work. With the advent of coal mining it was discovered that open flames in mines were sometimes dangerous, owing to the fact that explosive mixtures of methane gas frequently occurred. This led to a series of investigations to produce a lamp that would primarily prevent explosions and secondly detect the dangerous gas.

Both of these results were first accomplished by Sir Humphrey Davy in 1816, just about a century ago. His well-known hand safety lamp, Fig. 1, is still used. In principle it consists of a luminous flame completely surrounded by a fine wire gauze which allows the explosive mixture to pass through and burn quietly on the inside of the lamp, thus indicating the presence of the gas, but which cools the burning gases sufficiently when they are passing out again to prevent their igniting the mixture that is outside the lamp, thus creating a safe condition. If, however, the lamp is allowed to remain in a gas mixture, the burning gas inside the gauze will soon heat it to incandescence and thus cause an explosion. When gas is detected, the lamps must therefore be almost immediately removed from that section, which is considered dangerous, until it is properly ventilated and then shown to be free from gas. Even then, since that section is inclined to be gaseous, the miners will be required to use "safeties." The small amount of light afforded by these lamps, the finding of a suitable place to hang them, and the necessity of moving them about as the work progresses makes them undesirable. Though lamps also using the Davy principle have later been developed to give more light, the other objections still remain.

Where mines are not subject to gas, or excessive coal dust, the open-flame oil lamp is most generally used, Fig. 1, though this has in the last few years been somewhat displaced by the open-flame acetylene lamp of high candle-power. The oil lamps give more light than the "safeties" and since they are carried on the miners' caps their work is always illuminated. The flame is smoky, however, and even in well ventilated sections a few of these lamps will vitiate the air to a most annoying degree. This, also, applies to acetylene lamps and these have the added disadvantages of requiring frequent reloading with carbide and water and a continual adjustment of the water flow to maintain the proper pressure.

Open Flame Oil Lamp Davy's Safety Lamp

Fig. 1

The electric incandescent lamp naturally obviates the objections found in the open-flame type lamps. While the electric lamp will not detect gas, this can easily be accomplished by employing a few Davy lamps for this purpose. Special electric gas detectors are now being developed and it will probably only be a matter of a few months before thoroughly reliable devices of this type will be on the market.

The advantages of the electric lamp are so great that little objection should be found to the supplementary use of a few Davy lamps to detect gas in those sections in which it may occur. For many reasons, it is not practicable to use the ordinary power distribution system for mine lighting purposes except in well established locations, such as shafts, pump rooms, stables, etc. This condition has led to the development of a portable electric lamp to replace the hand or cap flame lamp. Several years ago the primary battery was tried with carbon filament bulbs for hand lamps, the weight being too great for its consideration as a hat lamp. After repeated trials it was found that such lamps were not practical on account of the high cost of maintenance, for not only did they have to be daily inspected, cleaned and distributed, the same as oil safety lamps, but also the zinc or other active elements and the electrolyte had to be removed daily and frequent replacements had to be made of burned out lamps. One can readily understand that the cost of these materials and labor would be far more than the cost of oil for oil lamps, and that no means of securing any very great reduction existed so long as the generation of current depended on a non-reversible chemical reaction. Though the primary battery lamp thus eliminated itself, the idea of a portable electric mine lamp remained firmly impressed upon the minds of the coal operators and made the way easier for the development of the storage battery lamp which soon followed.

The low efficiency of the carbon filament lamp at first necessitated batteries of such size and weight that only hand lamps could be considered, as in the case of primary cells, if a reasonable time of burning was to be obtained. Unlike the primary cells, the storage battery operates through a reversible chemical cycle, first receiving a charge by passing current from one electrode to the other and then giving up this charge when required, an operation which can be repeated many times before the electrodes wear out. The corrosive electrolytes and the necessity of venting at first offered many difficulties to making a reliable battery of good mechanical design, but these were gradually overcome until now very satisfactory lamps are in common use.

Most of these early efforts were made in Europe, especially in England and Germany, and not until the tungsten lamp came into service a few years ago did the development of mine lamps really start in this country and then along a different line, namely, that of the cap lamp. The higher efficiency, that is, lower wattage per candle, of the tungsten lamp made a smaller and lighter battery possible. A further reduction in weight in the lead battery was accomplished by the use of thin instead of thick plates, so that, by placing the battery in a suitable metal container, the miner is able to carry it on his back and have a flexible connection to a lamp held in a suitable holder and reflector on his head. While both the oil cap lamp and the electric cap lamp illuminate the miner's work, the electric lamp possesses the distinct advantage that it gives off no smoke or odor. The light is steady and of good quality. The man has both hands free for his work and needs not bother moving his lamp about.

Bureau of Mines

Because the Bureau of Mines possesses an intimate knowledge of mining conditions, its engineers are no doubt the best qualified to specify what should be the requirements for a portable electric mine lamp. The Bureau has been actively interested in this development and has adopted standards which have been changed as the art developed. Before any design of lamp can be used in gaseous mines, it must pass the mechanical and electrical tests prescribed by the Bureau, now covered by Schedule 6-A which was issued by the Bureau in February, 1915. These tests are made to represent reasonably severe service conditions so that a design that will pass them should stand up under actual conditions.

The mechanical tests relate to the strength of the device as it is assembled for the miner to use. The battery in its metal box must not break or leak when dropped in various ways, and it must not leak when subjected to "picking" or "shovelling" motions. Neither must the metal box and cover, with their attachments, be seriously damaged by these tests. The cable must endure much slatting in an oscillating machine, to represent several weeks or months of wear.

The electrical tests are of the incandescent lamp, the lamp safety device, and the battery. The incandescent lamp is required to show an average candle-power equal to, or preferably above, a specified amount found in practice to be a good working minimum value. Lamps under test must not vary from their average candle-power more than 30 per cent and from the average current consumption more than 6 per cent. Furthermore, the lamps must have a reasonable length of life, which has been set at not less than 300 hours, or a little over a month's operation. There would be serious objection to a lamp burning out more frequently than this as each burnout means that the miner loses time in coming out to get a new lamp.

The distribution of light is another important factor in the matter of illumination. It should be more intense at the center and graded off toward the edges over an angle sufficiently wide that all objects in the vicinity of the miner, and within his range of vision, will come within the illuminated area.

A glowing lamp filament has been proved by the Bureau to be dangerous. It is therefore necessary to supply each device with a safety switch that will break, or otherwise discontinue, the current through the filament when the bulb is broken.

Tests with light and heavy blows in the directions most likely to cause failure are applied to each device and it must not fail on any test in order to pass, for obviously one failure in a mine might mean death to many miners and much damage to property.

Batteries must be proved by test to possess a capacity sufficient to burn the lamp through an entire shift of 8 to 10 hours with a margin of safety.

An Approved Lamp

Under Schedule 6-A, the Bureau of Mines have issued approval to the General Electric Company for two mine lamp designs; or, rather, one main design and one modification of the main design to meet special conditions. It is the special feature of these designs that will be described. In both designs the cap lamp, cable, battery, lock, and cover contacts are the same; in fact the only difference between the two outfits is in the metal container for the battery, the one having a steel case and cast aluminum cover, Fig. 2, and the other having a cast aluminum case and cover. The former is suitable for most mining conditions, but where the service requirements are unusually severe the latter fills this need by reason of its superior strength An illustration of either type of outfit as carried by the miner is given in Fig. 3.

Light

The first requisite of a mine lamp is to give light for the miner to find his way through the various unlighted passage ways to his work and then to enable him to perform that work in an efficient manner during the entire shift. It is therefore quite necessary that the light should decrease as little as possible in brilliancy during the time the miner is "inside." With the lamps already mentioned, this is accomplished by using an ironclad exide battery whose voltage characteristic is given in Fig. 4. Except for the sudden small decrease in voltage which takes place in the first few minutes on a freshly charged battery, the change over 9 hours is only 6 per cent, or less than 1 per cent per hour. This change in voltage corresponds to a 20 per cent reduction in candle-power which is not noticeable except when carefully compared with a lamp burning from a freshly charged battery. A voltage regulation of this amount, which insures an almost constant brilliancy throughout the entire shift, is only possible to obtain with a lead battery.

Fig. 2. Steel-Case and Aluminum-Cover Battery with Miners Lamp Equipment Assembled Ready for Use

The distribution of light is exceptionally good, Fig. 5. A porcelain reflector of irregular shape is used, thereby eliminating those sharp changes in brilliancy that are characteristic of polished metal reflectors. Although the former does not give as good an efficiency as a new metal reflector, it maintains its service for an indefinite time; whereas the metal reflector will become tarnished and lose its brilliancy and any effort to clean it will result in spoiling the surface or in leaving it in a condition that will make it more readily tarnishable. If the porcelain reflector becomes dirty or dusty it can easily be cleaned by washing and is then just as good as new. Furthermore, by having it mounted in such a way that it is not in contact with the outside shell it is not readily damaged. If it is damaged it can be easily replaced at small cost.

Fig. 3. General Electric Miners' Lamp Properly Worn by Miner (Battery Box Under Jumper)

The cap shell is fitted with hooks for mounting the lamp on the miner's cap at such an inclination forward as to throw the beam of light directly upon the work which the miner is doing.

Safety Device

As has been indicated before, much depends upon the perfect operation of the safety device. In the two lamps described, the safety feature consists of two flexible contacts which hold an elliptical shaped bulb having a contact at either end with the filament extending through the lamp between its two contacts. Fig. 6 shows this safety device lamp mounting holding the bulb. Any blow which will break the bulb in any manner will force the lamp out of the contacts. It will be seen that this device will operate independently of the containing shell, reflector, etc.

Battery

Much depends upon the battery. If it does not supply current to light the lamp for the full working time the miner will have to stop work sooner than otherwise, thus decreasing the output of coal for the mine owner and causing a loss of pay to the miner. It may also be difficult for him to find his way out of the mine if he does not have assistance from someone who has a lamp. With the ironclad exide battery, Fig. 7, a reliable source of power is assured. The battery plates are very rugged and have established a reputation in mine locomotives and heavy trucks for their ability to withstand heavy duty conditions and severe shaking. The plates are contained in a strong, well-designed, semihard rubber jar that will stand an unusual amount of abuse. By making the metal containing case of proper design for the conditions under which the equipments are to operate, no trouble has been experienced from cracked or broken jars. The cover is fastened to the jar by a double capillary seal, which is absolutely acid-tight and yet of such simple construction that it can readily be removed at short notice for renewing the plates when this is necessary. The simplicity

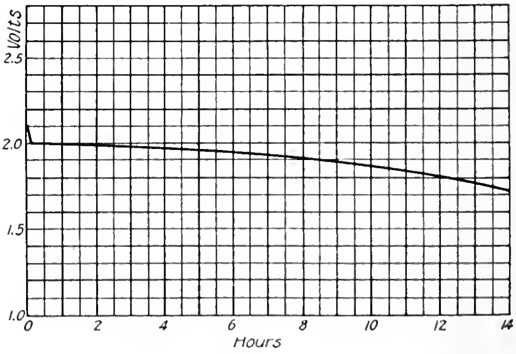


Fig. 4. Voltage Characteristic Curve of Ironclad Exide Battery

of the design, the long life of the plates, and the ease of making renewals should appeal to operators who have had experience with mine lamps. The excellent voltage characteristic of this battery is shown by the curve in Fig. 4.

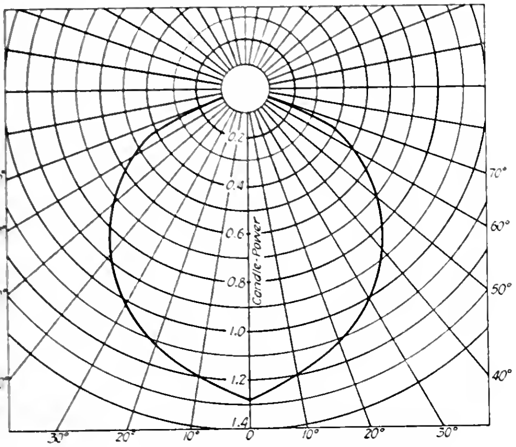


Fig. 5. Chart showing Light Distribution of Miners' Lamp

The filling and venting scheme is very simple and effective. To fill the battery the vent plug is removed, which gives free access to the cell space, and the level of the electrolyte is brought to within a small distance below the edge of the plug opening. The vent plug is very effective in preventing spilling of the electrolyte and is securely seated in place by a quarter-turn of the plug, which draws it down against a rubber gasket in a suitable seated surface on the jar to prevent any leakage of acid. The electrolyte, which is the usual battery acid (sulphuric), is corrosive in its action on metals and will damage all kinds of cloth except pure wool, yet on account of the degree of perfection which has been obtained in making a strong non-breakable jar, a perfectly seated vent plug, and a non-spilling vent no acid can escape while the cells are in operation. Though carelessness in seating the vent or in not wiping off any acid which may escape when the battery is being filled or examined may cause a slight amount to run down the front of the jar, not enough can escape from the metal containing case at any time to damage the miner's clothing. Alkaline electrolytes are not corrosive to some metals nor do they attack clothing in the same way as the acid electrolyte, but in filling the cells with the alkaline solution the effect on the attendant's hands is frequently very bad and this strong caustic would be equally harmful should it come in contact with the miner's body. This cauterizing or burning effect is used by physicians and surgeons and is due to the extremely solvent action of the alkali on the skin and other tissues. Attendants who have handled both kinds of electrolyte agree that they prefer the acid electrolyte to the alkaline.

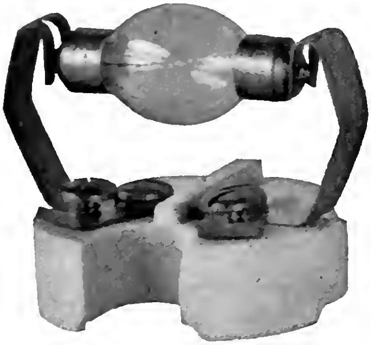


Fig. 6. Safety Lamp Mounting with Bulb in Place

Fig. 7. The Ironclad Exide Battery

The batteries are charged for the same number of hours that they are discharged, the charging current being somewhat higher than the discharge current. Practically no vapor or fumes of any kind escape from the batteries under these conditions. The vents do not become clogged with salt crystals, which might cause a rise of pressure in the case sufficient to result in an explosion with possibly serious consequences to a miner if he were carrying the lamp. With metal vent plugs having very small apertures this danger exists.

Fig. 8. Miners' Lamp Disassembled

Miners are often called upon to work in unusual positions, such as lying on their back or side which leaves the battery plates partially exposed. However, as long as the electrolyte is in contact with the plates, the ironclad exide battery will deliver practically full value of current to the lamp for the full rated time. Even if the battery is turned bottom side up, the lamp will burn for five or six hours.

Fig. 9. Proper Method of Placing Battery on Shelf for Charging (Battery Ready to Enter Contacts)

Fig. 10. Battery under Contacts, Charging (Note Position of Contacts)

It is often pointed out that lead batteries are seriously damaged by repeatedly over-charging them, or by allowing them to be discharged below a certain voltage, or by reversing their polarity. Where a considerable number of lamps are employed and proper attendance is supplied, there seems little or no excuse for such conditions to exist. It would only be occasionally that lamps would be discharged to zero voltage, as when emergency crews work for long hours in the mine and might accidentally leave some lamps in a discharged condition. Such batteries can be readily put into operating condition again by proper charging. With reference to over-charging, it can be said that operators are always on duty during times of charging and there is no reason why batteries should be kept on the charging rack longer than the required length of time. Also, over-charging is undesirable in any battery for it means an unnecessary waste of power and the electrolysis of the water in the electrolyte, which is proportional to the amount of charging current flowing in each cell.

For charging the batteries a very simple charging rack has been devised which will obviate any chance of charging the batteries in the wrong direction. The terminals of the battery are a different size and if the battery is reversed it will not make contact. When the battery is placed in the rack and has just made contact, a small contact switch automatically opens and disconnects the shunt resistance. When a battery is taken out this switch closes, so that the current is not broken in the circuit and the rheostat on the switchboard does not have to be adjusted. The entire battery support is raised off of the main supporting shelf, so that any acid accidentally spilled when filling the batteries can be readily cleaned off. The batteries are inclined at a small angle, which facilitates filling them with water or acid while they are charging on the rack. The details of this rack are shown in Figs. 9 and 10.

Cable

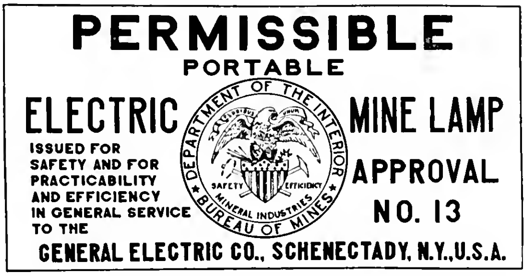
The flexible cable connecting the battery with the cap lamp is a very important part of the equipment and much thought and expense has been given to the development of this part of the apparatus. At first it was thought that a flexible metal armor would give a protecting coat which would enable the cable to last a long time. The fact that this armor had to be flexible immediately presented many difficulties. It was found from actual experience that the metal would break in a very short time and present sharp edges which would either cut the cable or tear the miner's clothing. It was therefore necessary to give up the application of metal armor, except for those short lengths of very flexible armor at the ends of the cable to support it and prevent sharp bending where it enters the cap or cover of the battery case. In place of the full length metal armor was substituted a reasonably heavy coating of very pure rubber which was found to last for a considerable time. Some cables of this type have been known to be in daily service for six months or more. The continual bending of the cable also necessitates a special construction in stranding the conductors and in spiralling the double lead inside the rubber covering.

To relieve the pull of the lead on the terminal, the cable is clamped by a flexible support which positively grips the cable and prevents any slipping.

Simplicity in Design

Every part of these approved lamps has been so designed as to be readily accessible for repairs and inspection, as shown by Fig. 8. This feature is essential in any small device of this kind where large quantities are to be used. For instance, if 1000 cables are to be repaired, the work should be capable of being done with the minimum amount of trouble and lost time. In this device there are no soldered connections to make and the clamping device in both the head piece and the battery case cover can be quickly removed, the cable pulled out, and a new one put in its place, or the old one cut off and slipped back without actually taking it out of the bushing.

The reflector in the head lamp is readily removable for cleaning; and when it is removed, the cable, the clamp, and the safety device contacts are exposed and can readily be repaired or renewed.



PERMISSIBLE
PORTABLE
ELECTRIC MINE LAMP
ISSUED FOR SAFETY AND FOR PRACTICABILITY AND EFFICIENCY IN GENERAL SERVICE TO THE
APPROVAL NO. 13
GENERAL ELECTRIC CO., SCHENECTADY, N.Y., U.S.A.

Fig. 11. The Permissibility Nameplate appearing on Portable Electric Mine Lamps of General Electric Co. Manufacture

The battery box and cover lock is of very simple construction; by simply removing two screws, which are so placed as to be conveniently reached, the parts can be quickly removed and replaced. The battery contacts, in case they should become damaged, can also be quickly removed and new ones put in their place.

In case of damage to the battery plates or to any part of the battery, the cover can easily be lifted off after slightly warming it. On account of the long life of the plates and the durability of the rubber jars and covers, these batteries will give long service; and since the owner can renew the plates when they are worn out the maintenance expense will be low.

Other Applications

The field of application for a safe portable electric lamp is much broader than that of mine service. In general, it can be said that the portable electric lamp is especially applicable wherever portable lights must be employed under conditions which preclude the use of open-flame lamps. According to this designation, it will be seen that the electric lamp is particularly serviceable in chemical industries, paint and varnish plants, ammunition plants, warehouses, ships, boiler shops, etc.

In many of these special applications it is necessary to modify the design to meet the special requirements. For instance, certain watchmen's lamps are designed to be carried in the hand and must be furnished with a suitable handle and snap switch, and must give a concentrated beam. Another example is supplied by lamps for ship service. There, it may be desirable sometimes to use the lamp as a cap lamp and at others as a hand lamp. The cap lamp can be made convertable by certain modifications or two separate lamps can be used.

The possibility, therefore, of extending the application of the portable electric lamp to many new lines of service seems very promising and should result in many interesting and useful developments.

FORCE AND SHRINK FITS

By Sanford A. Moss

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The many years' shop use of force and shrink fits has resulted in a good practical knowledge of the subject. This knowledge being purely empirical, however, makes a supplementary mathematical treatment desirable. The author gives the complete mathematical theory, shows how this verifies the empirical knowledge, supplies many details which could not be ascertained empirically, and collates and classifies the various points of the subject in a way that could never be done empirically. Various fragments of the mathematical theory have been published from time to time, probably covering the most essential matters. However, every detail is here covered so thoroughly that the article forms a complete treatise.—Editor.

Various isolated details relating to force and shrink fits have been published from time to time, but a complete discussion of the whole subject from a rational standpoint has never before been given. The subject has been previously treated principally from an empirical point of view. It will be shown, however, that the empirical conclusions can be rationally deduced. The points covered in previous publications (listed in the bibliography at the end of this article) are included here for the sake of completeness and there is also given considerable new matter.

The problem discussed is that which arises when a hub is secured tightly on a shaft having a diameter somewhat greater than the hub bore. There are three methods of securing the hub to the shaft. The first and safest is the use of a hydraulic press which forces the shaft into the hub. The second is the heating of the hub until it expands enough to go easily over the shaft, and the third is the driving of the shaft into the hub. We will pay no further attention to the methods as the stresses finally produced are independent of it.

Force Fit Allowances

The amount by which the shaft diameter exceeds that of the hub bore is called the "allowance" for the force or shrink fit. It is rational to make the total allowance proportional to the original shaft diameter. That is, the allowance is a certain number of thousandths of an inch per inch diameter. This is called the "force fit per inch of bore," and is given in the formulas by Y. For a steel hub a common value of Y is 0.001 inch or one mil per inch. Force fits of ½ mil to 2 mils per inch are used with steel. For a cast iron hub the value of Y varies from 0.00025 to 0.0005 inch, that is, from ¼ mil to ½ mil per inch. Rarely values of one to two mils per inch are used with cast iron. The stresses and general considerations arising from these various amounts of force fits will be further discussed later.

As will be shown, the stresses in hubs of similar proportions vary directly with the force fit per inch, Y. For instance, with an outside diameter of hub equal to twice the bore there will be the same stress with a force fit of one mil per inch for all actual diameters, and double the stress for a force fit of two mils per inch. Hence, it is rational to have a total fit allowance which varies directly with the diameter, that is, a constant value of the force fit per inch of bore. This has usually been done empirically and it is here shown that the empirical practice has a sound mathematical basis. The proper allowances, stresses, force for pressing, etc., vary somewhat but not greatly with the relative thickness of the hub and with the size of the hole in the shaft if it is hollow. That is to say, there are somewhat different conditions for the case of a hub twice the diameter of the bore, three times the diameter of the bore, or many times the diameter of the bore. The difference for usual cases is not very great, however. The exact laws will be given. The general formulas are, of course, also applicable to the case of a comparatively thin ring or tire shrunk on a wheel. For such cases, however, the results are quite different than when the outer ring is a hub with a diameter two or three times that of the bore.

General Nature of Ring Stresses

When a circular body such as a hub, or shaft, or ring is stressed as in the force fit case, there are two stresses each independent of the other, in the radial and tangential directions, respectively. Each of these is constant all around the circumference at any given radius. Each of these stresses produces elongation or contraction in its own direction. The amount per unit length is directly proportional to the stress and inversely to the modulus of elasticity. There is also contraction or elongation in the other direction. The ratio of the deformations in the two directions is called Poisson's ratio, which we will take at the best value for steel, as 0.3. The net deformation per unit length in either the radial or tangential direction is therefore due to both radial and tangential stresses.

Stresses with Force Fits

The hub when in place on the shaft is pressed outward by it, so that there is an outward or radial compressive stress at the bore of the hub. In its opposite aspect, the mutual pressure gives an inward or radial compressive stress on the outside of the shaft. The interior of the hub is in exactly the same state as a thick cylinder without ends subject to internal fluid pressure, such as a gun. Due to the radial compressive stress in the hub, there is produced a tangential tensile stress at the hub bore. This stress is slightly greater than the radial stress for a thick hub and much greater for a thin hub. It causes the maximum stress in the hub. Similarly, there is produced a tangential compressive stress at the shaft surface.

In the case of the hub, the radial and tangential stresses gradually decrease as we proceed to circumferences farther from the bore. The radial stress finally becomes zero at the outer diameter if the hub is merely a ring, while the tangential stress reaches a definite value smaller than at the bore, but not zero. This value is nearly zero if the hub is a thick ring.

In the case of a solid shaft, both radial and tangential stresses are equal at the surface and remain constant at the same values throughout the interior.

In the case of a hollow shaft the radial stress decreases as we go inward and becomes zero at the edge of the hole, while the tangential stress increases. If the hole in the shaft is small, the radial and tangential stresses are equal at the outer surface and have nearly the same values throughout the interior, until near the hole. Then the radial stress rapidly decreases to zero, and the tangential stress rapidly increases to twice the value at the surface.

If the hole in the shaft is of appreciable size the radial stress decreases gradually from the surface value to zero at the hole. The surface value of the tangential stress is greater than the value for a solid shaft and greater than the radial stress, and the value increases as we go inward to a value at the hole greater than that for a very small hole, and greater than twice the radial stress at the surface. This tangential stress at the hole for the case of a shaft or inner ring with a large hole will, if the hub is relatively thinner, cause greater stresses than exist in the hub.

As stated, the maximum stresses in the hub are at the hub bore. (These are also the maximum stresses in the system unless the shaft or inner ring is relatively thin.) The force for pressing also depends on the stresses at the hub bore. Now the conditions at the hub bore are very little affected by the metal at a distance from the bore. That is to say, the conditions at the hub bore do not change appreciably if the outer diameter of the hub is varied, or if there are heavy or light spokes and outer rim, or if there is a hole in the shaft or inner ring of large or small diameter. Hence we may exactly compute the conditions at the hub bore by use of values for outer diameter of hub or inner diameter of hole in inner ring (if there is any) which are inexact. This gives legitimacy to the general system of computation fully discussed later. This system treats any case of an irregular hub or wheel forced on a shaft, or of a rim or tire forced on an irregular center or wheel, as equivalent to an outer cylindrical ring forced on an inner cylindrical ring or solid cylinder.

Equivalent Simple Stress for Steel, etc.

In any case such as the present, where there is stress in more than one direction, we must have some criterion as to when the combined stresses will cause the same conditions, so far as failure is concerned, as simple tension in a testing machine. That is to say, we must compute at the most dangerous point that simple stress which would produce the same effects, so far as failure is concerned, as the actual compound stresses. This we call the greatest equivalent simple stress. There are three different theories which have been used in cases of compound stress for computation of the equivalent simple stress; the Maximum Strain Theory, the Maximum Stress Theory and the Maximum Shear Theory. These matters have been discussed by a number of writers.*

In the case of steel and other materials where the failure by simple stress in the testing machine occurs at practically the same value for tension or compression, it is found that the actual cause of failure is not the direct rupture or tearing apart of the molecules due to pure tension but is instead a sliding of the molecules past each other due to shear. Failure due to simple compression in the testing machine is obviously failure by shear. Failure of steel or similar materials in a tension testing machine is due to exactly the same action, a sliding at an angle of 45 degrees, and not to tearing. Hence, for such materials in any case of compound stresses, we have to compute that simple stress which will produce the existing shearing stress. This is to be compared with the stress which occurs at failure in tension or compression in a testing machine. This is called the "maximum shear theory." The formulas given later showing the greatest equivalent simple stress according to the maximum shear theory are to be used in all cases of steel or other materials which fail for the same stress in tension and compression. That is to say, there will be failure when the greatest equivalent simple stress according to the maximum shear theory reaches the value giving failure for simple tension or compression in a testing machine.

Equivalent Simple Stress for Cast Iron

In the case of cast iron, failure by tension occurs at a much lower stress than failure by compression. The failure by compression is really failure by shear just as in the case of steel and when there are compound stresses which are compressive in both directions, as in the case of the inner ring or shaft of the present discussion, the maximum shear theory must be used.

However, when there are compound stresses in cast iron, one or more of which are tensile stresses, failure by direct tension or tearing apart of the molecules may occur sooner than failure by shear. In such cases the greatest tensile stress must be found by the maximum stress theory and compared with the tensile stress which causes failure of cast iron in the testing machine. There must also be found the greatest equivalent simple stress according to the maximum shear theory which is to be compared with the compressive stress which causes failure of cast iron. For the hub or outer ring of our case the stress by the maximum shear theory is always less than twice the stress by the maximum stress theory. Since the ratio of compressive and tensile stresses causing failure in cast iron is much greater than two, we will in the case of the hub always have failure by pure tension before we have failure by shear. Hence, for cast iron hubs the maximum stress theory must be used, which will give the greatest tensile stress. This must be seen to be safe as compared with the tensile stress which causes failure of cast iron in testing machines.

It may be remarked that there is really no such thing as failure by pure compression. We cannot push one molecule into another. A cube or sphere subjected to uniform pressures on all sides, such as would be the case when immersed in fluid under high pressure, would never fail. What we call failure by compression is really failure by shear or sliding.

Maximum Strain Theory

Before the maximum shear theory was known, the maximum strain theory was used. This stated that failure would occur when the sum of the deformations due to compound stresses equaled the deformation due to that simple stress in a testing machine which caused failure. This theory should no longer be used. However, in order that comparisons may be made, formulas of the maximum strain theory are given throughout.

Computation of Any Case by Use of Equivalent Cylindrical Rings

As already remarked, the metal at a distance from the force fit surfaces has very little influence. This can be seen by use of different values for outer diameter of outer ring in the formulas given later. Similarly,

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*See "Compound Stresses," by S. A. Moss, *Machinery*, August, 1914, Vol. 20, No. 12, p. 1046.

by trial of different values of the inner ring hole diameter it will be seen that unless the inner ring wall is very thin the exact size of the hole is of little importance. In a previous paper "Increase of Bore of High-speed Wheels by Centrifugal Stresses," Transactions Am. Soc. Mech. Engrs., Vol. 34, 1912, page 895, an introduction to the present subject was given. Curves are there given and here reproduced showing values of stress, etc., for various diameter ratios. Inspection of these curves, Figs. 1, 2, 3 and 4, shows that the various values differ little for ordinary ratios and the diameter only begins to have effect when outer hubs or inner rings are comparatively thin.

Hence, any case of force fit may be taken as equivalent to an outer ring forced on an inner ring or shaft. That is to say, if we have a hub with spokes, or a wheel disk, or any irregular shape we estimate the outer diameter of a plain cylindrical ring which, when forced on, will give the same effect as the actual case. If the inner part is irregular, such as when a rim is forced on a wheel center, we estimate the inner diameter of a plain cylindrical ring which gives the same effect. The above discussion shows that only a rough estimate of the equivalent outer and inner diameter is necessary to give good results.

Hence the formulas are for the general case of a cylindrical outer ring forced on another cylindrical inner ring, hollow or solid shaft, and we select the outer and inner diameter of the rings which are equivalent to any actual case. For a solid wheel, such as a steam turbine wheel disk, comparatively thin at the outer portion, the equivalent ring would be about one-half to one-third the wheel diameter. For a wheel with spokes and a thick hub, we would add a very little to the outer diameter of the hub. For an outer ring, such as a locomotive tire, we would estimate a mean diameter.

For the inner ring we make similar estimates. For a solid or hollow shaft no estimate is needed. For a locomotive wheel with spokes, the equivalent inner diameter would be one-half to one-third the outer diameter. For a thin rimmed wheel with spokes on which another rim is to be shrunk, we would have an inner diameter somewhat less than the inner diameter of the rim.

The length of the force fit, which occurs in the formula for force for pressing only, is the actual length of the surface over which pressure exists. Hence when a hub is pressed on a longer shaft, the length is the hub length. When a short plug is forced in a longer hub, the length is the length of the plug. While a shaft is being forced in a hub, the force required at any time when the shaft is partially in is proportional to the actual length of the shaft in the hub at the time. Hence as the shaft enters inch by inch, the force for pressing increases uniformly to the full value corresponding to the hub length.

Approximate Values for Usual Cases

In the following are listed a few of the more important general results obtained by the formulas. The formulas themselves must of course be used in order to solve any special case.

For the case of a cast iron hub or outer part, all of the like pressures, stresses and forces involved are about 60 per cent of those for a steel outer part, the shaft or inner part being steel in both cases. The figure 60 per cent is for a rather heavy hub, five times the bore, and a solid shaft, or a lighter hub and a hollow shaft. The ratio changes but little however for a lighter hub and is 57½ per cent for a hub of twice the bore and a solid shaft. The exact formula is given later at (6).

When the hub is in place on the shaft it is expanded somewhat from its original value, but the shaft is also compressed. The sum of the hub expansion and shaft compression is of course equal to the force fit. The shaft compression forms an appreciable fraction of the force fit, and the hub does not expand by nearly the full amount of the force fit as has often been assumed. For both parts of the same material the hub expansion comprises about 60 per cent of the total amount of the force fit for a heavy hub and a hollow shaft. This is for a hub five times the bore and a shaft hole three-tenths of the bore. For a solid shaft and hub five times the bore the hub expands 67 per cent; while for a lighter hub, the hub expands a somewhat greater amount, up to 74 per cent of the force fit for a hub of twice the bore. The exact formula is given later at (11). Fig. 1 gives values of the ratio for both parts of the same material.

For an outer part with half the modulus of elasticity of the inner, as for a cast iron hub and a steel shaft, the hub expands a lesser amount.

For a light hub twice the bore diameter and a solid shaft, the hub expansion is 85 per cent of the force fit, while for a heavier hub five times the bore diameter it is 80 per cent. The formula is given at (11).

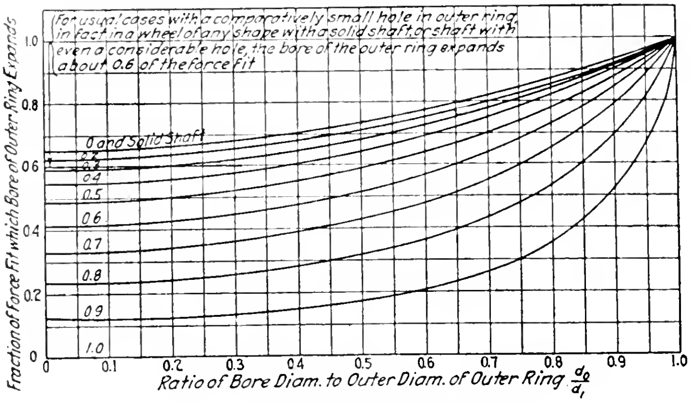

Fig. 1. Ratio of Expansion of Bore to Force Fit. Both Parts of the Same Material

Figures on curves denote ratio of diameter of hole in inner ring to diameter of bore of outer ring $\frac{d_2}{d_0}$.

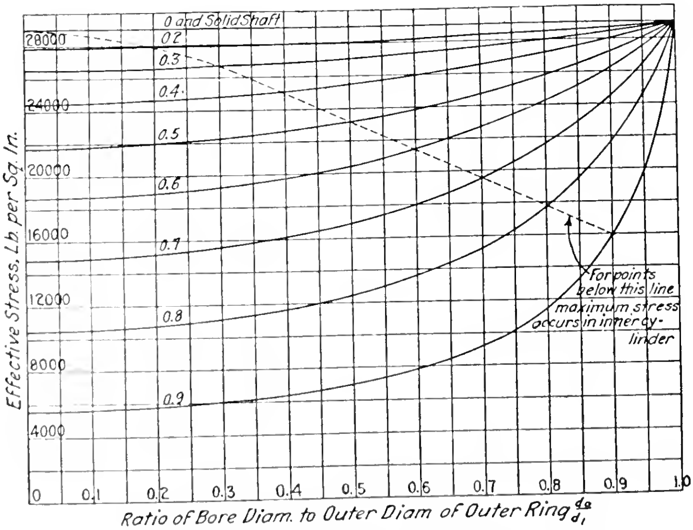

Fig. 2. Effective Tensile Stress at Bore of Outer Ring. Force Fit of 0.001 In. Per In. of Bore. Both Parts Steel

Stress is directly proportional to force fit per inch of bore. Figures on curves denote ratio of inner diameter of inner ring to bore diameter $\frac{d_2}{d_0}$.

The hub expansion is proportional to the radial stress, so that the expansion for a cast iron hub may be obtained from that for a steel hub by multiplying by the ratio of stresses first mentioned, and by the ratio of the moduli of elasticity, 2.

The maximum stress, on which the safety of the system depends, is the equivalent simple stress at the hub bore computed as already discussed.

For a solid shaft, and both parts steel and for *any hub* diameter this stress is 29,000 lb. per square inch for a force fit of one mil per inch of bore. Such an amount of force fit and hence such a stress is commonly used. The stress is directly proportional to the force fit per inch so that for a value of 1½ mils the stress is 1½×29,000 which gives some permanent set with steel. Such an amount is occasionally used. Even as much as 2 mils per inch may be used without risk of rupture of a good steel hub, but this gives considerable permanent set. The general formula is given at (15). Fig. 2 gives the maximum hub stress when both parts are of steel.

For a solid shaft and both parts of steel it develops that the equivalent stress due to the combination of the hub expansion and radial compression is the same as the maximum tensile stress computed on the incorrect assumption that the hub expands the full amount of the force fit. Hub stresses have been computed on the latter basis, and thus have accidentally turned out to be correct, although the method has no basis in fact.

For a solid steel shaft and a cast iron hub, the maximum equivalent stress is tension as given by the maximum stress. For a force fit of ½ mil per inch of bore, there is a hub stress of 4500 lb. per square inch for a very heavy hub and 5200 lb. for a lighter hub. This is about as large a force fit and stress as is used commonly for cast iron hubs. Values as high as 1 or even 2 mils per inch have been reported, but probably give risk of rupture. Lower values down to ¼ mil per inch of bore are also used, giving stresses half of those above, or about 2500 lb. per square inch. The exact formula (which must be used for hollow shafts) is obtained by substituting (5) or (6) in (8).

As is later discussed in the remarks on force for pressing, there is in most cases considerable uncertainty as to the exact amount of force fit on account of very slight errors in truth of the shaft and bore. Hence a force fit which seems to be one mil per inch may, on account of irregularities, be somewhat greater in places, so as to give greater maximum stresses than shown by the formula.

It must be noted that the maximum stress given exists only in a narrow region close to the bore surrounded by less stressed metal. There is also an absolutely dead load, with no stress alternation. Hence very high values of stress are permissible.

The formulas give correct relative values, so that when experience shows that a given force fit with a certain grade of workmanship in truth of bore and shaft gives safe maximum stresses, the force fit for some other hub or ring thickness to give the same maximum stress can be computed with accuracy.

The shaft or inner ring stresses are usually less than the hub stresses. However, for a hollow comparatively thin inner ring they may be greater, and must be found to be safe. The maximum stress is the tangential compressive stress at the edge of the hole. If the ratio of inner to outer diameter is the same for the inner ring as for the outer ring, this maximum stress in the inner ring is the same as the maximum equivalent simple stress in the outer ring by the maximum shear theory. If the inner ring is thinner than this, the maximum stress in it is greater than the maximum value in the outer ring. The general formula is at (19). Fig. 3 gives the maximum inner ring stress, when both parts are of steel.

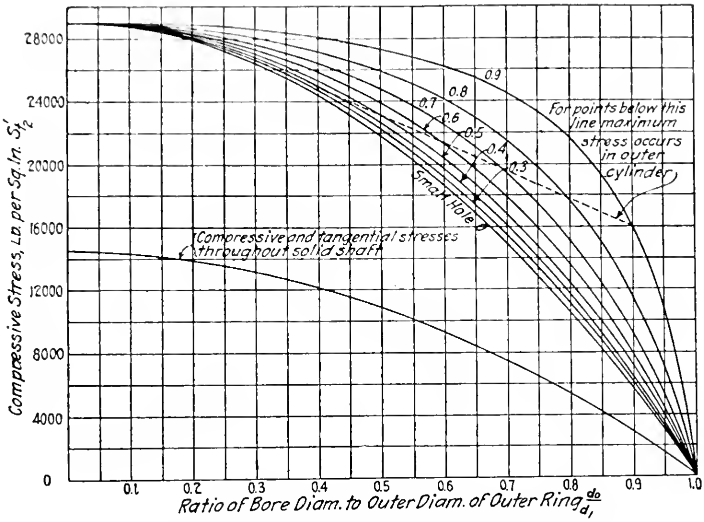

Fig. 3. Compressive Tangential Stress S'_{t2} at Inner Diameter of Inner Ring. Force Fit of 0.001 In. Per In. of Bore. Both Parts Steel

Stress is directly proportional to force fit per inch of bore. Figures on curves denote ratio of inner diameter of inner ring to bore diameter $\frac{d_2}{d_0}$. Values given are the maximum effective stresses in inner ring.

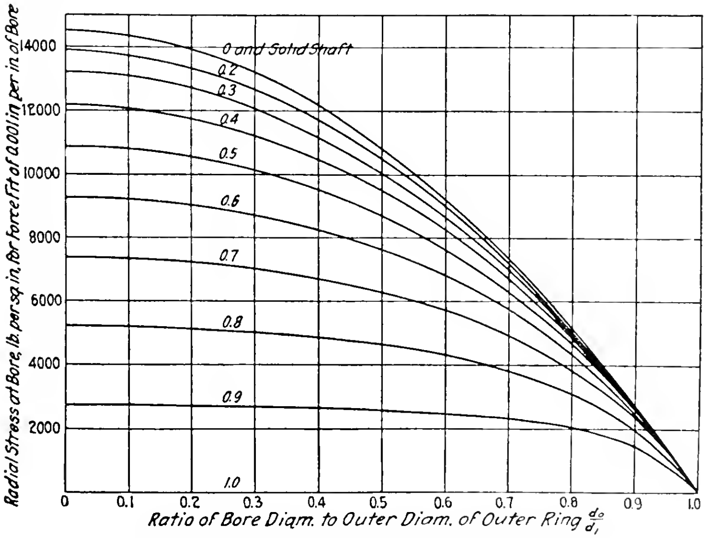

Fig. 4. Radial Stress at Bore S. Force Fit of 0.001 In. Per In. of Bore. Both Parts Steel

Stress is directly proportional to force fit per inch of bore. Figures on curves denote ratio of diameter of hole in inner ring to diameter of bore of outer ring $\frac{d_2}{d_0}$.

If the inner ring is comparatively thick, the stresses in it are less than in the hub and need not be computed. For a very small hole the maximum stress in the inner part is twice the radial stress at the hub bore. For no hole at all, or a solid shaft, the maximum stress in the inner part is only half as great, and is equal to the radial stress at the hub bore.

The radial stress at the hub bore is also equal to the radial stress at the outside of the shaft or inner ring, as well as to the radial pressure between the two. This radial stress also gives means for computing the force for pressing, since this force is equal to the radial stress, times the total area of the force fit surface, times the coefficient of friction.

For a solid shaft and both parts of steel and a force fit of one mil per inch of bore, the radial stress is 10,850 lb. per square inch for a hub of twice the bore, 13,900 lb. for a hub five times the bore, and about 13,000 lb. for an intermediate case, a hub three times the bore.

For a solid steel shaft and a cast iron hub the values for the same hub ratios, two, five and three, are respectively 6250, 8340 and 7700 pounds per square inch for a force fit of 1 mil per inch of bore. The general formula is at (6). Fig. 4 gives the radial stress at the hub bore when both parts are of steel.

TABLE I

NUMERICAL VALUES FOR SOLID STEEL SHAFT

The stresses and forces for pressing are for a force fit of 1 mil per inch of bore. Values for other amounts of force fit are proportional. (Safe values are 1 mil per inch for a steel hub and ½ mil per inch for a cast iron hub.) The first figure where two are given is for a steel hub and the second for a cast iron hub

	Light Hub	Medium Hub	Heavy Hub
Ratio of equivalent outer diameter of hub to bore diameter d_1/d_0	2.0	3.0	5.0
Ratio of like values for cast iron and steel hubs	0.575	0.592	0.60
Ratio of hub expansion to total force fit	0.74 0.85	0.68 0.82	0.67 0.80
Maximum equivalent stress, lb. per sq. in.	29000 10430	29000 9540	29000 9060
Radial stress, lb. per sq. in.	10850 6250	13000 7700	13900 8340
Minimum tons force for pressing, per inch of hub length and per inch of bore diameter (Also tons force for pressing, for each mil of total force fit and each inch of total hub length.)	0.66 0.38	0.78 0.46	0.84 0.50

Great variation exists in the force for pressing. The available data on this subject are the appended bibliography and the personal study of a great many unpublished records of force fits. All of this indicates that most workmanship is far from perfect so far as accuracy of hub bore and shaft turning is concerned. It is, of course, obvious that very minute errors of truth will make the actual amount of force fit greater than the measured amount, and so increase the force for pressing. Even the most carefully bored hole or turned shaft may have slight projections beyond the line of the true cylinder. Reamed holes and ground shafts are more nearly perfect. There may also be feed marks which may be smoothed or "ironed" out during the pressing. Exact alignment of the press and lubrication of the fit surfaces are also important factors. In a given shop the practice is usually uniform, so that a coefficient of friction and a constant for pressing force may be found which will give fairly uniform results, but will not agree with results in another shop.

The following figures for usual cases are based on the lowest values which the writer has found, and are for reamed holes and ground shafts. Ordinarily the force for pressing is about twice as great, but may be seven times as great. The figures given are computed from the previously given values of S, the radial stress, and the formulas in V using 0.038 as the coefficient of friction.

For a solid shaft, and both parts of steel, and a force fit of one mil per inch of bore, the force for pressing for each inch of hub length and each inch of bore diameter is 0.66 tons for a light hub, twice the bore, and 0.84 tons for a heavy hub, five times the bore, and 0.78 tons for an intermediate hub, three times the bore. For a solid steel shaft and cast iron hub, the figures are 0.38, 0.50 and 0.46 tons.

The total force for pressing is found by multiplying the given numbers by the number of mils per inch of bore force fit, and by the hub length, and by the bore diameter. Or, the total force for pressing may be found by multiplying the numbers given by the total number of mils force fit and by the hub length in inches. That is, for a steel hub 8 inches long with a force fit of 6 mils total, the force for pressing for a medium hub is 0.78×8×6 or 37½ tons. For a cast iron hub 8 inches long with 3 mils total force fit we have 0.46×8×3 or 11 tons.

As remarked, these values are for excellent workmanship; and for an ordinarily good case, the force would be about twice as great. Hence, roughly, the force in tons for an ordinary cast iron hub is the length times the total force fit in mils. The preceding figures are all tabulated in Table I.

NOTATIONS FOR FORMULAS

All dimensions are in inches. All stresses are in pounds per square inch. Compressive stresses are negative and tensile stresses positive.

E = Modulus of elasticity, lb. per sq. in. 29,000,000 for steel, 14,500,000 for cast iron.
V = Poisson's Ratio. 0.3 for steel. Same value taken for cast iron.
Y = Force fit per inch of bore. Excess diameter of shaft over hub bore, in inches, divided by bore in inches.
d_1 = Equivalent diameter of outer ring or hub in inches.
d_0 = Initial diameter of shaft in inches.
d_2 = Equivalent diameter of hole in shaft or inner ring in inches.
d = Diameter at any interior point in inches.
Subscript ($_1$) denotes values for outer ring or hub.
Subscript ($_2$) denotes values for inner ring or shaft.
S = Radial stress at bore, in lb. per square inch, common to both inner and outer rings. This is also the pressure between the two.
S_r = Radial stress at any diameter.
S_t = Tangential stress at any diameter.
μ = Coefficient of friction, or ratio of force for pressing to total radial pressure.
l = Length of hub in inches.

Derivation of Formulas

A general discussion of the derivation of formulas for the case of both parts of the same materials was given by the writer in the previous paper, Trans. A.S.M.E., Vol. 34, 1912, p. 895. By an extension of the same methods, the values for parts of different materials are readily obtained, and give the following general formulas.* The formulas for radial and tangential stress at the bore for the case of a solid shaft agree with those given by Prof. Arthur Morley in *Engineering*, Aug. 11, 1911. The balance of the formulas for parts of different materials with a solid shaft, and all of the formulas for parts of different materials with a hole in the inner ring or shaft, are here published for the first time.

The general formula for radial stress at the bore, for both inner and outer ring, as well as the radial pressure between, is

$$S = -\frac{Y}{\frac{1}{E_1}\left(\frac{d_1^2/d_0^2+1}{d_1^2/d_0^2-1}+V_1\right)+\frac{1}{E_2}\left(\frac{1+d_2^2/d_0^2}{1-d_2^2/d_0^2}-V_2\right)}$$

For the case where the shaft is solid, we put $d_2=0$ in this formula.

The radial stress at any diameter d in the outer ring is

$$S_r = S\left(\frac{d_1^2/d^2-1}{d_1^2/d_0^2-1}\right)$$

The tangential stress at any diameter d in the outer ring is

$$S_t = -S\left(\frac{d_1^2/d^2+1}{d_1^2/d_0^2-1}\right)$$

In this case the product of the two minus signs gives a positive or tensile stress.

The radial stress at any diameter d in the inner ring if there is a hole in it, is

$$S_r = S\left(\frac{1-d_2^2/d^2}{1-d_2^2/d_0^2}\right)$$

The tangential stress at any diameter d_2 in the inner ring if there is a hole in it, is

$$S_t = S\left(\frac{1+d_2^2/d^2}{1-d_2^2/d_0^2}\right)$$

The radial and tangential stress throughout a solid shaft, regardless of diameter, is the above value for S with $d_2=0$.

The tangential strain at any diameter d, that is, the deformation per unit length, is $(S_t-VS_r)/E$. The equivalent simple stress which would produce this strain is

$$(S_t-VS_r).$$

The total increase in diameter at any diameter d is $d\ (S_t-VS_r)/E$.

The equivalent simple stress which would produce the existing shear at any diameter d is the greatest stress if the radial and tangential stresses have the same sign, as is the

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* These were deduced with the assistance of Mr. C. A. Schellens.

case in the inner ring or shaft, and the tangential stress plus the positive value of the compressive stress where they have different signs as in the outer ring or hub.

The values for any particular diameter d_1, d_0, or d_2 are found by substituting it for d in any of the formulas obtained as has been mentioned. By making such substitutions in each of the various cases, there are obtained the following complete collection of explicit formulas for every value in every case.

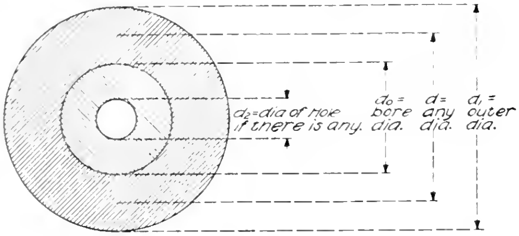

Fig. 5. Diagram of a Force Fit of a Hub or Ring over a Solid or Hollow Shaft

Y = Amount of Force Fit in Inches per Inch of Bore

FORCE-FIT FORMULAS WITH SOLID OR HOLLOW SHAFT OR INNER RING, WITH SAME OR DIFFERENT MATERIALS

I. Formulas for Radial Stress at Bore, S

This is the radial stress at the outside of the inner ring or shaft and the radial stress at the bore of the outer ring or hub, as well as the radial pressure between the rings. The formulas give values for various cases with the same and different materials. This stress must first be computed by the proper one of the formulas, in order to find any other stress.

A. Formulas for radial stress at bore, S, with rings of different materials.

E_1 = Modulus of elasticity of outer ring or hub.
E_2 = Modulus of elasticity of inner ring or shaft.
V_1 = Poisson's ratio of outer ring or hub.
V_2 = Poisson's ratio of inner ring or shaft.

(1). Radial stress at the bore with rings of different materials, when inner ring or shaft has a hole of appreciable size.

$$S = -\frac{Y}{\frac{1}{E_1}\left(\frac{1+d_0^2/d_1^2}{1-d_0^2/d_1^2}+V_1\right)+\frac{1}{E_2}\left(\frac{1+d_2^2/d_0^2}{1-d_2^2/d_0^2}-V_2\right)}$$

(2). Radial stress at the bore with rings of different materials, when shaft has no hole or only a small hole.

$$S = -\frac{Y}{\frac{1}{E_1}\left(\frac{1+d_0^2/d_1^2}{1-d_0^2/d_1^2}+V_1\right)+\left(\frac{1-V_2}{E_2}\right)}$$

B. Formulas for radial stress at bore, S, with rings of same material.

E = Modulus of elasticity.
V = Poisson's ratio.

(3). Radial stress at bore with rings of same material, when inner ring or shaft has a hole of appreciable size.

$$S = -\frac{EY}{2}\left(\frac{(1-d_0^2/d_1^2)\,(1-d_2^2/d_0^2)}{1-d_2^2/d_1^2}\right)$$

Fig. 4 gives values from this formula for $E = 29{,}000{,}000$.

(4). Radial stress at the bore with rings of same material, when shaft has no hole or only a small hole.

$$S = -\frac{EY}{2}(1-d_0^2/d_1^2)$$

The upper curve in Fig. 4 gives values from this formula for $E = 29{,}000{,}000$.

C. Formulas for radial stress at bore, S, with modulus of elasticity of inner ring or shaft twice that of outer ring or hub, but with same Poisson's ratio.

This includes case of steel shaft and cast iron hub.

E = Modulus of elasticity of shaft (steel).
$E/2$ = Modulus of elasticity of hub (cast iron).
V = Poisson's ratio for both shaft and hub.

(5). Radial stress at the bore with a steel shaft and cast iron hub, when the shaft has a hole of appreciable size.

$$S = -\frac{EY}{\frac{2\,(1+d_0^2/d_1^2)}{1-d_0^2/d_1^2}+\frac{1+d_2^2/d_0^2}{1-d_2^2/d_0^2}+V}$$

(6). Radial stress at the bore with a steel shaft and cast iron hub, when the shaft has no hole or only a small hole.

$$S = -\frac{EY}{2}\left(\frac{1-d_0^2/d_1^2}{\frac{3+V}{2}+\frac{(1-V)}{2}\frac{d_0^2}{d_1^2}}\right)$$

Ratio of any like stresses for steel and cast iron hubs on a solid steel shaft, other things being equal

$$= \frac{3+V}{2}+\left(\frac{1-V}{2}\right)\left(\frac{d_0^2}{d_1^2}\right)$$

II. Formulas for Outer Ring or Hub

D. These formulas apply to any one of the six cases above, but in each case the value of S must be inserted from the proper one of the above formulas. The values of E_1 and V_1 are the values for the outer ring or hub. For both *parts of the same material, these become E and V the same as for the inner ring or shaft.*

For hub of cast iron, with steel shaft, E_1 becomes $E/2$ where E is the value for the steel shaft, and V_1 becomes V the same as for the shaft. The formulas below also apply to a cylinder without ends with the internal fluid pressure of S pounds per square inch.

(7). Radial stress at any diameter d

$$= S\frac{(d_1^2/d^2-1)}{d_1^2/d_0^2-1}$$

This gradually decreases from the value S at the bore to zero at the outer diameter d_1.

(8). Tangential stress at the bore

$$= -S\frac{(1+d_0^2/d_1^2)}{1-d_0^2/d_1^2}$$

This is the greatest stress in the outer ring and is therefore the greatest equivalent simple stress according to the maximum stress theory. It is the stress on which the safety of a cast iron hub depends. It is a tensile stress.

(9). Tangential stress at any diameter d

$$= -S\frac{(d_1^2/d^2+1)}{d_1^2/d_0^2-1}$$

This gradually decreases from the value above at the bore to the value below at the outside.

(10). Tangential stress at outside

$$= -S\frac{2}{d_1^2/d_0^2-1}$$

(11). Actual increase in diameter of bore

$$= \frac{-S\,d_0}{E_1}\left(\frac{1+d_0^2/d_1^2}{1-d_0^2/d_1^2}+V_1\right)$$

It is to be noted that $Y\,d_0$ is the amount of force fit, so that the fraction of force fit which the hub expands in general

$$= \frac{-S}{E_1 Y\,(1-d_0^2/d_1^2)}\left[1+d_0^2/d_1^2+V_1(1-d_0^2/d_1^2)\right]$$

For both parts of the same material, the fraction of the force fit which the hub expands

$$= \tfrac{1}{2}\,\frac{1-d_2^2/d_0^2}{1-d_2^2/d_1^2}\left[1+d_0^2/d_1^2+V(1-d_0^2/d_1^2)\right]$$

Fig. 1 gives values from this formula for $V=0.3$.

For an outer part with half the modulus of elasticity of the inner part, as for a cast iron hub and a steel shaft, and for a solid shaft, the fraction of the force fit which the hub expands

$$= \frac{2\,(1+d_0^2/d_1^2)+2\,V\,(1-d_0^2/d_1^2)}{2\,(1+d_0^2/d_1^2)+(1+V)\,(1-d_0^2/d_1^2)}$$

$$= \frac{2.6+1.4\,d_0^2/d_1^2}{3.3+0.7\,d_0^2/d_1^2}\text{ for }V=0.3$$

(12). Greatest equivalent simple stress per maximum strain theory.

$$= -S\left(\frac{1+d_0^2/d_1^2}{1-d_0^2/d_1^2}+V_1\right)$$

This is due to the strain at the bore given by the above formula.

(13). Actual increase in diameter at any diameter d

$$= \frac{-S\,d}{E_1}\left(\frac{d_1^2/d^2+1+V_1\left(\frac{d_1^2}{d^2}-1\right)}{d_1^2/d_0^2-1}\right)$$

This gradually decreases from the value above at the bore to the value below at the outside.

(14). Actual increase of outside diameter d_1

$$= \frac{-S\,d_1}{E_1}\,\frac{2}{d_1^2/d_0^2-1}$$

(15). Greatest equivalent simple stress by the maximum shear theory

$$= -S\frac{2}{1-d_0^2/d_1^2}$$

This is the stress on which the safety of a steel hub depends according to the maximum shear theory, accepted by most authorities. It is at the bore.

For both parts of steel, etc., the greatest equivalent simple stress is that given by the maximum shear theory

$$= \frac{EY\,(1-d_2^2/d_0^2)}{1-d_2^2/d_1^2}$$

Fig. 2 gives values from this formula for $E=29{,}000{,}000$.

For a solid steel shaft with modulus of elasticity, E, and for a cast iron hub with half of this modulus, the greatest stress is to be found by the maximum stress theory, and is the tangential stress at the hub bore

$$= \frac{EY}{2}\,\frac{(1+d_0^2/d_1^2)}{\left(\frac{3+V}{2}+\frac{(1-V)}{2}\frac{d_0^2}{d_1^2}\right)}$$

$$= \frac{EY(1+d_0^2/d_1^2)}{3.3+0.7\,d_0^2/d_1^2}\text{ for }V=0.3$$

This is a tensile stress and must be found to be safe for cast iron in tension.

III. Formulas for Inner Ring or Shaft

These formulas apply to any one of the six cases of I, but in each case the value of S must be inserted from the proper one of the formulas of I. These are either (1), (3) or (5) in Section E and (2), (4) or (6) in Sections F and G.

The values of E_2 and V_2 are the values for the inner ring or shaft. For both parts of the same material these became E and V, the same as for the outer ring or hub. For a steel shaft, with hub of cast iron, the E_2 becomes E the value for steel, and V_2 becomes V the same as for the hub.

E. Formulas for inner ring of shaft when it has a hole of appreciable diameter.

(16). Radial stress at any diameter d

$$=S\left(\frac{1-d_2^2/d^2}{1-d_2^2/d_0^2}\right)$$

This gradually decreases from the value at the outside, S, to zero at the hole diameter d_2.

(17). Tangential stress at outside diameter d_0

$$=S\left(\frac{1+d_2^2/d_0^2}{1-d_2^2/d_0^2}\right)$$

(18). Tangential stress at any diameter d

$$=S\left(\frac{1+d_2^2/d^2}{1-d_2^2/d_0^2}\right)$$

This gradually increases from the value above at the outside to the value below at the inside.

(19). Tangential stress at hole diameter d_2

$$=S\frac{2}{1-d_2^2/d_0^2}$$

This is the greatest stress in the inner ring and is the greatest equivalent simple stress according to the maximum stress, or maximum strain, or maximum shear theory since it is the only stress at the hole diameter. If the inner ring is relatively thinner than the outer ring, that is if $d_2/d_0 > d_0/d_1$, this is greater than the greatest equivalent simple stress in the outer ring by the maximum shear theory.

For both parts of the same material, the tangential stress at the hole diameter

$$=-EY\left(\frac{1-d_0^2/d_1^2}{1-d_2^2/d_1^2}\right)$$

Fig. 3 gives values from this formula for $E=29{,}000{,}000$.

(20). Actual decrease in outer diameter d_0

$$=-\frac{S\,d_0}{E_2}\left(\frac{1+d_2^2/d_0^2}{1-d_2^2/d_0^2}-V_2\right)$$

Hence, the fraction of force fit which the shaft contracts is

$$-\frac{S}{E_2\,Y}\left(\frac{1+d_2^2/d_0^2}{1-d_2^2/d_0^2}-V_2\right)$$

(21). Actual decrease in diameter at any diameter d

$$=\frac{-Sd}{E_2}\left(\frac{1+d_2^2/d^2-V_2\,(1-d^2_2/d^2)}{1-d_2^2/d_0^2}\right)$$

This gradually increases from the value above at the outside to the value below at the hole diameter.

(22). Actual decrease in the hole diameter d_2

$$=-\frac{S\,d_2}{E_2}\,\frac{2}{1-d_2^2/d_0^2}$$

F. Formulas for a solid shaft, or for a shaft with a small hole except for the region close to the hole.

(24). Radial and tangential stress at the outside and throughout all parts of the solid shaft, and at the outside and throughout a shaft with a small hole except for the region very close to the hole

$$=S$$

For a solid shaft this is the greatest equivalent simple stress according to either the maximum stress or maximum shear theory. It is less than the maximum stress in the outer ring or hub.

(25). Actual decrease in outer diameter d_0

$$=-\frac{S\,d_0}{E_2}\,(1-V_2)$$

Hence the fraction of the force fit which the shaft contracts

$$=-\frac{S}{E_2\,Y}\,(1-V_2)$$

(26). Actual decrease in diameter at any diameter d

$$=-\frac{Sd}{E_2}\,(1-V_2)$$

(27). Greatest equivalent simple stress for solid shaft, by the maximum strain theory

$$=S\,(1-V_2)$$

This is due to the constant strain throughout the shaft, given by the formula above.

G. Formulas for a shaft with a small hole, for region close to the hole.

(28). The general values at any diameter d close to the hole must be found by using the formulas (16), (18) and (21) taking account of the actual diameter of the hole d_2. The radial and tangential stresses in all portions of the shaft are very nearly the constant value S given by (2), (4) or (6) until near the hole and then vary quite rapidly as the hole is approached. The smaller the hole, the more rapid the variation. The radial stress changes to zero at the edge of the hole and the tangential stress changes to twice the value for the constant region. Theoretically, for the case of an infinitely small hole, the stresses would change to these values, at the edge of the hole, at an infinite rate.

(29). Tangential stress at the hole, for a shaft with a small hole

$$=2\,S$$

This is the greatest stress in a shaft with a small hole, and is the greatest equivalent simple stress according to either the maximum shear or the maximum stress theory. If we use the maximum shear theory, it is less than the greatest stress in the outer ring or hub.

(30). Actual decrease in diameter at the hole, for a shaft with a small hole

$$=-\frac{2\,S\,d_2}{E_2}$$

(31). Greatest equivalent simple stress for a shaft with a small hole by maximum strain theory

$$=2\,S.$$

This is due to the strain at the hole, given by the formula above.

IV. Complete Formulas for Both Parts of Same Material, with Solid Shaft

These formulas are obtained by substituting the value of radial stress at bore S from (4) in all of the formulas II and III. They are listed because this case is most common. The complete formulas for the other five cases could be obtained in the same way, and need not be here listed.

E = Modulus of elasticity.

V = Poisson's ratio.

H. Formulas for outer ring or hub with both parts of same material, and solid shaft.

(4). Radial stress at bore, and radial pressure between rings

$$S=-\frac{EY}{2}\;(1-d_0^2/d_1^2)$$

The upper curve in Fig. 4 gives values from this formula for $E=29{,}000{,}000$.

(32). Radial stress at any diameter d

$$=-\frac{EY}{2}\;(d_0^2/d^2-d_0^2/d_1^2)$$

(33). Tangential stress at bore

$$=\frac{EY}{2}\;(1+d_0^2/d_1^2)$$

This is the greatest equivalent simple stress according to the maximum stress theory, and applies when both parts are cast iron. It is a tensile stress.

(34). Tangential stress at any diameter d

$$=\frac{EY}{2}(d_0^2/d^2+d_0^2/d_1^2)$$

(35). Tangential stress at outside,

$$=EY\frac{d_0^2}{d_1^2}$$

(36). Fraction of force fit which hub expands

$$=\tfrac{1}{2}\,(1+d_0^2/d_1^2+V\;(1-d_0^2/d_1^2)\,)$$

The upper curve of Fig. 1 gives values from this formula for $V=0.3$.

(37). Greatest equivalent simple stress by the maximum strain theory

$$=\frac{EY}{2}\,(1+d_0^2/d_1^2+V\,(1-d_0^2/d_1^2)\,)$$

(38). Actual increase in diameter at any diameter d

$$=\frac{Yd}{2}(d_0^2/d^2+d_0^2/d_1^2+V(d_0^2/d^2-d_0^2/d_1^2)\,)$$

(39.) Actual increase of outside diameter d_1

$$=Y\;d_0^2/d_1$$

(40). Greatest equivalent simple stress

$$=EY$$

This is the stress on which the safety of the system depends according to the maximum shear theory, and applies when both parts are steel.

I. Formulas for solid shaft, with both parts of same material.

(41). Radial and tangential stress at outer diameter, d_0, and at all other diameters,

$$S=-\frac{EY}{2}\,(1-d_0^2/d_1^2)$$

This is the greatest equivalent simple stress in the shaft according to either the maximum stress or maximum shear theory.

(42). Fraction of force fit which shaft contracts

$$= 1/2\,(1 - d_0^2/d_1^2)\,(1 - V)$$

(43). Actual decrease in diameter of any diameter d

$$\frac{Yd}{2}\,(1 - d_0^2/d_1^2)\,(1 - V)$$

(44). Greatest equivalent simple stress per maximum strain theory

$$= -\frac{EY}{2}\,(1 - d_0^2/d_1^2)\,(1 - V)$$

V. Force for Pressing

These formulas apply to any case. The value of S, the radial stress at the bore, must be inserted from the proper one of the formulas (1), (2), (3), (4), (5) or (6).

μ = Coefficient of friction, or ratio of force for pressing to total radial pressure.

d_0 = diameter of bore in inches.

l = length of hub in inches.

$$\text{Force for pressing in tons} = -\frac{\pi}{2000}\mu\, d_0\, lS.$$

The value of the coefficient μ varies greatly according to the character of the surface, lubricant, and (most important of all) the truth of the surfaces. For a well ground shaft and reamed hole, μ is about 0.038. For other cases it may be 2 to 7 times this value.

Force for pressing in tons, for excellent workmanship $= -0.00006\, d_0 lS$. (This is for $\mu = 0.038$.) For good workmanship the force may be about twice this value, and for poorer workmanship up to about seven times this value.

VI. Formulas for a Thin Ring Inside or Outside a Heavy Hub or Shaft

This is the case where a thin bushing is forced in a hub, or a thin sleeve is forced over a shaft. The sleeve or bushing is supposed to be so thin compared with the hub or shaft that no appreciable stress is produced in the latter.

The inside and outside diameter of the thin ring are supposed to be nearly alike. Cases where the diameters differ appreciably require the formulas previously given.

For this case, the radial pressure on the thin ring, and the radial stress in it, and the force for pressing are all very small. The tangential stress is constant throughout the thin ring and is practically the only stress existing. Hence it is a simple stress and gives the criterion for safety.

E = Modulus of elasticity of thin ring.

Y = Force fit in inches per inch of bore.

EY = Tangential stress

BIBLIOGRAPHY

Fits and Fittings—Stanley H. Moore—Trans. A.S.M.E., vol. 24, 1903, p. 1158. (Refers to articles by Prof. Wetmore and F. C. Kelly in Vol. 22, *American Machinist.*)

A Record of Pressed Fits—C. F. MacFill—Journal A.S.M.E., 1913, p. 1657. (Refers to article by Prof. Arthur Morely, *Engineering*, Aug. 11, 1911.) Discussion, Journal, A.S.M.E., March, 1914.

Increase of Bore of High Speed Wheels by Centrifugal Stresses—S. A. Moss—Trans. A.S.M.E., vol. 34, 1912, p. 895.

Elastic Limit with Compound Stresses—S. A. Moss—*Machinery* (New York), Aug., 1914.

Messrs. C. A. Schellens and W. G. Fisher of the Lynn Works of the General Electric Company have furnished the writer with much mathematical and force fit data respectively.

A NEW METHOD OF ARTIFICALLY LOADING GENERATORS FOR TEST

By Robert Treat

Power and Mining Engineering Department, General Electric Company

The method described in this article for loading a generator is classified as "new" not so much in reference to its date of origin as to its relation to the engineering profession. The value of the method will be apparent on reading the article which explains the advantages of the method, furnishes a summary of instructions for using it, and describes how to overcome any difficulties that may be encountered in it.—Editor.

In making tests on hydro-electric plants, it is quite frequently found necessary to provide artificial loads for the generators. In such cases it has been the general practice to use a liquid rheostat formed by placing the electrodes in either the forebay or the tailrace, according to convenience, or sometimes in a special tank with salt solution. Such an apparatus, besides having numerous troubles of its own, produces only a unity power-factor load; whereas the majority of generators are designed for operation at about 0.8 power-factor. A scheme free from the objections to the liquid rheostat method was first made public in a paper on the Huronian Company's Power Development by Robert A. Ross and Henry Holgate, read before a joint meeting of the Mechanical and Electrical Sections of the Canadian Society of Civil Engineers, April 25, 1907. Since then the method has been used a number of times in various tests by R. A. Ross & Company, Consulting and Supervising Engineers, of Montreal. Through the courtesy of Mr. J. Norman Smith, Chief Engineer of that Company, the writer has been given the most important details from its experience; and these are now published for the benefit of any who may desire to use this method.

This same scheme was independently originated and successfully used by Mr. O. H. Ensign, Chief Engineer of the United States Reclamation Service, in testing the generators at the Cross Cut Hydro-electric Station, Salt River Project, accounts of which have occured in the technical press.*

With these exceptions, this method of loading generators does not seem to be as generally known as its merits justify.

The scheme is exceedingly simple, and consists merely in connecting another generator (when one is available) to the machine under test, with one phase reversed, so that the load generator runs in the opposite direction of rotation as a synchronous motor. When both machines are up to speed and are excited to full voltage, the gates of the wheel which is motoring are gradually opened until the required load is obtained, the wheel in this case acting as a water brake. The generator and motor fields may now be varied to produce any power-factor and voltage desired.

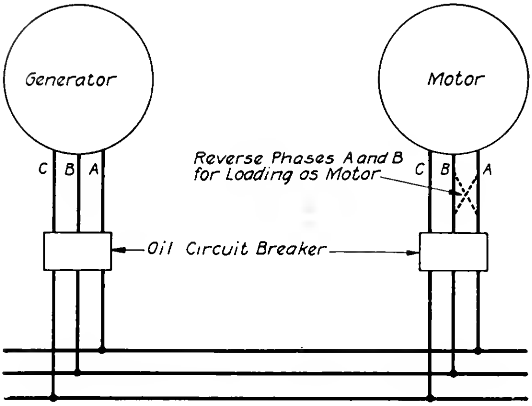

Fig. 1.

The following instructions prepared by R. A. Ross & Company for the guidance of its men are of interest:

INSTRUCTIONS FOR RUNNING WATER-WHEEL GENERATOR-MOTOR TEST

1. Transpose any two legs of the motor leads (this will reverse the direction of rotation of the motor; see Fig. 1: say place *B* in *A* and *A* in *B* on the motor leads).

2. Close the main generator switches connecting the generator and the motor electrically together.

3. Excite both the generator and the motor.

4. Admit water to the generator wheel only, until both machines are turning over.

5. Note that the motor is operating in the reverse direction to that which it would operate as a generator.

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* *Engineering News*, April 20 June 22, 1916.

6. Raise the voltage and the speed of the generator to normal by operating its field rheostat and by admitting water to the generator wheel.

7. Admit water slowly to the motor waterwheel to act as a brake, as required, to secure any desired load on the generator up to its wheel capacity.

8. Vary the field excitation on the generator and the motor to secure any desired power-factor.

9. The generator instruments will indicate the output of the generator; the instruments on the motor need not be taken into consideration.

10. If the exciters are directly connected to each generator and one exciter is not sufficient to excite the two machines, it will be necessary to reverse the exciter connection on the motor exciter to suit the reversal of direction of rotation.

11. The governor mechanism should be disconnected from the motor, as it might be damaged by reversal of rotation, but an operator should be in attendance, to shut off the water to this wheel, in case of the circuit opening to the motor, when the water passing into the motor waterwheel would stop same, and reverse direction of rotation, causing it to speed up rapidly and possibly run way.

12. By acutal operating conditions it has been found that quite a small gate opening on the motor waterwheel is all that is necessary to produce full load on the generator under test.

A few of the troubles experienced by others are noteworthy. One most important point is to have the draught tube of the motoring unit filled with water before attempting to start; otherwise the hunting and surges set up by the wheel revolving against a load which is intermittent rather than steady may trip the oil circuit-breakers, or cause the machine to break from synchronism. On starting, the motoring unit cannot be started from its own wheel, as it would then run in the wrong direction. Usually two duplicate machines can be started together from rest, as described in the foregoing instructions; viz., by exciting both fields, connecting the armatures together, and admitting water to the generator wheel until it starts. The low-frequency currents produced in the generator armature will then drag along the field of the motoring unit and the two machines will run in synchronism from the start. Trouble may occasionally be encountered due to high static friction in the bearing of one or both machines. This would necessitate opening the generator wheel-gate so wide, in order to "break it from rest," that the resultant large amount of water would cause the generator to accelerate too rapidly and it would break from synchronism with the motor. This may be overcome, in some cases, by starting the machine as a plain induction motor; i.e., by not exciting the motor field until it is partly up to speed. If this is not successful, the gates of both units may be opened just enough to start them turning over, *without* switching them together. As soon as the units start revolving, the gates should be closed and field applied to whichever unit is necessary to make them come to rest *at the same instant*. Just before they stop they should be switched together, fields applied to both machines, and the generator gate opened until they start together. This procedure will eliminate the high static bearing friction and no difficulty should then be experienced in getting started. It is doubtful if much trouble will be encountered with horizontal units; but vertical machines, expecially those equipped with Kingsbury or plate-type thrust bearings, are likely to be obstinate. Is should be particularly noted that Kingsbury bearings are usually designed for *one direction of rotation only*, and some care must be taken when applying the test herein described to machines equipped with them. However instances are known, particularly the tests at Cross Cut previously mentioned, where Kingsbury bearings have been run backward without any apparent distress.

The question may be raised as to what effect this method of testing will have on the water wheels; whether impelling them directly against the flow of water will not result in strains and distortions that may be injurious. The writer has referred this subject to a number of the most prominent waterwheel builders in the United States, and very few have cared to make any very definite statements on this point. The consensus of opinion, however, seems to be that there is little question of harmful stresses in high-head wheels, but there may be some doubt as to low-head units. The writer would recommend conferring with the waterwheel builders in each individual case where this method of test is being considered. It is believed that when this method shall have become better known and more generally used, wheel builders will be less conservative about approving it.

For much of the information of interest and value appearing in this article the writer desires to express his appreciation to Mr. W. A. Doble, Chief Engineer of the Pelton Waterwheel Co.; to Mr. J. Norman Smith; to Mr. O. H. Ensign; and to various waterwheel builders through their engineering organizations.

LAMP SALES OF THE EDISON LAMP WORKS DURING 1916

By Henry Schroeder

Assistant to Sales Manager

This short article is of interest from the fact that lamp sales afford a fair indication of the industrial activity of the country over a period of time. The number of Edison lamps sold during the year 1916 exceeded the sales for the previous year by almost fifty per cent, even though the lamp business for 1915 was larger than for any previous year. The small hand flash lamp and the automobile have been mainly responsible for the very large increase in the use of miniature lamps.—Editor.

The total business, seventy-three and one-half million lamps, is the largest in the history of the Edison Lamp Works, and an increase of more than one-third over the previous year. Approximately one-third was sold direct to central stations, one-third direct to street railways and other purchasers, and the remaining one-third through jobbers and dealers as agents.

The sale of Mazda lamps, a total of sixty-two and a half million, is nearly seven-eights in numbers and about nine-tenths in value of the total business, and is also the greatest in any year, being a gain of approximately 50% over the previous year. Practically two-thirds of the Mazda lamps sold were of the large style. The sale of miniature Mazda lamps gained more than 60 per cent in number over 1915.

LAMP SALES IN 1916

Type	Numbers of Lamps	Percent of Total Numbers	Approximate Percent of Total Value
Large Mazda	44,000,000	60	90
Miniature Mazda	18,500,000	25	
Gem	7,750,000	10-½	7
Carbon	3,250,000	4-½	3
Total	73,500,000	100	100

The seven and three-quarter million Gem lamps sold is about 25 per cent less than for the year previous. The number of carbon lamps sold (which includes the small amount of miniature carbon lamps) is about a million lamps more than in 1915, but now represents in value only about three per cent of the total business. In 1906, when carbon lamps were practically the only ones sold, they reached their maximum sale of about thirty million lamps.

These figures are diagramatically shown in Figs. 1 and 2.

Reasons for the increased sales of lamps have been analyzed as follows:

General increases due to improved trade conditions—new buildings, factories, stores, etc.

Increase in large Mazda lamp sales due to replacing burned out carbon and Gem lamps with Mazda lamps.

Increase in miniature lamp sales due to increased use of flashlights and automobiles.

Decrease in Gem lamp sales due to central stations discontinuing the free renewal of these lamps.

The majority of Gem and carbon lamps sold are of the 50 and 60-watt sizes, and it is expected that the demand for these lamps will soon cease to exist.

The large size Mazda lamps for standard lighting service include a variety of sizes, the more commonly used Mazda B (vacuum) lamps being the sign lamps and the 25, 40, 50 and 60-watt lamps. Mazda C (non-vacuum) lamps for standard lighting service are most popular in the 75 and 100-watt sizes. For street series lighting service Mazda C lamps are practically the only ones in demand. Carbon and Gem series lamps have not been manufactured for several years.

Large Mazda lamps are also made for a variety of other uses, such as decorative purposes (in round and tubular bulbs), show-case lighting, street railway cars, steam railroad train lighting service, floodlighting of buildings, locomotive and street railway headlights, stereopticons, etc.

During the year 1916 the number of Mazda C lamps sold totaled about three and one-half millions compared to one and a half millions in 1915. While this is only 8 per cent of the lamps sold, their value represents about 30 per cent of the total large Mazda lamp business of 1916.

Nearly a million lamps for street series lighting service were sold in 1916 as against half a million in 1915. That the average candle-power of series lamps has increased is shown by the fact that in 1915 20 per cent, and in 1916 27 percent of the lamps sold were of 250 candle-power and over.

The eighteen and a half million miniature Mazda lamps sold is, in round numbers, divided as follows:

1916 MAZDA MINIATURE LAMP SALES

Service	Number
Automobile	5,750,000
Flashlight	10,500,000
Candelabra	500,000
Christmas Tree	1,750,000
Total	18,500,000

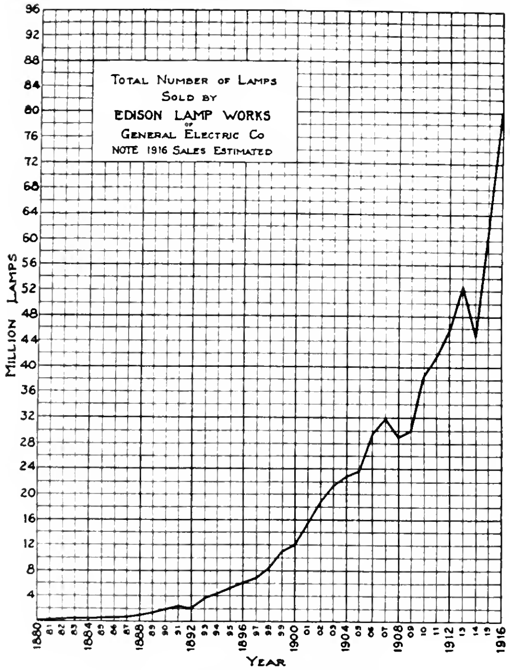

Fig. 1. Total Number of Edison Lamps Sold in the United States, 1880-1916

The Mazda Christmas tree lamps were first put on the market about September first. They are made in a variety of colored imitations of various fruits, flowers and animals. A small clear round bulb lamp is also made for this purpose, which has been very popular. They are 14-volt lamps intended to burn eight in series on 110-volt circuits, and can be burned in series with carbon Christmas tree lamps.

The sales of flashlight lamps in 1916 were twice the number in the previous year.

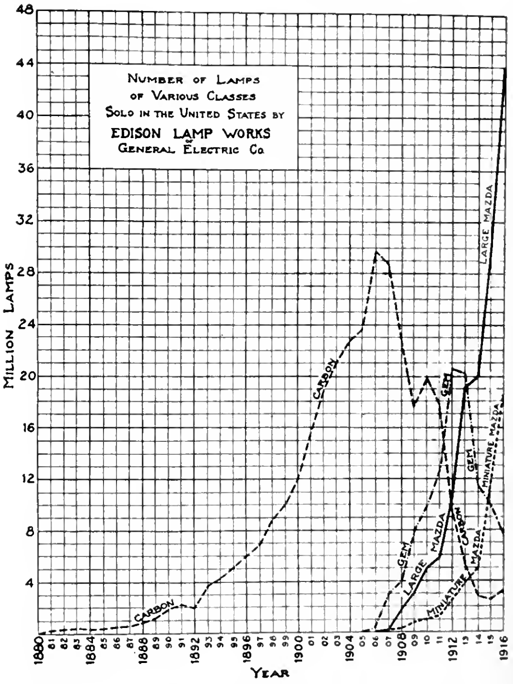

Fig. 2. Number of Edison Lamps of Various Classes Sold in the United States, 1880-1916

GENERAL ELECTRIC REVIEW

A MONTHLY MAGAZINE FOR ENGINEERS

Manager, M. P. RICE
Editor, JOHN R. HEWETT
Associate Editor, B. M. EOFF
Assistant Editor, E. C. SANDERS

Subscription Rates: **United States and Mexico, $2.00 per year; Canada, $2.25 per year; Foreign, $2.50 per year; payable in advance. Remit by post-office or express money orders, bank checks or drafts, made payable to the *General Electric Review*, Schenectady, N. Y.**

Entered as second-class matter, March 26, 1912, at the post-office at Schenectady, N. Y., under the Act of March, 1879.

VOL. XX., NO. 5

MAY, 1917

CONTENTS

THE NATIONAL CAPITOL

The beauty of this building was wonderfully emphasized by the flood of light directed on it during Inauguration. Other views and a description of the lighting installation will be found on pages 417 to 420

GENERAL ELECTRIC REVIEW

THE WORLD'S RAILWAYS AND ELECTRIFICATION

Three of the articles presented in this issue of the Review deal with the important subject of steam railroad electrification, those by Mr. Beeuwkes and Mr. Hare having special reference to the Chicago, Milwaukee & St. Paul Railway, and the third by Mr. Armstrong bearing upon the relation of railway electrification to the conservation of our natural resources.

In connection with these papers, a brief glance at the electrification situation may be of interest. There are in the Americas today roughly 358,000 miles of railroads operating with steam locomotives as compared with about 217,000 miles in Europe and 117,000 miles in Asia, Africa and Australia. The electrified divisions of steam railroads in the United States which may properly be classed as trunk line electrifications aggregate approximately 2500 miles, or more than double the steam road conversions in Europe.

Soon after the successful operation of Sprague's first trolley car at Richmond in 1887, electrical enthusiasts began to aspire to the electrification of our existing railroads. The Baltimore & Ohio put the first steam road electrification into operation in 1895 hauling heavy passenger and freight trains through a series of tunnels from the Camden Station northward a distance of 3.7 miles. The next step of importance was the equipment in France of the Paris-Orleans Railway in 1900 with electric locomotives for subway terminal service.

In the early 1900's, several steam roads in England and United States resorted to multiple unit trains for heavy suburban passenger service, but the next large installation of electric locomotives was on the New York City terminals of the New York Central and the New Haven Railroads.

Up to this time electrification had been adopted mainly to obviate the smoke nuisance and to facilitate the handling of heavy suburban passenger traffic. Economic reasons were advanced as secondary considerations and it was difficult to secure sufficient operating data to bear out claims of more economical operation for electric equipment.

In 1913, however, the Butte, Anaconda & Pacific Railway purchased electrical equipment to supplant the heavy steam locomotives used for hauling ore trains between Butte and Anaconda with the definite intention of reducing operating expenses over and above reasonable charges against the increased investment. As was shown in tables published in the November 1914 issue of the Review, the economies due to electrification exceeded the predictions of engineers, and this showing largely influenced the decision of the directors of the Chicago, Milwaukee & St. Paul Railway to electrify its 440-mile section of mountain railroad.

The actual operating data from electrifications abroad have been negligible and the character of all earlier projects precluded definite comparisons, so that data on the Butte, Anaconda & Pacific Railway have been especially illuminating. In this issue we are publishing the first data secured from the electrical operation of the Chicago, Milwaukee & St. Paul Railway which will doubtless receive the careful scrutiny of both railway operators and electrical engineers. From these preliminary data there is every reason to believe that figures for a longer period will be wholly favorable to electric train haulage.

That the results are eminently satisfactory to the railway officials is attested by the decision of the directors to make further conversion, as recorded in Mr. K. R. Hare's article in this issue. The description of the projected extension from Othello to the coast cannot fail to create the impression that the railway officials are relying upon electrification to solve the most trying problems of railway operation.

OPERATING RESULTS FROM THE ELECTRIFICATION OF THE TRUNK LINE OF THE C., M. & ST. P. RY.*

By R. Beeuwkes

Electrical Engineer, Chicago, Milwaukee & St. Paul Railway

Railway officials and the engineering fraternity the world over have evinced great interest in the electrification of the Chicago, Milwaukee & St. Paul Railway and statements giving comparative results between steam and electrical operation will be subject to careful study. In an article in our issue of November 1916, Mr. C. A. Goodnow, Assistant to the President of the Chicago, Milwaukee & St. Paul Railway, gave a general summary of the advantages which have been secured by electrification, which constituted an unqualified endorsement of the project. While the data included in Mr. Beeuwkes' article cover a period of only three months each for the years 1915 and 1916, the information is given in such detail as to allow a very satisfactory comparison. In several cases the author has noted the fact that the data given are perhaps too favorable for steam operation. From the apparent willingness of the Railway Company to authorize the publication of operating data, it may be expected that after a full year of electrical operation figures will be published which will still further emphasize the superiority of electricity over steam for trunk lines railways.—Editor.

The first electric locomotives were placed in operation on the Rocky Mountain Division of the Chicago, Milwaukee & St. Paul Railway on December 9th, 1915, between Deer Lodge and Three Forks. In April 1916 electrical operation was extended to Harlowton on the east and early in 1917 the entire 440 miles was equipped for electrical operation.

The 440-mile electrified section is now divided into two operating divisions of which only one, the Rocky Mountain Division, has been running long enough to get reasonably reliable data concerning operation. I may say, however, that on the Missoula Division we have been handling 3000-ton trains as a standard through the worst winter months, and the entire operation is working out very successfully.

Fig. 1. Substation at East Portal showing Snow Conditions in the Bitter Root Mountains

Fig. 2. Substation and Bungalows at Avery, the Western End of the Present Electrification

Although the figures for electric operation are very favorable, it should be remembered that they can hardly as yet be considered as final, because the steam figures represent the results of many years of effort and experience, while those for electricity are based on the use of apparatus that is entirely new in important respects, and on an operating experience of less than a year.

With regard to the operating organization, substation operating forces and line and locomotive maintenance forces have been added, but otherwise no change, except in the way of reduction as will be described, has been made in the original steam organization and personnel. This includes the engineers and their helpers on the locomotives.

The change from steam to complete electric operation was made in the course of a few months with remarkable facility, its rapidity being governed entirely by the rate at which the manufacturer was able to supply the electric locomotives. The instruction of the engineers was done by having four or five General Electric men on the ground who had assisted in testing the locomotives at the works and who were thoroughly familiar with the electrical details. These men spent all their time for some months riding the different locomotives and explaining their electrical operation to the engineers, this being done on trains in regular operation.

Harlowton is the eastern terminus of the Rocky Mountain Division and the station where electric operation begins. Here are located the usual roundhouse facilities, a portion of which has been partly reconstructed

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* Paper read March 16, 1917, before the New York Railroad Club.

to accommodate the electric locomotives. Three Forks separates the division into the East and West sub-divisions, and was a former steam engine division point. Deer Lodge is the western terminus of the Rocky Mountain Division.

Under steam operation engines were changed at Deer Lodge, Three Forks and Harlowton; thus, a steam locomotive made about 113 continuous miles. At the end of this run it was put in the roundhouse or shop to have it cleaned, boilers washed, etc. and for any light repairs. All heavy repairs were made at Deer Lodge. This necessitated a large roundhouse and shop force at each of the three points mentioned. Freight trains were tied up in the yards and there were the other usual costly and vexatious delays. All train and engine crews changed at each of the through subdivision points mentioned except passenger train crews, who ran through from Deer Lodge to Harlowton. Under steam, the cabooses and many of the engines were assigned, which of course made it necessary to take the caboose from the train at each subdivision point.

With the introduction of electricity we were able to double what I may call the cruising radius of our locomotives. As far as the railroad is concerned we have eliminated Three Forks entirely. All locomotives run the entire 226 miles from Deer Lodge through to Harlowton with only a light inspection of bearings and pantographs at Three Forks. The shop and roundhouse are entirely closed down, seven or eight miles of tracks have been removed, and the comparatively large roundhouse force previously employed has been replaced by a single electrician. All locomotives and cabooses are pooled, the men being given suitable locker space to store their lanterns, flags, tools, etc. Through freight trains do not leave the main track and often are not switched at all. At Harlowton the engine is given a rough inspection and any light repairs made that are necessary. Detailed inspection and maintenance work is done at Deer Lodge.

The same change in operation has been effected on the Missoula Division, Avery to Deer Lodge; in this case Alberton being the steam engine division point which has been eliminated.

Comparison of Passenger Train Delays

Table I shows, for the Rocky Mountain Division, a comparison of passenger train delays for October, November and December under steam operation in 1915 and electric operation in 1916. These data are considered important not merely because they indicate the comparative reliability itself of service under the two systems, but because the item of reliability has such an important bearing on the general relative performance and economy.

The data are given for passenger service only, as freight records are not kept in such shape that such data can readily be derived from them.

The passenger service consists regularly of two heavy steel 8-car through trains each way per day, and one 3-car local each way between Butte and Harlowton.

In considering the data, two points should be borne in mind; first, that the schedule time of the through trains under electricity was reduced forty minutes from that under steam; second, that the table shows, for both systems, net minutes delay only; i.e., all delays or portions of delays that were made up do not appear.

Comparative data are shown for only three months, as complete electric passenger service only went into effect shortly before October. For some of the items listed, particularly an item of the nature of "Accidents and Derailments," this is entirely too short a period on which to base reliable comparisons, and these items are included merely to make the records complete.

It should also be borne in mind that during the months of electric operation the amount of freight business done was for one month 40 per cent and for three months 29 per cent greater than the corresponding months of steam operation, a circumstance which renders the electrical showing, as shown on the slide, all the more favorable.

It will be noted from Item 31 that the number of trains run under steam and electricity, respectively, is practically the same.

The first four items indicate, among other things, that the dispatcher is better able under electric operation to plan and predict train movements. This may be accounted for on the basis of less variation in speed, fewer number of trains for a given business (that is, freight trains), and fewer trains delayed. In any event, in these three corresponding months steam passenger trains waited for the right-of-way 1910 minutes as against 254 minutes for electric trains.

Item 5 is Extra Mail, Baggage and Express, meaning that the trains were delayed the time shown because it took longer to load or unload the baggage, mail or express than the time allotted.

Item 6, Extra Cars, means simply extra heavy trains. Delays on this account were only one ninth as great under electricity as under steam. Our electric engines will handle ten or eleven steel cars on the 2 per cent Piedmont grade very comfortably.

Item 7, Excess Time Switching Cars, is self-explanatory. The cars referred to are generally extra coaches or business cars.

Items 8 and 9, which are respectively Extra Stops for Passengers and Railway Crossings, are self-explanatory.

Item 10, Electric Block Signal at Danger, is included for the sake of completeness. The original direct current signal system, as already stated, had to be changed to alternating current when we changed to electricity for operating, and the new signal system is not yet in final working order or completely installed.

Item 11, Slow Orders, has the usual significance.

TABLE I

ELECTRIFICATION DEPARTMENT

Passenger Train Delays under Steam Operation in 1915, and under Electrical Operation in 1916

	Rocky Mountain Division Time in Minutes	October		November		December		Total	
		Steam	Electrical	Steam	Electrical	Steam	Electrical	Steam	Electrical
1.	Blocked Behind Passenger					57		57	
2.	Blocked behind freight	42	15	8		274	15	324	30
3.	Meeting passenger	102	17	504	45	647	162	1253	224
4.	Meeting freight	73		77		126		276	
5.	Extra mail-baggage express			26		327	167	353	167
6.	Extra cars	37	15	9		149	26	195	41
7.	Excess time switching cars	48		99	20	93	98	240	118
8.	Extra stops for passengers					25		25	
9.	Railway crossing	26		5		167		198	
10.	Electric block signal at danger			67		10	82	77	82
11.	Slow orders	14				5		19	
12.	Bad weather conditions			235		210		445	
13.	Poor coal	—		36		80		116	
14.	Hot bearings engine		112	58	14	21	515	79	641
15.	Other conditions, engine	98	42	205	200	230	555	533	797
16.	Hot bearings, car			54	40	65	95	119	135
17.	Other conditions, Car	270	15	47	100	345	225	662	340
18.	Accidents and derailments	1302	767	357	895	391	1425	2050	3087
19.	Other causes, Note 1		618		394	177	128	177	1140
20.	Total minutes delayed	2012	1601	1787	1708	3399	3493	7198	6802
21.	Total number of trains delayed	24	17	49	24	84	40	157	81
22.	Total number of trains making schedule time	121	118	98	105	81	84	300	307
23.	Total number of trains making up time	43	51	33	50	21	62	97	163
24.	Total time made up	885	1436	547	1691	378	1640	1810	4767
25.	Due mechanical features, locomotive heaters		139		14		710		863
26.	Due electrical features locomotive		25		100		45		170
27.	Due overhead		335		90		108		533
28.	Man failures with electrical apparatus		200						200
29.	Total due electric operation		699		204		863		1766
30.	Per cent electrical to total delays		43.6		11.9		24.9		26.0
31.	Passenger train miles	39426	40169	41276	40549	38628	38519	119330	119237
32.	Minutes delay per 100 train miles, total	5.1	3.99	4.35	4.22	8.70	9.05	6.03	5.70
33.	Minutes delay per 100 train miles, electrical		1.74		.50		2.24		1.48

NOTE 1. Bad order trolley—failure of power—snow or rock obstructions—failure of gas at terminals, etc.

Item 12, Bad Weather Conditions. In speaking of bad weather conditions in our electrified territory we generally have in mind extremely low temperature, sometimes forty or fifty degrees below zero in places for days at a stretch, or the heavy snows which occur in the Bitter Root Mountains.

Under steam operation the cold weather conditions were at times very serious, resulting in entire temporary suspension of service, particularly freight on account of reduction of steaming capacity or the freezing up of locomotives. The electric locomotives on the contrary, as was to be expected, are not affected by the cold weather, and the contrast with steam operation is truly remarkable and a source of great gratification to our operating department. Instead of the capacity of the electric locomotive being reduced on account of the cold, it is increased on account of the lessened heating of the motors. It might have been expected that such low temperatures would result in many trolley and transmission troubles due to contraction of wires and cables, but the construction is particularly suited to such conditions and we now have but little trouble on this score.

The table shows 445 minutes delay to passenger steam engines, although during the cold weather many of the trains had to be run double-headed. We have never, under any conditions, required the use of more than one electric engine on any passenger train.

Item 13, Poor Coal. Electric operation is not influenced by this condition.

Item 14, Hot Bearings, Engine. Of the 555 minutes charged to electric operation in December, 70 are due to one case where a cellar pin came out of one of the bearings of the leading truck, so that the figures do not really represent average comparative results. We have had more trouble with electric motor bearings than we expect to have ultimately, as there has been some difficulty in obtaining proper lubricant and the packers have had to acquire new experience in handling the high speed bearings involved.

Item 15. This includes miscellaneous conditions not included in the preceding items. In connection with the electric engines, much of the delay was due to difficulties with the flash boiler and parts used for train heating. A great deal of experimental work has been and is still being done on this apparatus, which is the only portion of the locomotives not as yet entirely successful. In Item 15 are also included time lost due to inattention on the part of round-house attendants, resulting in insufficient supply of oil or water for the heating apparatus, time lost on account of using freight locomotives for

Fig. 3. 100,000-Volt Transmission Tower for Long Span

Fig. 4. Standard 100,000-Volt Wood Pole Transmission

hauling passenger or milk trains and the like, or trouble with electrical or mechanical parts.

Item 16, Hot Bearings, Car. Self explanatory.

Item 17, Other Conditions, Car. On account of regenerative braking there has been a marked reduction in delays due to repairing brake rigging and changing shoes.

Item 18, Accidents and Derailments. These, of course, are accidents and derailments occurring to other trains and delaying the passenger trains. This item is very much higher for electricity than for steam, which would be expected, considering the longer trains, the newness of the electric operation, and the fact that the existing great shortage of freight cars has required keeping or putting in service equipment whose condition would ordinarily not warrant its use. The real facts, however, are, that these accidents and derailments occur so seldom that a much longer period than 3 months must be taken to arrive at any accurate comparative results.

Item 19, Other Causes. Other things being equal, this item would necessarily be higher for electricity than for steam, as it includes delays due to all troubles in the electric system exclusive of the locomotives. Of these electrical troubles most are due to the pantograph in some way fouling the overhead construction either because of the trolley wires or the track getting out of alignment, or one track rail being low. Failure of power, either on trolley or transmission side of sub-stations, except for the interval required to throw in an automatically opened circuit breaker, is practically negligible.

It will be noted from Item 21, that the minutes delay attributable to the electric system, outside of the locomotives, amounts to about 8 per cent of the whole.

In this connection it might be stated that the best organization of maintenance forces and means of transporting these forces to the location of troubles has not yet been determined upon and the percentage of delays due to trolley troubles is therefore considerably higher than we ultimately expect it to be. Also the troubles themselves should diminish, as not only were our poles set in all kinds of weather conditions, but also much new rail was laid and ballasting done during the process of electrification, and it will take some time before the poles and track get finally settled into permanent position.

Item 20, Total Minutes Delayed. It will be noted that the total minutes delayed is about the same for the two systems, but the number of trains delayed, Item 21, is reduced about 40 per cent under electricity. (Of the trains delayed under electricity about 85 per cent were delayed about the same length of time as the average steam train was delayed, the remaining 15 per cent suffered considerable delay mainly on account of accidents and derailments to other classes of trains.) Item 22 shows that about the same number of trains ran in schedule time under steam and electricity, while the number of trains making up time increased about 60 per cent and the time made up about 150 per cent under electricity.

Item 25, Due Mechanical Features of Locomotive; Item 26, Due Electrical Features; Item 27, Due Overhead (Meaning the electric system outside of the locomotives); and Item 28, Man-failures, give the delays due to electric operation in more or less detail as reported by the electrical master mechanic.

The mechanical features include mainly train heaters, as already referred to, bearings, pantographs and air system. Delays due to electrical features are comparatively slight, a rather surprising and gratifying fact considering the number of new features, such as the use of 3000 volts direct current and direct current regeneration, which are incorporated in the locomotive, and further, considering that only a year ago the engineers operating these locomotives were all driving steam engines.

Item 27, Due Overhead, has already been referred to. I might say in this connection that the double trolley wire construction as used by us has proved very successful, absolutely sparkless collection of current being obtained under all conditions of speed and amount of current. Items 29, Total Due Electric Operation, and Item 30, per cent Electrical to Total Delays, show that 26 per cent of the total delays were attributable to the electric system as a whole.

The general inference to be drawn from the data given is that the electric service is at least as reliable as the steam and bids fair to ultimately become considerably more reliable.

Comparison of Steam and Electric Locomotive Performance

Table II shows, for the Rocky Mountain Division, a comparison of locomotive performance for October, November and December under steam operation in 1915 and electric operation in 1916. It should be understood that the figures given, while sufficiently correct for comparative purposes, as they are taken from the same report forms, are not to be considered as strictly accurate when considered individually, the forms being those from which the data could most conveniently be obtained in the short time available.

Taking first the passenger data: As already described, passenger service in this division consists of two through trains each way daily and one local each way. The local ran between Deer Lodge and Harlowton during one part of these three months and between Butte and Harlowton during the remaining part. This fact, and the running of special trains, accounts for the slight variation in Train Miles of Item 1. It will be noted that the total miles under steam and electricity were almost exactly the same.

Item 2, Helper Engine Miles, increased under steam as the temperature decreased; but this service with its extra crew cost, switching delays, etc., has been eliminated under electricity. It should be noted that the figures given do not contain any allowance for return trips of helpers down the mountain.

Item 3, Number Engines. This is the number actually assigned to this service, both on the road and in shops, by the district master mechanic. The electric engines include five double units and two split locomotives and the number can probably be reduced when train heating apparatus is got into shape and minor electrical improvements completed, which matters have required more shopping than will ultimately be necessary. The number of steam engines, on the other hand, is a minimum, as freight engines in helper service were often used to help passenger trains, a fact which is not taken into account in the figures shown. Therefore, less than half as many electric as steam engines are required for the same service.

Item 4, Train Miles per Engine, is derived from the preceding figures, and on the basis of what has just been said, the figures are high for steam and low for electricity. Our record for an electric engine is 9052 miles, made in June 1916.

TABLE II

ELECTRIFICATION DEPARTMENT

Data on Operation under Steam in 1916, and under Electricity in 1916

Rocky Mountain Division		October		November		December		Total	
		Steam	Electrical	Steam	Electrical	Steam	Electrical	Steam	Electrical
	Passenger								
1.	Train or train engine miles	39426	40169	41276	40549	38628	38519	119330	119237
2.	Helper engine miles	4738		7966		12048		24752	
3.	Number engines	13	7	13	7	13	7	13	7
4.	Train miles per engine	3040	5730	3180	5800	2970	5510	9190	17040
5.	1000 kw-hr. at power co's meters		1217	—	1109.5		1152		3478.5
6.	K.w.h. per train mile		30.3		27.4		29.9		29.1
7.	Coal, total tons	3380		4150		3730		11260	
8.	Coal, lbs. per train mile	171		201		193		188	
	Freight								
9.	1000 ton miles	98512	125522	93228	130848	91122	107717	282862	364087
10.	Train miles	60666	65400	58014	63299	58257	57311	176937	186010
11.	Helper engine miles	16605	7022	20422	7544	19336	5591	56363	20157
12.	Number engines	42	15	41	15	44	15	43	15
13.	1000 ton miles per engine	2405	8370	2270	8720	2070	7170	6745	24260
14.*	Number subdivision trains	535	585	532	583	526	543	1584	1711
15.†	Ton miles per train mile	1625	1920	1605	2070	1563	1880	1600	1960
16.	Total time, hours	6094	5022	5946	5084	5785	4429	17825	14535
17.	Minutes per 1000 ton miles	3.70	2.40	3.83	2.33	3.81	2.47	3.78	2.39
18.	1000 Kw-hr. at power co's meters		4696		5119		4528		14343
19.	Kw-hr. per 1000 ton miles		37.4		39.1		42.0		39.4
20.	Total Tons coal	12150		13670		13230		39050	
21.	Lbs. coal per 1000 ton miles	247		294		291		276	

NOTE: * Subdivision train—one train over one subdivision; divide by 2 for trains over entire division.

† "Ton-miles per engine mile" equals tons per train with one electric engine and short helper service, or with one steam engine and longer helper service: In this connection consider Item 17.

Total regeneration over entire division, month of November, equals 11.3% of consumption at motors.

Passenger on 2% grade, Jan. 21-27, 1917—regeneration = 42.8% of consumption at motors.

Passenger on 1.66% grade, Jan. 21-27, 1917. Regeneration = 23.1% of consumption at motors.

Item 5, Thousands of Kilowatt-hours at Power Company's Meters, shows the actual electric energy purchased and chargeable against this service. Every electric engine is equipped with a kilowatt-hour meter, which on each trip is read at points of commencement of motoring and again at commencement of regeneration, thus giving a record of the engineer's performance as regards use of power. The figures shown in the table are the net energy read at the locomotive, increased by a suitable amount for line and substation losses. The efficiency of the system, Power Company's meters to locomotives, is running now at 67 to 70 per cent.

Items 6, kilowatt-hours per Train Mile, and Item 7, Coal, pounds per Train Mile, are self-explanatory. The coal figure is only approximately correct.

Considering the freight data: Item 1, Thousands of Ton Miles, shows an average increase during the months of electric operation of 28.8 per cent over that of steam; for November, the increase was 40 per cent. In this connection the superintendent of the division has stated that to handle the 1916 business with steam, double tracking would have been necessary. The latter would still, of course, have required extra motive power. Possibly, the superintendent did not intend that his statement should be taken literally, but in any event it is reasonable to assume that under the business conditions which existed during the electrical months, and the resulting congestion, the figures for steam would be too favorable.

Item 10, Train Miles. This is used in obtaining item 15 below.

Item 11, Helper Engine Miles. The figures show that for the same ton miles there would be over three times as many helper engine miles under steam as under electricity. No account is here taken of the return trips of helpers or their otherwise running light. This is a considerable item under steam, but is small for electricity.

Item 12, Number of Engines, is possibly a little high for steam on account of some of these engines being at times used in passenger helper service, as already explained. The number of electric engines given is the number purchased for this service and is considered sufficient. We are unfortunately obliged to use our judgment in this matter, as many of the locomotives purchased for the Missoula Division, not then under electrical operation, were available and used. Twenty-eight locomotives are now easily handling business for the two divisions.

Using the figures as they stand and deducting Item 13, Thousands of Ton Miles per Engine, we find that the electric engine handles about 3½ times as many ton miles per month as the steam engine, and from Item 17, Minutes per Thousands of Ton Miles, that the electric engine cuts 30 per cent from the time to do a given business, partly by faster running, partly by heavier trains.

Item 14, Number Subdivision Trains, shows for the three months that there were an average number of division trains involved of 8.6 for steam and 9.3 for electricity.

Item 15, Ton Miles per Train Mile. This is about the same as tons per train, and 22 per cent greater for electricity than steam. The electric train, it might be considered at first glance, ought by comparison to be heavier, but it should be remembered that the steam train for a considerable part of the time has two locomotives on it. The tonnage of the through freight is greater than shown, the average figures being considerably lower on account of the comparatively light local freights being included.

Items 18 and 19, showing consumption of electric energy, are derived in the same manner as previously described for passenger service, and later in conjunction with items 20 and 21 give a comparison of relative amounts of coal and electricity used by us to handle a given business. Under present conditions we are paying for electricity on a kilowatt-hour basis, and it is costing considerably less than coal did.

As to the effects of regeneration on the power consumption, this varies more or less, but it will be noted that for the month of November, the amount of regenerated power measured at the locomotives was 11.3 per cent of the total power consumed at the motors. Some of this power goes over the trolley direct to locomotives which are motoring, and the rest goes through the substations, reversing the motor-generators and either flowing into the Power Company's transmission system or along the Railway Company's line to other substations.

The power-saving feature of regeneration, I may say, is not considered by us so important as the increased safety and ease with which trains are handled on the heavy mountain grades and the saving in wear and tear on brake shoes and equipment. So much has already been said by others about this feature of our installation that I will not go further into the matter here.

The Train Sheet is a graphic timetable for twenty-four hours of operation on the Harlowton-Deer Lodge Division. The horizontal scale shows the stations, many of them only passing track locations, in their proper relative positions, and the vertical scale the hours of the day. Each slanting line represents a train, the heavy lines being passenger trains and the light lines freight or work trains. This chart therefore gives an idea of the typical number of trains and the business done, for which the figures in the accompanying tables apply. It also shows the exact location of each train on the division for each moment of the day.

On the right of the train sheet is an electric load curve which shows at any moment the amount of electric power delivered to the system at any instant and the corresponding locations of the different trains. A profile along the lower side of the diagram shows the grade at each point on the line and is of interest in checking up the power demands as shown by the load curve.

For example, it is shown that the amount of power consumption varies from a maximum of 20,000 kw. at 3.08 p.m. to a minimum of less than zero at 10.10 p.m., at which time the regenerative braking was taking place to a sufficient extent to supply all of the power losses on the railway system and actually return some power to the Power Company's supply system; how much we cannot tell, as the curve drawing meters do not register negative kilowatts.

Following is a synopsis of the conditions at 3.08 p.m. when the power demand was greatest. Locating the trains from right to left, we find:

1. No. 15, Through 8-car, steel, passenger, about 650 tons, west bound, just pulling up to the summit of the Belt Mountains on the 2 per cent grade, heavy motoring.
2. No. 92, Local Freight about 1000 tons, eastbound up the 1 per cent grade.
3. No. 16, Through 8-car steel passenger, about 650 tons, eastbound up the 1 per cent grade, light motoring.
4. 1/64 Through freight, 2500 tons, eastbound on a siding at Josephine.
5. 2/64 Through freight, 2500 tons, eastbound down the 0.3 per cent grade, light motoring.
6. Extra freight, westbound, 2200 tons, just pulling into Three Forks up the 0.3 per cent grade, light motoring.
7. No. 33 Local passenger, westbound, about 250 tons up the 2 per cent grade.
8. 1/62 Through freight, eastbound, 2500 tons up the 1.66 per cent grade.
9. No. 93, Local freight, westbound, 750 tons, just pulling into Butte yard, light motoring.
10. 2/62 Through freight, eastbound, 2850 tons up the 1.08 per cent grade.
11. 1/61 Through freight, westbound, 2300 tons down the 1.08 per cent grade, light regeneration.
12. 3/62 a light engine on the siding at Morel.

This gives us 10 trains moving, of which two are drawing heavy power, seven light power, and one returning a little power to the line.

Now let us examine conditions at 10.10 p.m.

1. Extra freight, eastbound, 1100 tons down the 1 per cent grade, light regeneration.
2. 2/61 Through freight, westbound, 2000 tons, down the 1 per cent grade, light regeneration.
3. 4/61 Through freight on a siding at Piedmont.
4. No. 18, Through 8-car steel passenger, eastbound, about 700 tons down the 2 per cent grade, heavy regeneration.
5. 3/61 Through freight, westbound, 2400 tons, down the 1.08 per cent grade, light regeneration.
6. 3/62 Through freight, eastbound, on siding at Finlen.
7. 1/64 Through freight, eastbound, 2000 tons up the 1.08 per cent grade, light motoring.

Thus we have five trains feeding power into the line and one taking power from the line, the net result being that the railroad actually gives power back to the Power Company.

Under the present conditions, we are running with a monthly load factor—ratio average load to maximum load—of about 40 per cent, but expect within a few months to have installed a so-called power indicating and limiting system, which will automatically indicate to the dispatcher the exact amount of power which the whole system is drawing at any instant and will automatically within certain limits hold the maximum down to a certain pre-determined amount, this with the object of keeping as low as possible the maximum amount of power which we have to contract for with the Power Company, and on basis of 60 per cent of which amount our minimum power bill is based.

ST. PAUL TO ELECTRIFY OVER CASCADE MOUNTAINS*

By K. R. Hare

Associate Editor, Railway Age Gazette

The electrical operation of the C., M. & St. P. Ry. over the Rocky Mountain range is proving so thoroughly successful that the directors have authorized the electrification of the lines over the Cascade Mountains. The extent of the proposed work is described in the following article.—Editor.

On Thursday, January 25, the board of directors of the Chicago, Milwaukee & St. Paul voted to extend its electrified zone from Othello, Wash., west to the Pacific Coast. The new electrification involves about 250 miles of main line and will cost approximately $6,250,000, exclusive of locomotives, but including bonding, catenary, transmission lines and substations. Contracts for the material and equipment required will be placed in the near future and work will be started as soon as possible. It is expected that the extension will be in operation some time during the year 1918.

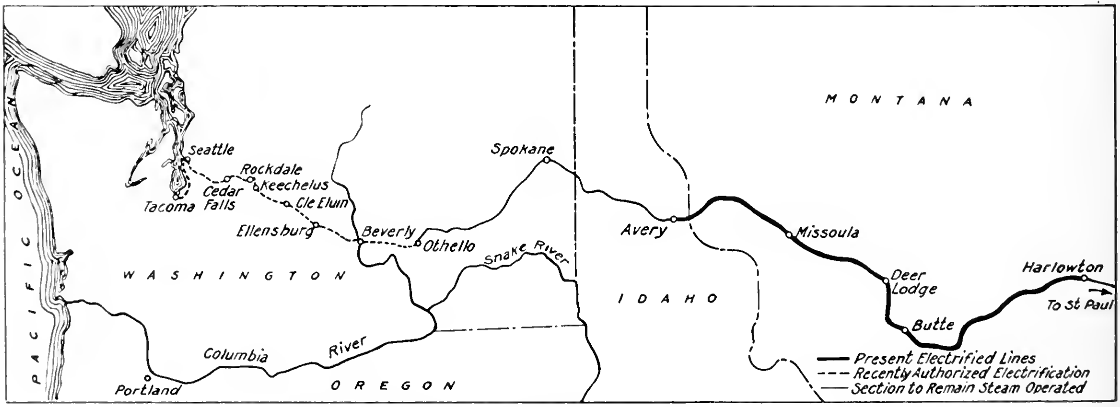

Fig. 1. Map showing Section of C., M. & St. P. now Electrified and to be Electrified

By referring to Fig. 1 it will be seen that the eastern terminus of the new electric zone will be about 225 miles west of Avery, Idaho, the western terminus of the section of line now under electric operation. This means that the district or section of line between Avery and Othello will continue to be steam operated. When the present plans are completed the St. Paul will be electrically operated from Harlowton, Mont., to Avery, Idaho; and from Othello, Wash., to Seattle and Tacoma, Wash., a total of approximately 690 miles, which is a distance practically equal to that from New York to Cleveland, Ohio.

It is not considered economical at this time to electrify the section between Avery and Othello, as between these two points the St. Paul traverses rather level country characterized by easy grades and few curves. West of Othello, however, are the grades encountered in the Columbia river valley and the extremely mountainous district over the Cascade mountains between the Columbia river and Seattle, including the 12,000 ft. tunnel at Snoqualmie Pass. Fig. 2 is a profile of the St. Paul line between Othello and Seattle; reference to it will show that there is 37 miles of 0.4 per cent ruling grade between Othello and Beverly on the Columbia river and about 20 miles of 2 per cent ruling grade from there west to a point several miles east of the cascade tunnel between Keechelus and Rockdale. West of the tunnel the line descends for 19 miles on a 1.7 per cent ruling grade to Cedar Falls, and between Cedar Falls and Seattle, a distance of 40 miles, the ruling grade is 0.8 per cent. Due to the mountainous country traversed by this section of the St. Paul, the curvature is necessarily heavy and in this respect closely resembles the character of the line between Harlowton, Mont., and Avery, Idaho.

The traffic consists of three passenger trains and an average of from four to six tonnage freight trains each way daily. The direction of heavy tonnage is eastbound. One Mallet locomotive now brings 2,100 tons eastbound to Cedar Falls, where a Mallet helper is put on for the 1.7 per cent grade to the tunnel at Rockdale. Under the proposed electrical

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* Reprinted from the *Railway Age Gazette*, February 2, 1917.

operation, one electric locomotive will bring about 3,000 tons to Cedar Falls, and an electric pusher will be used for the steep grade from there to the tunnel. Besides the increase in tonnage, the speed on the heavy grade section, now very low under steam operation, should be about doubled.

System to Be Used

The same system of electrification will be used on the new extension as has been used and found so successful on the original section electrified. The electric locomotives which will be purchased to operate over the new electrified zone will be identical with those in service on the Montana electrification. The same double-trolley, wooden pole, catenary construction and the same type of transmission line and system of feeders will be used, as the several months' trial of the present installation has indicated that no changes in these details are necessary or advisable. Briefly, the system of operation will be 3,000 volts direct current at the trolley, energy at this potential being furnished from substations containing motor-generator sets and transformers supplied from transmission lines of various hydro-electric companies, supplemented by a 100,000-volt line paralleling the track and owned by the railroad company.

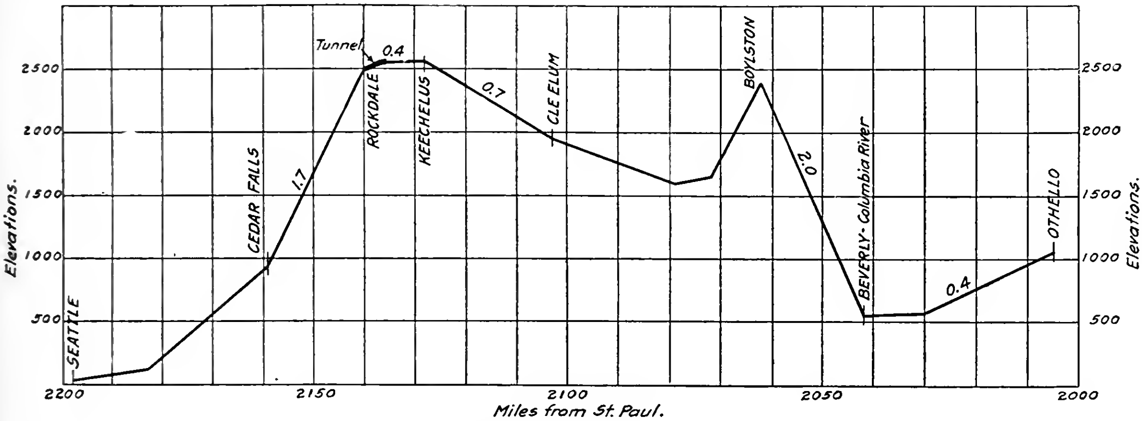

Fig. 2. Profile of Section of Railway to be Electrified

The electric locomotives will each be constructed of two units permanently coupled together, the halves being duplicates, but each half capable of independent operation. The locomotives weigh 282 tons, have a running tractive force of 85,000 lb. and a starting tractive force of 126,000 lb. The passenger locomotives have a gear ratio permitting the operation of 800-ton trains at a speed of approximately 60 miles an hour on tangent level track. The average passenger train on the St. Paul weighs from 650 to 700 tons and is hauled over the two per cent grades of the present electrified divisions without a helper. The freight locomotives are designed to haul 2,500 tons up a one per cent grade at 16 miles an hour, and on the Rocky Mountain electrification two of them have been used successfully to haul 3,500 tons on a two per cent grade. In many cases it was found necessary to increase the length of the passing siding so that the maximum hauling capacity of the locomotive could be utilized.

The decision to use, on the extension, the same system and the same type of equipment which is now being used speaks well for the success of 3,000-volt direct-current operation for heavy main line service. C. A. Goodnow, assistant to the president, in charge of electrification on the St. Paul, states that he is particularly impressed with the satisfactory manner in which the locomotives are running, and with the ease and speed with which they handle the heavy trains over the grades and curves encountered on the mountain divisions. It is a literal fact that the present electrification has eliminated the Rocky mountains as far as railroad operation is concerned on the St. Paul.

On the Rocky mountain electrified division the running time for both freight and passenger trains has been reduced by about 30 per cent, and operation under this schedule has proven most reliable; in fact, the electric locomotives are now counted on to make up the time lost on adjacent steam operated divisions. The increased reliability obtained by the use of the electric locomotive is one of the chief advantages of electric operation. The electric locomotives keep going with a full tonnage train under all conditions of weather and over all kinds of road.

When trains are hauled by electric locomotives it is found that their movement is so uniform and that failures of the electrical equipment are so rare that one set of train despatchers can easily handle trains on the section now under electrical operation where two sets were required under steam operation. Under electrical operation the time between Three Forks and Deer Lodge has been reduced from 12 to 8 hours for heavy freight trains and in addition the tonnage has been increased on the maximum grades from 1,700 to about 3,000 tons. This tonnage is now handled at the speed of about 16 miles an hour on the heaviest grades, whereas the best that the steam engine could do with the lighter trains was about 8 miles an hour. The electric locomotives, which will be used on the new section, often cover 250 miles a day on the Rocky mountain division and are standing up under this hard service extremely well. Mr. Goodnow, when talking about this feature of electrical operation, said that present indications tended to show that the maintenance cost of the electric locomotive will be remarkably low.

The locomotives used between Othello and Seattle will naturally be equipped for regenerative braking, as this feature of the locomotives now in use has given great satisfaction. Mr. Goodnow states that regeneration effects a saving of approximately 14 per cent based on power used at the locomotive.

Power Supply

The general scheme for supplying electrical energy to the trains on the new electrification will be the same substantially as that adopted for the Montana installation. The power will be supplied by hydro-electric developments in Spokane, in the Cascade mountains and on the Pacific coast; all power will be purchased from private corporations. The contracts for furnishing such power will provide for about 40,000 kilowatts and each will contain an option covering whatever additional power may be necessay to take care of increased business. The cost of electric current will be approximately ½ cent per kilowatt hour and there will probably be provisions similar to those in the contract made with the Montana Power Company, which provides that the power-factor be limited to a variation of 20 per cent from unity and that the monthly load-factor will be equivalent to 60 per cent, when based on the contract load.

One of the greatest economies to be effected by the proposed electrification will be the saving in the cost of energy required to haul the trains. The railroad company's oil contracts have expired, and any new contract which it makes for oil will be based on a considerably higher price for this fuel. On the other hand, the contract which the railroad company entered into with the Montana Power Company for furnishing current for the Rocky mountain electrification runs for 99 years, during which time no changes in the cost of current can be made.

In connection with the advantages to be obtained by electrical operation it is interest-

Fig. 3. Electric Locomotive Coupled to Passenger Train on the C., M. & St. P.

ing to note that neither of the electrification projects of the St. Paul have been made necessary because of nuisance caused by locomotive smoke, congestion at terminals or at tunnels, but both were brought about because of the economy that can be effected by the substitution of electric for steam power. This economy will be particularly felt in both of the electrification districts because of the presence in each of cheap hydro-electric power, which fact has been an important factor in the decisions to electrify.

History of the St. Paul Electrification

Although the subject of electrification had been under consideration for some time it was not until November, 1914, that a contract was actually placed for equipment and material necessary to electrify the 113 mile division between Three Forks and Deer Lodge, Mont. This was simply the first step in a scheme which involved the extension of the electrified zone to cover 440 route miles between Harlowton, Mont., and Avery, Idaho, on the west; the whole foreshadowing the ultimate electrification of the main line to the Pacific coast. In view of the magnitude of the project, the progress which has been made is remarkable. By November, 1915, overhead construction had been completed for a distance of 200 miles and the 100,000-volt transmission line, which was erected by the railroad on its own right of way, had been completed for an equal distance and the lines from the Montana Power Company were ready for service. At that time the trackage actually ready for train operation included yards and sidings at Three Forks, Deer Lodge, and Piedmont and passing tracks at other points. Seven of the substations designed to supply power for the first half of the 440 miles of route were completed and electrical equipment practically installed.

Work on the construction of the forty-two 282-ton locomotives was at that time progressing rapidly. The first complete locomotive was placed on a test track early in September, 1915. In November, 1915, it had been turned over to the railroad company and was being exhibited at various points on its route from Chicago to the electrified division of the St. Paul. On November 13, the St. Paul made a test of one of the new locomotives on the tracks of the Butte, Anaconda and Pacific, as power was not yet available on the St. Paul.

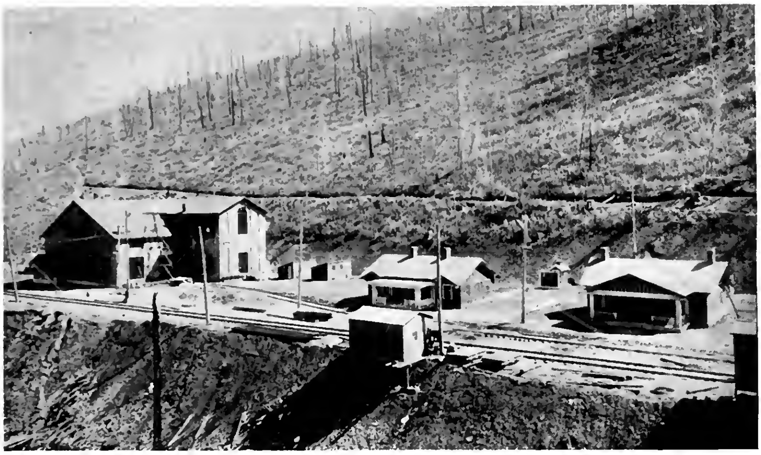

Fig. 4. East Portal Substation with Operators' Bungalows, C., M. & St. P. Station Contains Three 2000-kw. Synchronous Motor-generator Sets

On December 9, the Chicago, Milwaukee & St. Paul trans-continental "Olympian" was taken from Butte, Mont., to Piedmont by an electric locomotive, and on December 8 officers and directors of the road and officers of the General Electric Company made an inspection trip over the line in a fast train consisting of three special cars and one electric locomotive. The test consisted of operation at various speeds up to 70 miles an hour, with various tonnages. On December 9, two electric locomotives took a train of 48 loaded cars, 3,000 tons, from Butte up the two per cent grade to the summit of the Rocky mountains at a speed of 15 miles an hour and then continued down the descending grade on the opposite side. This was the inauguration of electric operation. It was not until January, 1916, however, that steam freight locomotives were entirely removed from the electrified division.

At about that time it was found that the electric locomotive could handle considerably more tonnage than the builders guaranteed, and it was also demonstrated by the various tests run during that period that the system of regenerative braking was entirely successful.

During the month of April, 1916, service was extended to Harlowton, Mont., making a total of 220 miles of electrically operated road. On November 1, the St. Paul put in operation the third electrified district, the line from Deer Lodge, Mont., to Alberton, a distance of 110 miles. This made the total length of line electrified, Harlowton to Alberton, a distance of 336 miles. On December 11, 1916, 76 miles were added to the electrified section which completed the electrification from Harlowton, Mont., to East Portal at the east end of the St. Paul Pass tunnel, making a total distance under electrical operation of 406 miles. During this month (January), the finishing touches are being put on the last 25-mile stretch of electrified district, and it is expected that the entire mountain division of 440 miles will be electrically operated by February 1.*

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* The complete electrification of the 440 miles from Harlowton to Avery went into operation at noon on February 24th when electric trains began operation through the mile and a half St. Paul Pass Tunnel at the summit of the Bitter Root Range.
—EDITOR.

PHASE TRANSFORMATION

By G. Faccioli

Electrical Engineer, Pittsfield Works, General Electric Company

The derivation of balanced polyphase power from a single-phase source of energy, without the use of rotating apparatus,* has been for many years greatly desired by engineers. Considerable interest should therefore be created by the following article which demonstrates how both voltage and current at quadrature with a single-phase source of supply can be obtained by means of inductance. However, by this method it is not possible to derive a balanced polyphase system, because in each case where quadrature power is derived there is always an excess of power delivered in one phase, so that the system is unbalanced. Although no attempt is made to suggest any practical application of the principles involved, this article will be found very instructive and interesting to those who wish to understand the mechanism by which an inductance can store energy and deliver it dephased from the original source of power.—Editor.

One of the most difficult problems connected with alternating-current phenomena is the derivation of polyphase currents from a single-phase circuit.

Since the power consumed in a true polyphase circuit is continuous, whereas the power given by a single-phase circuit must be pulsating, it follows that the single-phase supply circuit cannot transmit all of the power direct to the polyphase circuit, but that some form of storage of energy is necessary wherein part of the power coming from the single-phase circuit is temporarily stored and is turned over at the proper time to the polyphase circuit. Then the power that the polyphase circuit draws direct from the single-phase supply circuit and the power that the polyphase circuit draws from the storage may be made to superimpose so as to give a continuous flow of power. This, as is well known, can be accomplished by the use of rotating apparatus or by the simultaneous use of inductance and capacity.

This article describes a very interesting method of connections which attacks the problem by the use of only inductance and mutual inductance, and it involves a rather novel application of the transformer. Fig. 1 shows these connections.

The lines a and b are the conductors of a single-phase supply circuit, across which the electromotive force E is active. T_1 and T_2 are two windings, each with a different number of turns, wound on the same core of a transformer, which will be called the "phase transformer."

We will limit our study to the case of a non-inductive receiving circuit, as this scheme of connections (in its present form) is not applicable to inductive loads. The ohmic resistance r_1, which is in series with the winding T_1, and the ohmic resistance r_2, which is in series with the winding T_2, are the active

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* A motor-generator set, comprising a generator and a motor each equal in capacity to the power delivered, has been the only practical means by which this conversion could be made. Recently, however, the size of the rotating apparatus has been very much reduced by the development of Mr. Alexanderson and others, by which the rotating apparatus handles only a fraction of the energy delivered.

parts of the receiving circuit through which polyphase currents flow.

Fig. 2 is a vector diagram which shows how this is accomplished.

OE represents the supply electromotive force E.

EA and EB are the electromotive forces which exist across the coils T_1 and T_2 respectively.

We will assume that the number of turns of T_2 is greater than the number of turns of T_1, and therefore the vector EB is longer than the vector EA, and the ratio between EB and EA is the ratio of transformation between the turns T_2 and T_1.

OA is the electromotive force across r_1 and OB is the electromotive force across r_2.

It will be noted that EA and EB are in the same phase, as the two coils T_1 and T_2 are wound on the same core of the phase transformer and this transformer is assumed to have no ohmic resistance and no leakage. Furthermore, the vectorial sum of EA and AO gives OE. In fact, the vectorial sum of the voltages across T_1 and r_1 must be the supply voltage E. Similarly, the vectorial sum of EB and BO gives again OE, as the vectorial sum of the voltages across T_2 and r_2 must be E.

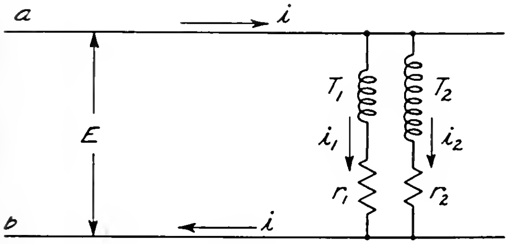

Fig. 1

Since OA is active across r_1 a current i_1 will flow through r_1 (and necessarily also through T_1).

Since the voltage OB is active across r_2, a current i_2 will flow through r_2 (and necessarily also through T_2).

The resultant of i_1 and i_2 gives the total current, i, taken from the supply circuit.

The resulting magnetization of the phase transformer is given by the ampere-turns supplied by the current i_1 flowing through the coil T_1 plus the ampere-turns supplied by the current i_2 flowing through T_2. Since the number of turns of T_2 is greater than the number of turns of T_1, the vectors OC and OD represent respectively the ampere-turns of T_1 and T_2. The total magnetization of the phase transformer is therefore represented by OM.

Now OM must be in quadrature with EA and EB. since EA and EB are the voltages induced by OM.

The electromotive forces OA and OB and the currents i_1 and i_2 are displaced in phase by an angle ω.

The phase angle ω between the two phases OA and OB can be varied by varying the ratio of transformation of the phase transformer and by varying the constants of the receiving circuit.

A few typical cases will be considered.

Case (1)

The phase displacement between Phase *I* and Phase *II* is 60 deg. and Phase *I* lags 60 deg. behind the supply electromotive force, so that Phase *II* lags 120 deg. behind the supply electromotive force.

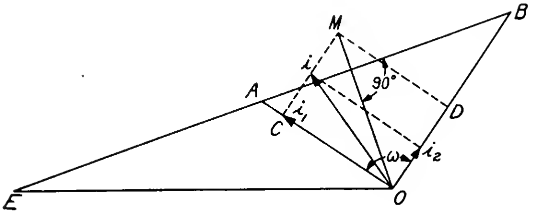

Fig. 2

Case (2)

Phase *I* and Phase *II* are in quadrature, that is to say the voltages and currents in the receiving circuits constitute a two-phase system.

This case is important because a phase displacement of exactly 90 deg. cannot be obtained between two circuits by the use of simple inductance in series with resistance.

Case (3)

Phase *II* is exactly in quadrature with the supply electromotive force, so that Phase *II* receives no power from the supply circuit.

This case is, so to speak, a "limit case" because the electromotive force and current of Phase *II* are exactly in quadrature with the supply electromotive force.

Phase *I* may either be used to carry load or it may be used as a "teaser." In the latter case Phase *I* draws power from the circuit, and through the phase transformer this power passes to Phase *II*.

Let:

r_1 = the active resistance of Phase *I*,
r_2 = the active resistance of Phase *II*,
n_1 = the number of turns in coil T_1 of the phase transformer,
n_2 = the number of turns in coil T_2 of the phase transformer,
α = the ratio of transformation, i.e. $\frac{n_2}{n_1}$
k = the voltage produced by one ampere-turn in one turn of the phase transformer,
i_1 = the current of Phase *I*,
i_2 = the current of Phase *II*.

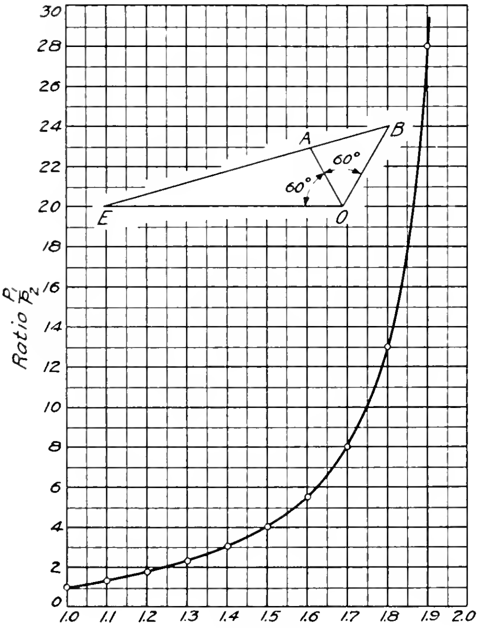

Fig. 3

Case 1

Phase *I* lags 60 deg. behind the supply electromotive force and Phase *II* lags 60 deg. behind Phase *I*.

A mathematical study of this case leads to the following conclusions:

(*a*) It is impossible to obtain equal power in Phase *I* and Phase *II*.

(*b*) The ratio between the power consumed in Phase *I* and the power consumed in Phase *II* varies with the ratio of transformation according to the curve in Fig. 3.

A numerical example will prove very instructive. Let us take the case in which the power Phase *I* is twice the power of Phase *II*, and therefore $\alpha = 1.25$. Let us assume

$k = 1$
$n_1 = 10$
$i_1 = 10$ amperes.

We have by calculation:

$n_1 = 10$ $n_2 = 12\frac{1}{2}$
$r_1 = 28.8$ $r_2 = 90$
$i_1 = 10$ $i_2 = 4$
$r_1 i_1 = 288$ $r_2 i_2 = 360$
$r_1 i_1^2 = 2.88$ kw. $r_2 i_2^2 = 1.44$ kw.
$E = 1440$ volts.

Fig. 4 gives the vector diagram of the quantities involved in this example. It gives the components of the electromotive forces for Phases *I* and *II*. It shows the resultant current drawn from the single-phase system which is 12.4 amperes lagging 76 deg. behind the supply electromotive force with a consequent power-factor of 0.242. Finally, it shows how the ampere-turns of Phase *I* combine with the ampere-turns of Phase *II* to give a resultant magnetomotive force in quadrature with the voltage of the phase transformer.

An examination of how the power is drawn from the single-phase circuit and is distributed between Phases *I* and *II* will prove instructive. The total power is drawn by the resultant current, which is 12.4 amperes, from the supply circuit which has a voltage of 1440 at power-factor 0.242. The total power is therefore

$$1440 \times 12.4 \times 0.242 = 4.32 \text{ kw.}$$

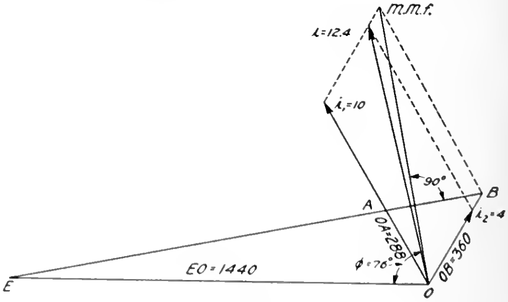

Fig. 4

Similarly, the power drawn by the current of Phase *I* is

$$1440 \times 10 \times 0.5 = 7.2 \text{ kw.}$$

while the power corresponding to the current of Phase *II* is

$$1440 \times 4 \times 0.5 = 2.88 \text{ kw.}$$

We have

Total power = 4.32 kw.
Power of Phase *I* = 7.2 kw.
Power of Phase *II* = 4.32 kw.
Power consumed in Phase *I* = 2.88 kw.
Power consumed in Phase *II* = 1.44 kw.

This means that the power is distributed through the following mechanism:

Phase *I* draws form the circuit 7.2 kw. Of these, 2.88 kw. are consumed in Phase *I*, and 4.32 kw. are transmitted through the phase transformer by Phase *I* to Phase *II*.

Phase *II* receives then through the phase transformer 4.32 kw. Of these, 1.44 kw. are consumed in Phase *II*, and 2.88 kw. are given back by Phase *II* to the supply circuit.

The total power, therefore, drawn from the circuit is 7.2 kw. drawn by Phase *I* minus 2.88 kw. returned by Phase *II*, that is to say 4.32 kw., of which 2.88 kw. are consumed in Phase *I* and 1.44 kw. are consumed in Phase *II*.

Case 2

Phase *I* and Phase *II* are in quadrature.

A study of this case shows that the ratio between the power consumed in Phase *I* and the power consumed in Phase *II* is equal to the ratio of transformation of the phase transformer.

Since this ratio of transformation must be larger than one, it follows that it is impossible to obtain equal power in Phase *I* and Phase *II*.

Case 3

Condition (*a*): Phase *II* is exactly in quadrature with the supply electromotive force and both Phase *I* and Phase *II* carry load.

A mathematical study of this arrangement leads to the conclusion that the ratio between the power consumed in Phase *I* (p_1) and the power consumed in Phase *II* (p_2) is

$$\frac{p_1}{p_2} = \frac{\alpha - 1}{1 - \alpha \cos^2 \omega}$$

in which α is, as before, the ratio of transformation of the phase transformer and ω is the phase displacement between Phase *I* and Phase *II*.

This formula shows us how to get equal amounts of power in both phases by choosing the proper ratio of transformation for a given phase displacement or the proper phase displacement for a given ratio of transformation.

Let us assume that the phase angle between Phase *I* and Phase *II* is 45 deg. Then, in order to have equal power in Phase *I* and Phase *II*, we must have $\alpha = \frac{4}{3}$. A numerical example will prove interesting.

Suppose that

$\omega = 45$ deg.
$\alpha = \frac{4}{3}$
$k = 1$
$n_1 = 10$ $n_2 = 10 \times 4/3 = 13\frac{1}{3}$
$i_1 = 10$ $i_2 = 10.6$
$r_1 = 100$ $r_2 = 88.8$
$p_1 = 10$ kw. $p_2 = 10$ kw.
$E = 2820$ Volts
$r_1 i_1 = 1000$ volts $r_2 i_2 = 940$ volts.

Resultant current $I = 19$ amperes at power-factor 0.37.

Phase *I* draws from the circuit 20 kw., of which 10 are consumed in Phase *I* and 10 are transferred to Phase *II*, which latter phase has no direct exchange of power with the supply circuit.

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Condition (*b*): Phase *II* is exactly in quadrature with the supply electromotive force and Phase *I* is not used to carry load, but it is used to draw from the supply circuit a certain amount of power to be transferred to Phase *II*.

It follows that this arrangement will be most efficient when the power consumed in Phase *I* is a minimum. In this case the polyphase circuit consists of Phase *II* and another phase, connected directly across the supply circuit, while Phase *I* is simply a teaser.

Fig. 5 shows the arrangement of the circuits. Fig. 6 is a vector diagram relating to this case.

OE = the supply electromotive force
OA = the electromotive force of the Teaser
OB = the electromotive force of Phase *II*.

Let i_1 be the current in the teaser. It is, evidently, in phase with the teaser voltage OA. The total power in the teaser circuit equals i_1 times the projection of the line voltage EO on i_1, or $i_1 \times OD$. The power wasted in the teaser resistance is equal to i_1 times OA. The power transferred to the quadrature phase must then equal $(i_1 \times OD) - (i_1 \times OA)$, or $i_1(OD - OA) = i_1 \times AD$. Assuming i_1 as unity, OD represents total power, OA represents the power lost in the teaser, and AD represents the useful power transferred to the quadrature phase. Evidently the efficiency of the teaser equals $\frac{AD}{OD}$, which must be made maximum.

This can be controlled by varying the angles ω and β.

It is evident from Fig. 6 that the ratio $\frac{AD}{OD}$ increases when β decreases.

At the limit, when $\beta = 0$, the teaser efficiency is 1, but this case is obviously impossible.

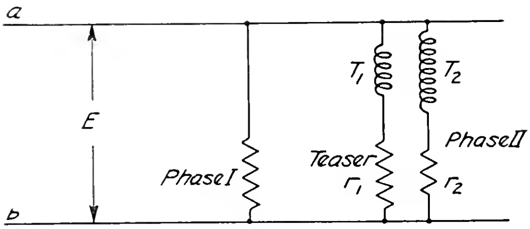

Fig. 5

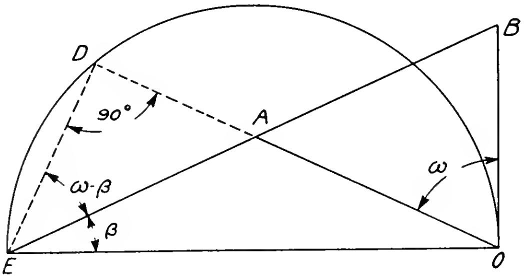

Fig. 6

We may then conclude that the best teaser efficiency is obtained when β is as small as possible and the phase displacement between Phase *I* and Phase *II* is $45° + \frac{\beta}{2}$.

The curves of Fig. 7 give the ratio between the power of Phase *I* and the power of Phase *II* for different phase displacements between Phase *I* and Phase *II* at different values of β.

. . . .

The discussion of these three typical cases gives a comprehensive idea of the possibilities of this scheme of phase transformation. First of all, the limitations already pointed out decrease substantially the practical value of the phase transformer—in its present form. It must be added that varying the value of r_1 and r_2, i.e., varying the load, changes the phase relation between the electromotive forces of the receiving circuit; and furthermore it must be remembered that the receiving circuit must be non-inductive.

It follows that these connections are mainly of theoretical interest. Their study, however, will strongly appeal to students of this class of phenomena, because of the unusual results accomplished.

For instance, in Case (1), the electromotive force of Phase *II* lags more than 90 deg. behind the supply electromotive force. In addition to this, in Case (2), the phase displacement between the electromotive forces of Phase *I* and Phase *II* is exactly 90 deg. But the most interesting of all is Case (3) (b), which shows the possibility of producing an electromotive force in exact quadrature with the supply electromotive force, and that this quadrature electromotive force is able to supply power to a receiving circuit in such a manner that this power will periodically reach its maximum when the supply electromotive force is zero.

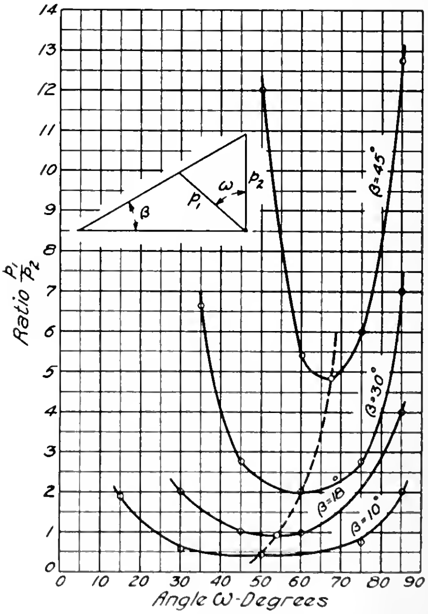

Fig. 7

The scheme which is the subject of this study was suggested by the late William Stanley. It is his last effort in the electrical art.

ELECTRICAL EQUIPMENT OF THE NEW CENTER DOOR, STEPLESS LOW WHEEL CARS FOR THE BOSTON ELEVATED RAILWAY COMPANY

By J. A. Queeney

Railway Department, General Electric Company

The car described in this article is the latest outcome of the continual attempt by street railway companies to achieve the two-fold purpose of reducing operating expenses to offset the increasing cost of operation, and to improve the service so as to build up a larger patronage—a very difficult problem. The light weight small wheel car, having rapid acceleration and high schedule characteristics, with facilities for quickly loading and unloading passengers, seems to best fill the bill. The special features of the new Boston elevated cars, such as the automatically operated doors, automatic control and automatic starting signal systems, lighting system, and motor fare box, are described.—Editor.

During the past few years the street railway companies have had to meet heavy increases in operating costs, which have been due largely to the higher wages paid and to the increased cost of materials.

Since the operating company is generally unable to raise the fare, the only alternative is to reduce expenditures by economies in operation; this condition has resulted in the study of the transportation problem along much more scientific lines than was customary a few years ago.

The traffic study has revealed many facts which were not heretofore fully appreciated by operators, and which are almost entirely unknown to those not directly in touch with electric railway matters. For instance, the extra power required for even a comparatively slight increase of the schedule speed in frequent-stop city service; the number of stops in a given service; the effect on the annual power bill due to the time required for getting passengers on and off the cars, operating doors, and transmitting starting signal to the motorman; the value of automatic acceleration; and the importance of coasting, are some of the factors that have a most important bearing on the economic operation of the electric railway system.

The Boston Elevated Railway Company will soon place in service 100 center-door, 24-in. wheel, stepless cars that are of special interest in that they have been designed and equipped with the view to incorporating all of the advantages outlined above by means of the following features:

Train operation of all motor cars.
Automatic acceleration.
Rapid acceleration and retardation.
Rapid loading and unloading facilities
Automatic starting signals when train is standing.
Automatic coupling of cars.

This installation is exceptional in that it is one of the few cases where a street railway management has purchased cars designed and equipped to take advantage of the recognized benefits and savings to be derived from the operation of trains of several motor cars in city service.

The operation of multiple-unit trains consisting of all motor cars having prompt and positive acceleration and deceleration provides the most reliable and economic method of handling the large crowds from factories and congested districts, specially during rush hours.

The exacting service demanded of the railway company is such that only the most reliable and efficient equipment can be tolerated; and after a most thorough investigation of its traffic requirements, the management decided that motor cars equipped for operation both singly and in train offered the most practical method of providing adequate transportation facilities for its passengers, for both present and future requirements.

The present arrangement provides for single car operation during certain hours of the day, with two-, three- or four-car trains during the rush hours, on Sunday, or on other occasions when the traffic is unusually heavy.

The following data represent the present operating conditions:

Total weight of car with average passenger load	52,000 lb.
Number of motors per car	4
Diameter of car wheels	24 in.
Length of running, round trip	8.645 miles
Length of running in tunnel	3.45 miles
Length of trip on surface	5.195 miles
Average number of stops per mile, surface	5½
Average duration of stops	10 seconds
Maximum grade, surface	700 ft., 6 per cent
Time round trip	45 minutes
Maximum line voltage	620 volts
Average rate of acceleration	1.75 m.p.h.p.s.
Average rate of braking	1.75 m.p.h.p.s.

Since the majority of the passengers are picked up in rather large groups, it was of the utmost importance that exceptional loading and unloading facilities should be provided for in designing the new car.

For over a year a number of trailer cars of practically the same design as the new motor cars have been in service and have proved highly satisfactory to both the public and the railway company.

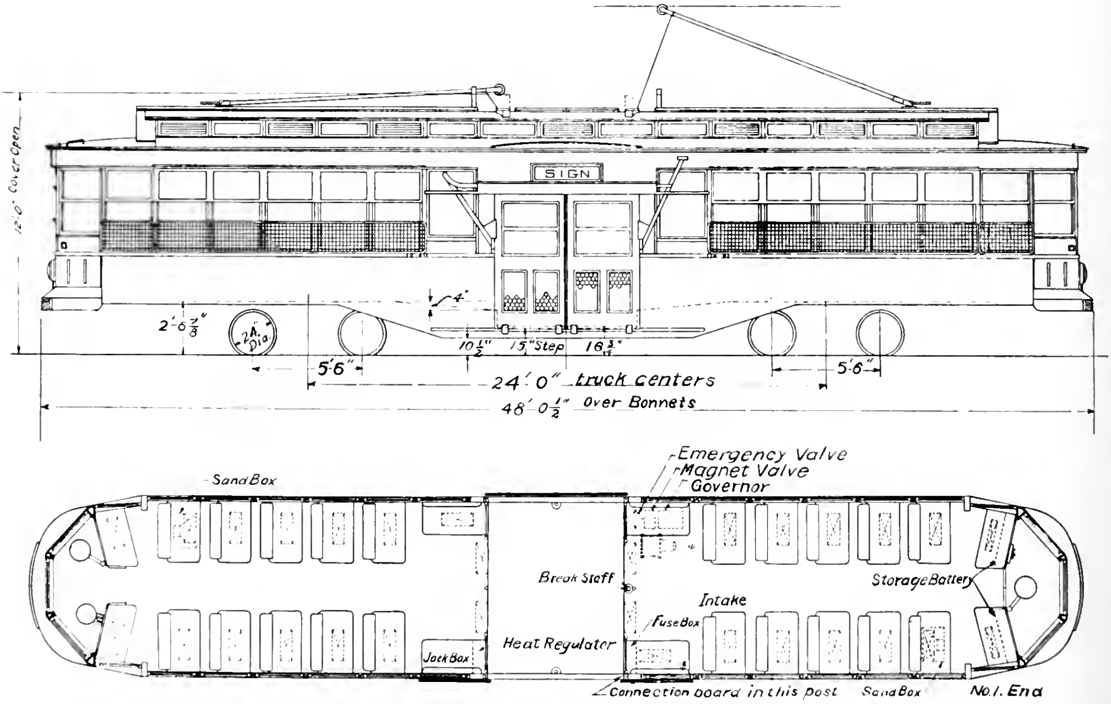

Fig. 1. Elevation and Plan of New Cars

Door Operation

Both the trailer cars now in service and the new center door motor cars have a 6-ft. 6-in. opening, with two sliding doors which open and close in approximately 2 seconds. The doors are pneumatically operated and controlled through a valve which is operated by the conductor through a system of levers. Due to the wide opening, and the elimination of a step coupled with a very efficient system of fare collection, a highly efficient system of loading and unloading passengers is obtained. In fact, tests which have been conducted at the Park Street station of the Tremont Street subway indicate that the new Boston Elevated center door car is the fastest loading and unloading car in operation to date.

Fig. 2 shows the estimated loading time of both the present semi-convertible motor car and the center door trailer, or new motor car. The center door car permits passengers to move at an average of three abreast. It will be noted that while the present motor car, which is arranged for end entrances and front exit (averaging two abreast), requires an average of 1.19 seconds per passenger to load, the new center door car is approximately 42 per cent faster, requiring but 0.69 seconds per passenger; or in other words, the average duration of stops with the new center door will be only 58 per cent of that of the present motor car.

This means that a materially faster schedule can be made with the new type of motor car than if the present type had been adhered to (assuming same weight and equipment), or the same schedule could be performed with less energy.

Motor Equipment

The motor equipment consists of four General Electric 247 motors and Sprague General Electric Type PC-5 automatic control, suitable for either single car operation or train operation. The equipment provides for the maximum rate of acceleration consistent with the comfort of passengers, and for maximum speed consistent with economy and street traffic conditions, thus providing for the maximum possible schedule speeds without sacrificing any of the advantages of simplicity and reliability of service of the simple non-automatic equipment.

This result is accomplished by the use of up-to-date multiple ventilated, commutating pole motors having liberal electrical and staunch mechanical design and a control system having a definite sequence of contactor operation with no interlocks on contactors.

The GE-247 motor rates 40 h-p. at 600 volts. It weighs 1730 lb. complete with axle, linings, gear cover and gearing. Fig. 3 shows the general characteristics of the GE-247 motor. Fig. 4 shows the high schedule possibilities of the Boston Elevated car equipped with four of these motors.

Control

The PC-5 control will be operated from a storage battery. In place of the regular receptacle and removable jumper connections generally employed when operating cars in train, the Boston Elevated Company adopted the combined air and electric coupler, which automatically connects the train cable by means of contacts located in the head of the coupler. The arrangement of contacts is shown in Fig. 5. This is not only in keeping with "safety first" practice in that there is less hazard in coupling, but it is a real time saver. The use of a storage battery and the automatic coupler gives the advantages of continuity of control current independent of the power supply, thereby providing means for reversing the motors in emergency and less liability to short circuits and grounds as a result of arcing between points.

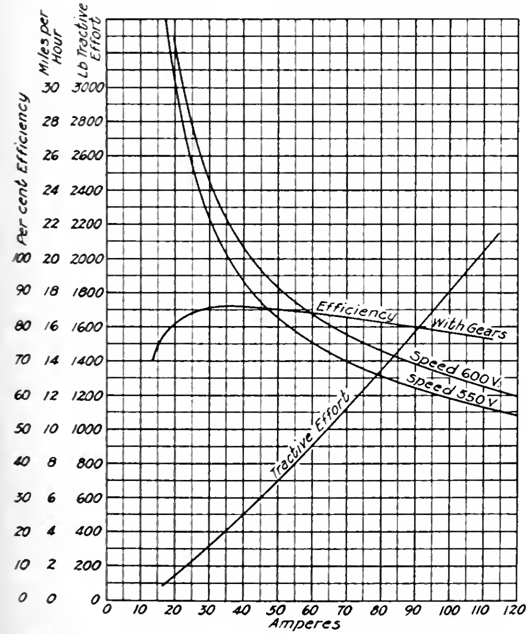

Fig. 3. Characteristic Curves of GE-247 Railway Motor

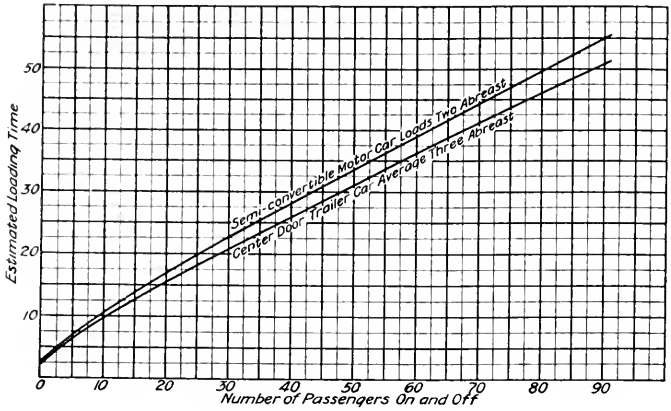

Fig. 2. Estimated Loading Time

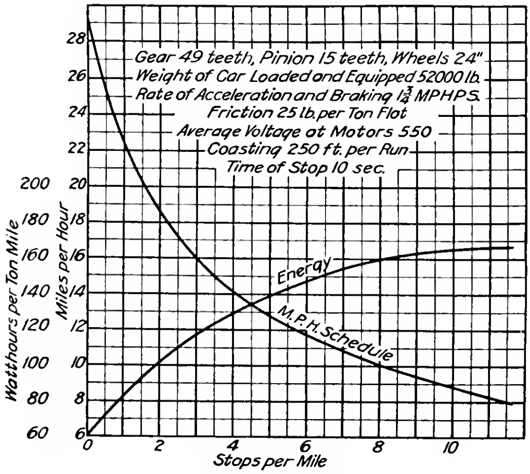

Fig. 4. Schedule of New Cars with 4 GE-247 Motors

The PC-5 control is itself arranged for automatic acceleration of the train at a predetermined current per motor. This inherently prevents abuse of the equipment and insures most economical operation from the power consumption standpoint. In the past this could be accomplished only by the use of somewhat complicated equipment because of the interlocking required for any arrangement of individually operated contactors. In the PC-5 control all of these complications for automatic operation have been eliminated.

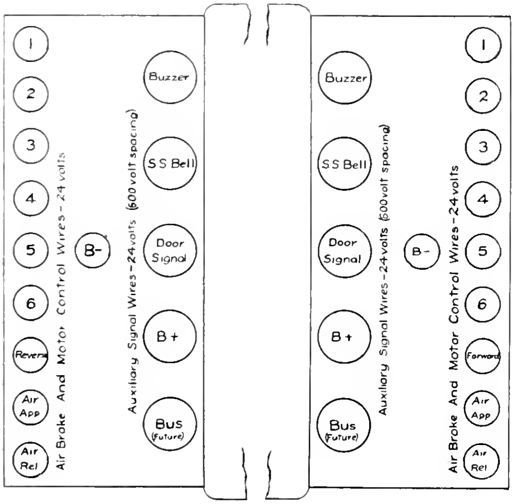

Fig. 5. Arrangement of Coupler Contacts

The main control consists of a series-paralleling motor controller, composed of a line breaker, eight contactors actuated by means of cams attached to a shaft, and a reverse switch for the motors, called a "reverser."

The arrangement of cams on the cam shaft is such that the contactors can never be closed except in a definite order. The cam shaft itself is operated by means of an air-operated mechanism controlled by two magnet valves. The energizing and de-energizing of the magnet valves is governed by a current limit relay, thus preventing the operation of the motor controller above a predetermined current.

On the cam shaft is also mounted a control cylinder with segments and fingers necessary to make the required control connections for each step, and to insure the proper functioning of the line breaker, reverser, and the cam-operated contactors. The line breaker is electrically controlled and pneumatically operated. Air is admitted to a small cylinder through a magnet valve, and the main contacts of the line breaker are closed by means of a piston. When the air is exhausted from the cylinder the main contacts are opened promptly by the action of a spring combined with gravity. The line breaker has a powerful magnetic blowout, capable of opening the power circuit under conditions far exceeding normal operation.

The reverser is of the cylinder type and is actuated by air, electrically controlled through two magnet valves.

The PC-5 control equipment possesses a number of unique features. The control is of simple design, having a few parts so arranged that, with the exception of the potential relay, all parts are enclosed in a single structure, which is wired and tested at the factory. The cam arrangement entirely eliminates interlocks from the individual contactors, thereby greatly reducing the number of parts and increasing its reliability in service.

Since the contactors are mechanically operated by cams on a cam shaft, a definite sequence of contactor operation is insured when turning on or off. All contactors are provided with individual magnetic blowouts. The line breaker with its magnetic blowout opens all arcs when turning off, and a second series break is provided by the contactor element.

A unique and important feature is the arrangement of all the arc chutes for the contactors in one hinged structure, which may be swung down, permitting free access to every portion of the contactors and arc chutes. In fact, all parts are readily accessible for inspection.

Master Controller

The master controller has a separate reverse handle and cylinder which is mechanically interlocked with the main cylinder, thus insuring that the reverse handle is thrown for either the forward or reverse direction before the main cylinder is turned on.

In addition to the fingers required for controlling the position of the reverser, the reverse cylinder of the master controller has twelve additional segments and fingers which provide for the electrical and mechanical interlocking of the head light, tail light, emergency lighting, signal, buzzer and fare box motor; that is, when operating cars either singly or in train it is only necessary for the motorman to place the reverse lever of the master controller which he is operating in the proper position, and all circuits are automatically connected.

The main cylinder has three positions; first, switching point series; second, accelerating point; third, accelerating point parallel.

In order to provide for unusual conditions in which an accelerating current greater than the predetermined value is required, the master controller contains a small switch operated by a lever located on the controller cap plate. Closing this switch energizes a train wire and bypasses the current limit relay, permitting the master controller to advance one step. By repeating the operation of closing and opening the bypass switch the motor controller will be advanced to running position indicated by the master controller and gives an acceleration similar to a non-automatic control.

The main handle of the master controller is provided with a "dead man's release" which cuts off the control current from the car or train whenever the motorman releases the controller handle.

To guard against possible emergency conditions whereby the motorman might loose control of the train due to some other master controller than the one he is operating having been accidentally brought in circuit, a push button switch is located in the side of the master controller which, when closed, short-circuits all storage batteries, thereby cutting off power from the motor controller on all cars of the train. However, the short-circuiting switch cannot be closed until the reverse lever of the master controller is moved to the reverse position; it being intended that the motorman first attempt to reverse the direction of current through the motor field before short-circuiting the storage batteries.

Operation

When the master controller is turned on, the reversers in the train are first thrown for the corresponding car movement and the control circuit is next established through the magnet valve and the line breaker. To insure proper sequence of operation, the reversers must throw to the proper position, and the line breaker must close before the series contactors can close and complete the motor circuit. The further progress of closing contactors is governed by the current limit relay, and is controlled through the master controller.

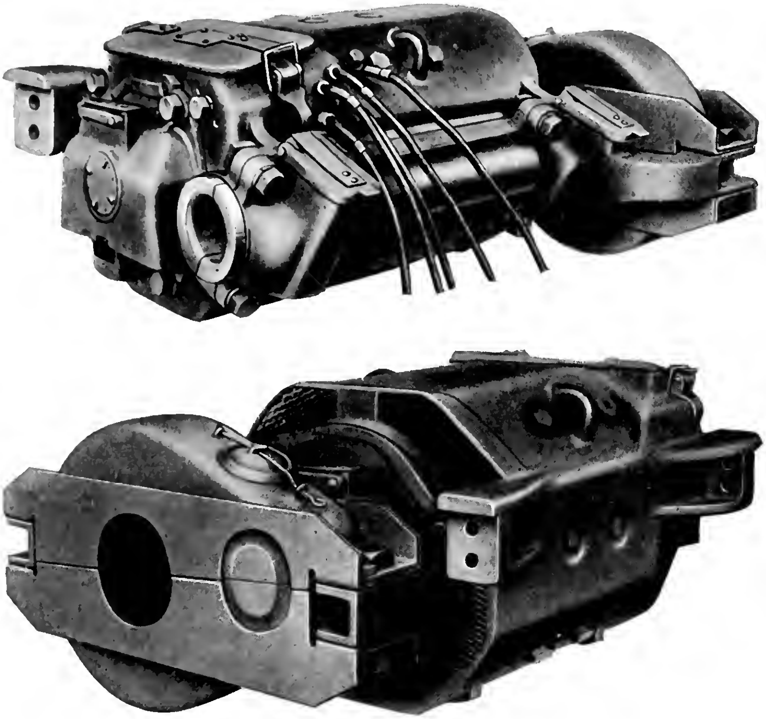

Fig. 6. The GE-247 Railway Motor

In the event of an overload upon the motors, the overload trip operation opens up the control circuits for the magnet valve coils, returning the line breaker and contactors to the open position. The control circuits are so arranged that in the event of the overload trip operation, the line breaker can not close until the reset coil has been energized and the motor controller has returned to the off position.

Control Switch

A small enclosed switch and fuse having three positions, "off," "on" and "reset," is provided in the control circuit for each master controller. When thrown to the "on" position, the moving arm is held latched in contact with a clip carrying current to the master controller. When thrown to the "reset" position, the setting coil on the overload relay is energized and the relay contacts closed. The moving arm is returned to the "off" position by means of a spring as soon as the handle is released. The construction of the switch makes it impossible to reset the overload relay without first opening the control circuit for the motor controller.

Storage Battery Equipment

Each car is equipped with a 40-ampere-hour storage battery which supplies power for operating the control and auxiliary electrical apparatus. The battery consists of 12 lead plate cells which provide a maximum of 32 volts and an average working potential of 24 volts. Bus wires are carried through the train, connecting all batteries.

The storage batteries are automatically charged by means of a relay and adjustable resistance in circuit with the compressor motor, the resistance being so adjusted as to divert the proper charging current to the battery.

Lighting System

Five circuits of five 23-watt, 115-volt Mazda lamps will be used for lighting the car during normal conditions. In addition to the 600-volt lighting system, each car is equipped with five 30-volt Mazda lamps operated from the storage battery and automatically brought into circuit whenever the main power supply is interrupted.

A lamp located in the rear cab serves to illuminate both the vestibule and the red colored lens of the tail light. By placing the reverse lever of the master controller in the forward position the headlight on the front end and the tail light on the rear end of a single car or train are brought into circuit.

If the trolley circuit is interrupted, the emergency lighting circuit is closed, two lamps of which illuminate the red lenses of the tail lamps on both ends of the car or train, and serve as well to illuminate the interior of the car.

Heating System

The system consists of four circuits of eight single coil heaters each, requiring a total of 10,880 watts. The circuits are automatically controlled through a thermostat, so that a uniform temperature is maintained. As all circuits will be cut in or out of circuit as a unit it is unnecessary to distribute the various circuits throughout the car, this arrangement permitting the simplest and most economical installation.

Signal System

In place of the bell cord generally used to transmit starting signal, the motorman receives his signal to start from a small Mazda lamp, so interlocked through contacts located at each door that it is lighted when all doors are closed. In addition to providing the starting signal, the lamp is used to illuminate the dial of the air pressure gauge.

When cars are operated in train the proper connections of the starting circuit between cars are made automatically by opening the cutout cocks of the air lines running between cars; each cutout being equipped with suitable contacts for completing the circuit.

Thirty push buttons are conveniently located throughout the car so that the passenger may signal the motorman to stop. These buttons operate a buzzer located in the motorman's cab and another at the conductor's position.

In the event of failure of either of these signal systems, the signal to start or stop the train is made by the conductor on a single stroke bell operated from the storage battery and controlled by a push button located at the conductor's position.

Fare Box Motor

In place of the manually operated fare box generally employed, the railway company has adopted one of the motor-driven type. Each fare box is operated by a small 600-volt motor which starts when the coin is deposited and operates continuously until all coins are registered, when it stops automatically.

This arrangement assists materially in speeding up the loading of passengers, lightens the duties of the conductor, and permits him to give his entire attention to the collection of fares.

CHEMICAL COMPOSITION *vs.* ELECTRICAL CONDUCTIVITY*

By Colin G. Fink

Edison Lamp Works, General Electric Company

The author states that the electrical conductivity of complex cold charges of an electric resistance furnace was found to be dependent upon the average size of the coke particles in the charge. On the basis of these early experiments a theory was developed which has been found applicable to a large variety of cases, such as the conductivity of metals and gels, flaming arc electrodes and compound brushes, porcelain, and other insulators. The chemical composition of two samples of material may be exactly the same and yet the electrical conductivity of one sample may be a thousand times higher than that of the other.—Editor.

Some years ago, while still at the university, I carried out a number of experiments on the electrothermic production of ultramarine. Powdered mixtures of sodium sulfide, china clay and carbon were interposed between carbon electrodes in a closed crucible furnace. I observed at the time that in order to keep the electrical resistance and the temperature of the charge fairly low so as to avoid decomposition of the ultramarine as soon as it was formed, it was necessary to use very finely divided carbon, such as lampblack With charges made up of powdered coke which was coarse compared to the lampblack, I could not get any appreciable current to pass between the carbon electrodes up to potentials of 250 volts.

Subsequently, I have found repeatedly that the electrical conductivity of mixtures of finely divided substances is a function of the relative size of the components.

Experimental

A series of tests was made in order to get values of a more quantitative nature. Two substances were selected, the physical properties of the one as divergent as possible from those of the other: a black metal powder, tungsten, and a white insulator powder, thoria. The advantages in this selection are manifold; both tungsten and thoria will stand very high temperatures and can therefore be made practically moisture-proof. It is a well known fact that in all high-resistance tests adsorbed moisture is a very disturbing factor. Metals such as copper and silver were not serviceable since they cannot be heated to high temperatures without partial vaporization, which though slight was sufficient to cover the surface of the insulator granules with a highly conductive film. Other factors that decided our selection in favor of tungsten and thoria were: (1) high state of purity; (2) availability of both in extremely fine powdered form (readily sifted through 250 mesh gauze); (3) constancy and stability under ordinary atmospheric conditions; (4) sharp distinction in color; (5) high specific gravities (which reduced the tendency to dust).

All mixtures here recorded were made up of equal weights of tungsten and thoria. As regards the size of the particles, as stated above, the mixtures would pass readily through silk having 250 meshes to the inch. The holes in this silk are about 0.001 in. in diameter. All attempts to segregate particles of a well-defined size by such methods as suspending in water, organic liquids or air, were frustrated on account of the persistent tendency of the very fine particles to form agglomerates.

We finally resorted to the familiar "tap test." This gave us fairly good comparative values of the fineness of the various powders used. Ten grams of the powder or powder mixture were filled into a 10 cc. glass graduate and tapped to constant volume; usually,

TABLE I

Mixture	Relative volume (v_r) of				Appearance of Mixture
	ThO_2	W	Mixture		
			Found	Calc.	
R	0.720	0.113	0.430	0.417	White
P	0.720	0.350	0.565	0.535	White
Z	0.576	0.235	0.389	0.406	White
T	0.305	0.113	0.200	0.209	White
S	0.305	0.330	0.275	0.318	Black
X	0.238	0.577	0.420	0.408	Black

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* Presented at the fifty-third meeting of the American Chemical Society, New York City, September 25 to 30, 1916.

after 7 minutes no further decrease in volume could be detected. The ultimate volume in cc. divided by 10 gave us the relative volume (v_r) as recorded in Table I. It can easily be demonstrated that the values for v_r are a function of the density and mean particle size. At first there seemed to be a serious objection to the tap test, namely this, that a powder composed of, say, equal parts of coarse and fine particles would give the same value for v_r as a second powder whose particle size was a mean between the two limiting sizes of the first powder. This objection to the tap test was automatically set aside since in the ordinary preparation of metal or oxide powders in single small lots by far the greater majority of particles are approximately of the same size. This tendency to form a "standard" size is a universal phenomenon, the dimensions of any particular standard being dependent upon the physical conditions such as temperature, strength of solution, etc., under which the particular powder is prepared. (Compare also, the uniform size of the crystals of granulated sugar as regulated by the strike pan.)

Referring to Table I, we note that the thoria powders varied in relative fineness between 0.720 and 0.238 and the tungsten powders between 0.577 and 0.113 cu. cm. per gram. The calculated value for v_r of any mixture is equal to one-half the sum of the v_r values of the ThO_2 and W constituents. These calculated values agree fairly well with the experimental and support our contention that the particles of any freshly prepared powder are of fairly uniform size. If this were not the case no such agreement between the calculated and experimental values would be possible.

As to the appearance of the mixture, if the v_r value for the white powder is high as compared with the value for the black powder, the appearance of the mixture is white; if the white powder is coarser than the black powder, the appearance of the mixture is black. In other words, whenever the ratio of v_r for ThO_2 to v_r for W is greater than 2, the mixture is white; if less than 2 the mixture is black. [The absolute density of W (19.6) divided by the absolute density of ThO_2 (9.8) = 2.]

Electrical Measurements

The powders were pressed into rods 4 cm. long and 0.5 cm. square. They were then placed in a tungsten-hydrogen furnace and fired at 1600-1650° for 3 hrs. This firing caused the rods to sinter together and rendered them practically proof against moisture. The fired rods were kept in a P_2O_5 desiccator.

The rods were then mounted between brass clamps and the resistance measured on a Wheatstone bridge with a sensitive galvanometer. Care was taken to make these measurements on days when the humidity of the air was low.*

In view of the differences in "color" of the various mixtures in the powdered form, it was not very surprising to find marked differences in the electrical resistances although the firing at 1600° resulted in an almost uniform shade for all of the mixtures. In Table II below are recorded four of the characteristic resistance values found. In the last column are the calculated specific resistance values.

TABLE II

Powder	Resistance	Resistivity
ThO_2 No. 2	Over 10^{12} Ohms	Over 10^{12} Ohms
Z	41.8	173.0
X	0.0271	0.108
W No. 1	0.0040	0.016

The powders, ThO_2 No. 2 and W No. 1, were pressed up into rods the same size as those for the mixtures; they were likewise fired at 1600° for 3 hrs.

Since in all of our original powders a small percentage of grains was present whose size was considerably smaller than that of the majority of the grains, the results tend to show that under ideal conditions of mixture, relative grain size, uniform distribution, etc., the resistivity values for white mixtures such as Z would be even higher than here recorded. Similarly, the resistivity values for black mixtures such as X would be even lower than those found, approaching a limiting value equal to twice that of the 100 per cent metal rod.

Conclusion

In general we may conclude that the electrical conductivity of a substance is primarily dependent upon the shape and the distribution of the fundamental grains or particles composing the substance, and secondly, upon the presence or absence of thin films of secondary material enveloping these ultimate grains.

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* Compare in this connection H. L. Curtis, "Surface Leakage Over Insulators," Phys. Rev. 3, 490.

On the basis of this theory we can account for the comparatively high conductivity of gels that contain but a trace of conducting material. We can also account for the marked difference in resistance of say two samples of commercial copper, whose chemical composition is identical, depending upon whether the impurity, such as sulfur, is uniformly dissolved in the metal or whether it forms a film ("cement") of copper sulfide around pure granules of copper. The latter case is to be regarded, as Bancroft suggested, as an emulsification of copper in copper sulfide. The high resistance of these surface films composed of say sulfide or oxide or arsenide accounts for the high resistivity values of copper containing but a trace of one or more of these impurities.

CONSERVATION OF RAILWAY RESOURCES*

By A. H. Armstrong

Railway and Traction Engineering Department, General Electric Company

The recent freight congestions have demonstrated the fact that the capacity of the steam railroads present equipment is insufficient to meet the service demands which are put upon it from time to time. The author of this article considers the means of increasing the capacity of the railroads—the installation of additional steam equipment, etc., *vs.* electrification. Continuing, he shows that electrification is the method dictated by economic reasons. Taking as an example the C., M. & St. P. electrification he discusses the features of high-voltage direct-current operation and then, generalizing, explains why this system is in excellent agreement with the ideas of future economic expansion of our big transmission systems and networks.—Editor.

The records of the past winter have strongly emphasized the limitations of our steam railroads and their lack of adequate motive power and rolling stock to take care of abnormal traffic conditions. Part of the failure of our transportation facilities is undoubtedly due to the restriction placed by the Interstate Commerce Commission on the one hand and to the growing demands of organized labor on the other. The result has seriously impaired the earning capacity of railroads and has rendered this form of security less attractive to the investor. Faced with the increasing difficulty of obtaining new capital to meet the demands of a growing traffic, steam road executives have been forced to adopt the hand-to-mouth policy of providing only the motive power, rolling stock, and track facilities absolutely required to meet the daily needs of normal traffic conditions. Any serious disturbance of the normal seasonal traffic movement, such as the congestion on Eastern Lines due to stoppage of foreign shipments by the submarine menace, results in such poor service that it almost reaches demoralization as evidenced by the records of the past few months.

Admitting the necessity for improved railroad conditions and also looking forward to a more favorable attitude by the government, which will attract to this form of investment the enormous new capital that must be expended during the next few years, there remains the all-important question as to how the needed additional facilities can be secured for the least increase in capital charge.

Perhaps the best way of approaching the matter is to gain a full appreciation of the fact that railroading as now undertaken is steam engine railroading, and present practice is built around the capabilities and limitations of the steam engine. Conserving our resources and making our country a self-supporting nation is the work of the immediate future; and not the least of such resources is the vast amount of new capital that has been brought to our shores during the past two years, a considerable portion of which it is hoped will be employed in rehabilitating our railroads. If this money is spent in the purchase of more steam engines, cars, and additional tracks, the railroads of the future will still be operated as steam engine railroads and the increased capacity of our lines may have been purchased at an almost prohibitive cost.

During the past decade of constantly increasing commodity prices there has been one conspicuous exception and that is the cost of electricity. Improvements in the efficiency of turbines, the establishment of large power houses with highly developed means of efficiently burning coal, and the economical development of water power in advantageous locations have all contributed to more than offset the increasing cost of manufactured products due to the rise in material and labor. The result is that today electricity is cheaper, is more reliable, and can be obtained over much wider areas than ever before.

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* Abstract of Lecture by A. H. Armstrong, delivered at Massachusetts Institute Technology, Feb. 28, 1917.

The operation of the heaviest freight and passenger trains by electric locomotives has been demonstrated as entirely feasible. The record of reliability, the low cost of maintenance of the electric locomotives, and the flexibility of this new type of motive power to meet the varied conditions of haulage service leave no room to doubt that electricity is destined to play a most important part in the future development of our railroads. Not only can present steam service be easily duplicated as regards the weight and speed of trains hauled, but it has been demonstrated that the electric locomotive is free from many of the restrictions placed upon train operation by the steam engine, and that it makes possible train weights, speeds, economies and improvements in operation thus far unattainable by the steam engine operator.

The last link in the 440-mile electrification of the Chicago, Milwaukee & St. Paul Railway between Alberton and Avery over the Bitter Root Mountains has just been completed and placed in regular operation. To those having knowledge of the facts regarding the operation of the electric locomotives on this road, it is plainly evident that the quality of service rendered is far superior to that previously attained or possible with steam engines. The winter of 1915 and 1916 will go down in history as probably the most severe ever experienced in Montana. For over three weeks the thermometer registered between 30 and 40 degrees below zero, playing havoc with steam engine operation on the adjoining divisions but affecting the operation of the electric locomotives not at all. It was a most flattering testimonial to the skill and care with which transmission lines and trolley construction were installed that there were no failures during such extremes in temperature, especially when it is noted that the utmost simplicity and economy had been exercised in building these lines. In fact, the entire installation is characterized by its simplicity and complete absence of forms of construction which had not been previously thoroughly developed and demonstrated. The motors and the locomotives, the substations and the trolley construction were all amplified in magnitude from similar types in successful commercial operation and the result has been that the change from steam to electricity was made with no interruption in service and under climatic conditions that were extremely abnormal.

It was found that the regular steam engine crews could be instructed in three or four weeks so that they were fully capable of taking out a train alone with electric locomotives and of rendering efficient service. A working knowledge of the electrical apparatus was readily acquired and the strongest booster for electrification is the converted steam engineer who fully appreciates his better surroundings, the greater ease and safety in handling his train, and the greater reliability which the electric locomotive offers in maintaining his schedule. His knowledge of air brake operation is, of course, a valuable asset, the same type of equipment being used on both steam and electric locomotives. In the latter case, however, the air brake is relegated to be in reserve as all braking on down grades is effected by the electric locomotive which returns, in the case of the Chicago, Milwaukee & St. Paul, approximately 10 per cent of its power back to the trolley as the result of holding back the trains on down grades. Aside from the matter of economy of power thus effected, the real advantage of electric braking lies in the possibility of successfully handling more cars down grade, at higher speeds, and with much greater safety than has been possible with steam engines braking with air. The full force of this statement is not realized until one has ridden down the 21 miles of 2 per cent grade between Donald and Piedmont on an electric locomotive holding back a 3000-ton freight train, when the smoothness of operation, complete control of the train, and general feeling of security brings home a full appreciation of the valuable asset of regenerative electric braking.

In this country, with its ample supply of power available from coal or water, the fact of the decreasing cost of electricity is becoming fully appreciated as exemplified by the constant development of huge transmission systems fed from a number of available power sites. A frequency of 60 cycles is becoming more and more universal, and in a few years it bids fair to become the standard frequency for generating and transmitting power with the possible exception of a few restricted localities where 25 cycles is strongly intrenched. In many instances considerable advantage to the railroad company may result from the purchase of power from an outside company, rather than to assume the burden of first cost and the operation of a separate powerhouse devoted solely to supplying the railroad load. The economical generation and distribution of electricity is a highly specialized business in itself and when conducted on a large scale and supplying a diversified load makes possible great reliability and low price for power. Whether power is purchased outside or produced in a railroad power-house, it is entirely proper, however, to view the possible electrification of our steam roads from the standpoint of power generation and distribution at high-voltage three-phase 60 cycles, and a type of locomotive should be adopted that will best meet the severe requirements of diversified haulage and also permit of economical distribution and conversion of power derived from a 60-cycle source.

The direct-current series motors driving the axles of the St. Paul locomotives are admirably fitted to the requirements of the variable speed of trains so necessary in crossing the broken profile of mountain divisions, and at the same time permit of economical conversion through synchronous motor-generator sets operating at efficiencies as high as 92 per cent at full load and providing for practically unity power-factor at all loads. The combination of high-voltage direct-current motors and synchronous motor-generator sets fits in so admirably with both the service requirements of the railroads and the apparently accepted standard of 60-cycle power distribution as to justify the strongest claims for its recognition as the proper system for general steam road electrification. The flexible characteristic of the series motor best meets the variable speed requirements so necessary in the operation of trains over a broken profile and power for these motors can be obtained through synchronous motor-generator sets from a general distribution net-work without interfering with the commercial, industrial, and lighting load that may be carried over the same transmission circuits.

In even this land of apparently unlimited supply of coal the tremendous waste of fuel inherent in steam engine operation cannot much longer go unchallenged. It is food for serious thought to know that one-third of the coal now consumed on a steam engine will move the same tonnage by electric locomotives if burned in a large modern power-house suitably located with regard to condensing facilities. Local conditions may also be such as to permit of the advantageous combination of ample condensing water available at the mines, thus eliminating any charge for coal haulage and permitting the use of a low and cheap grade of fuel having only a local short-haul market. Aside from the low power rate which is made possible by such favorable local conditions, there is the universal benefit to the railroad of relief from the necessity of hauling its own coal which on mountain grade divisions may readily reach 8 or 10 per cent of the total ton miles hauled behind the engine as represented in coal and carriers.

We are so much accustomed to consider the tender as a necessary part of the steam engine that it is not until the coming of a type of motive power like the electric locomotive that it is realized just how great a part of the operating expense is incurred in hauling this non-revenue company tonnage. Just by the introduction of the electric locomotive a 10 per cent reduction in total gross ton miles hauled is effected on heavy grade divisions, or what is more to the point, an increase of 10 per cent in revenue ton-miles with no increase in the previous cost of operation.

In addition, the electric locomotive provides much needed track relief on mountain grade divisions due to its higher speed, both up and down grade, greater number of cars that can be hauled with safety, and the elimination of stops now necessary with steam engines to take on water, test air brakes, and the delays of a general nature incident to the necessities of steam motive power.

It is a conservative statement to make that the substitution of the electric locomotive for the steam engine will result in doubling the daily tonnage capacity of a mountain grade division with no addition to the previous track facilities and will, in addition, release a large amount of rolling stock by reason of the considerable reduction in running time effected. Under favorable local conditions, therefore, electrification may provide the needed improvements on certain railroad divisions with a lesser expenditure of new capital than would be required to purchase the same results by adding more steam engines and tracks. And finally, electrification effects economies over steam operation which offer an attractive direct return upon the investment and which is additional to the benefits resulting from future increased tonnage movement.

America is indeed fortunate in being provided liberally with vast resources. Imagine the predicament of having no coal deposits within our borders and being dependent upon outside sources for such a vital necessity. But that is just the case with Italy, and the World War has most convincingly brought home to her the absolute necessity of making proper provision for power under her own control. Fortunately, there is an abundance of water power available and it is quite probable that after the war Italy will attempt to make itself independent of foreign fuel supply, as far as possible, by developing to the fullest extent its own natural advantages of hydraulic power.

Such railroad electrification as has already taken place in Italy has been along the lines of three-phase induction-motor locomotives fed from a double overhead trolley. The development of the Alexanderson split-phase method of converting single-phase into multiphase power permits the elimination of one of the present objectionable double overhead wires should it be found expedient to retain the induction motor type of locomotive. In view, however, of the unquestioned success resulting in the almost universal adoption in America of the high-voltage direct-current series motor, the interesting question is raised whether the development of the Italian State Railways should continue along its early pioneer lines or if this is not a most opportune time to take advantage of the progress of the art and adopt the high-voltage direct-current motor as best fitting into the general requirements of universal electrification.

The present extent of electrified tracks in Italy is small in comparison with the large work to be undertaken in the near future and should not be allowed to become the determining factor influencing a decision as to the system best suited to the needs of all classes of railway service. The many power developments interconnected by a network of transmission lines will undoubtedly be utilized as well for lighting and industrial purposes, hence the necessary requirement that the fluctuating railway load fed from the same circuits shall not be a disturbing factor. The use of synchronous motor-generator sets supplying railway load has been so successful in minimizing any effect upon distribution lines carrying a mixed load that their adoption appears to be most desirable. In fact, by proper design and adjustment of field values, synchronous motors may actually be made to act as voltage stabalizers regardless of the fact that their local load demand may be very fluctuating.

The matter of cheap reliable power is vital to the success of railway electrication from both an economic and operating standpoint. The general adoption of 60-cycle distribution in this country makes it possible to interconnect adjoining transmission systems, thus opening up wide possibilities in providing cheap power for railway purposes already extending, in some instances, over several divisions. As such large consolidated transmission networks are usually fed from a number of power-houses, there is also offered a promise of reliable service hardly possible to equal with a railway power-plant except by the expenditure of a prohibitive capital investment. Electric power development and railway electrification, therefore, appear to be most closely related and full appreciation of this fact may do much to lead to a better understanding of the economic and operating advantages of the high-voltage direct-current motor for all classes of traction service.

THE DEVELOPMENT OF THE COHERER AND SOME THEORIES OF COHERER ACTION

By E. C. Green

The first section of the following article historically narrates the early observations of coherer action, links the successive developments of the coherers that led to the practical wireless telegraph coherer of Marconi, and then describes a new type of coherer which is a part of recently developed lightning arrester alarms and high-frequency alarms. The second section presents with comments some of the theories that have been advanced to explain coherer action. In a subsequent issue will be given a full description of the application and operation of discharge alarms and high-frequency alarms.—Editor.

The electric wave detecting device, first known as a Branly tube and later as a coherer, has been the subject of much research. Many experimentalists in past years noticed that a number of metals, when powdered, were practically non-conductors when a small electromotive force was impressed on the loosely compressed particles, while they became good conductors when a high electromotive force was applied.

This knowledge can be traced as far back as 1835 to Monk of Rosenschoeld[*] who described the permanent increase in conductivity of a mixture of tin filings, carbon, and other conductors, due to the discharge through them from a Leyden jar. It seems that no attention was given to Rosenschoeld's observations at that time.

In 1852, S. A. Varley observed the high resistance of a mass of loose metallic powder and, it is said, four years later during a thunderstorm he noticed a very remarkable fall in its resistance.[†]

In 1866, C. Varley and S. A. Varley obtained a British Patent No. 165 in the specification of which was described a device for protecting telegraphic instruments from lightning. This device consisted of two copper points, almost touching each other, set in a small box filled with powdered carbon. They stated that powdered conducting matter offers great resistance to the flow of current at moderate voltage, but offers little resistance at high voltage. Even this announcement failed to create much attention.

Some very important observations were made by Professor D. E. Hughes in 1878, while engaged in research work on the microphone.[‡] In some of his experiments he used a tube of glass, filled loosely with zinc and silver filings, placed in series with a telephone and a single voltaic cell. Hughes seems to have discovered the very important fact that such tubes, when so used, were sensitive to electric sparks at a distance, as indicated by their sudden change in resistance. He showed these experiments privately to many scientific friends, but it was about twenty years later before his results were made public.[§] In the meantime other scientists had observed the same facts. In Italy, Prof. T. Colzecchi-Onesti made experiments on the changes in resistance of metallic powders, loosely compressed, under the action of various voltages. These observations were described in full in the Italian Journal, Il Nuevo Cimento, 1884 vol. 16, p. 58, and vol. 17, p. 35. He did not add very much, however, to observations already made by the Varley brothers.

In 1890, Prof. E. Branly, of Paris, published an account of a very comprehensive series of observations on the same subject that confirmed the work of previous observers and added a great deal of new information.

While Prof. Hughes seems to have discovered the fact that loose masses of powdered conductors are sensitive to electric sparks at a distance, it remained for Prof. Branly to make conclusive observations and thoroughly demonstrate this fact. In the majority of common metals he observed that the electric spark caused an increase in conductivity, while a few metals exhibited a decrease in conductivity,[‖] such as the contact between lead and lead peroxide. To Prof. Branly belongs the honor of giving to science a new weapon in the form of a tube or box containing metallic filings rather loosely packed between metal plugs. This tube was known as the Branly Metallic Filings Tube or Cymoscope, and is shown in diagrammatic form in Fig. 1.

He also showed that such a tube may be a conductor of very low conductivity when the filings are loosely arranged, but that the conductivity of the filings is suddenly increased by a nearby discharge of a Leyden jar or by any other nearby electric spark.

He used a galvanometer in series with such a tube and a single cell to detect the changes

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[*] See paper read before the St. Louis International Electrical Congress, 1904, by K. E. Guthe, on "Coherer Action".

[†] See the *The Electrician*, vol. 40, page 86.

[‡] See D. E. Hughes, Proc. Roy. Soc. Lond., May 9, 1878, vol. 27, p. 36.

[§] See Prof. Hughes' letter in *The Electrician*, May 5, 1899.

[‖] See E. Branley, *Comptes Rendus*, 1890, vol. 111, p. 785, also 1891, vol. 112, p. 90, or *The Electrician*, 1891, vol. 27, pp. 221, 448.

in conductivity. When an electric spark was made at a distance the galvanometer needle would become suddenly deflected, showing the greatly increased conductivity.

Branly observed that the same effect occurred in the case of two slightly oxidized steel or copper wires crossed in light contact, and further observed that this contact resistance dropped from several thousand ohms to a few ohms when an electric spark was produced many yards away.

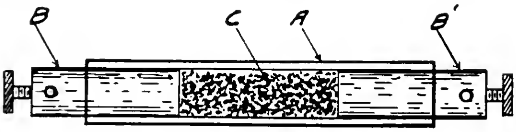

Fig. 1. Branly Metallic Filings Tube. ***A*, Insulating Tube; *B*, *B*¹, Metal Plugs; *C*, Metallic Filings, loosely packed**

Branly's work did not secure the notice it deserved until 1892 when Dr. Dawson Turner described Branly's experiments and his own additions to them, at a meeting of the British Association in Edinburgh.[*]

After the reading of Dr. Turner's paper Prof. George Forbes raised a very important question by asking whether it was not possible that Hertz waves might in a similar manner break down the resistance of a tube of loose metallic filings. This question showed that the real cause of coherence was not fully comprehended at that time.

In 1893, W. B. Croft exhibited Branly's experiments at a meeting of the Physical Society in London and read a paper on "The Action of Electric Radiation on Copper Filings."[†] In the exhibition of Branly's experiments Croft used a glass tube filled loosely with copper filings, connected in series with a galvanometer and a battery. No current passed when the filings were loosely arranged, but when a spark was made nearby the galvanometer deflected, showing the passage of current, and remained so until the tube was tapped back into a non-conducting state. This paper brought up the question as to how the electric spark caused the change in conductivity. Mr. Croft stated that the filings tube changed to a conductive state before the actual spark passed when the static electrical generator was started. Some thought the light from the spark caused the action.

In the same year, Prof. G. M. Minchin read a paper entitled "The Action of Electromagnetic Radiation on Films containing Metallic Powders".[‡] In this paper Minchin made special reference to the Branly tube, and stated that: "The waves sent out from the spark at once render the column [of metallic filings] a conductor."

It seems clear, therefore, that at the end of 1893 Prof. Minchin and a few other physicists had clearly recognized that the action discovered by Branly had its origin in electromagnetic radiation.

This paper was followed by one from Sir Oliver Lodge, entitled "On the Sudden Acquisition of Conducting Power by a Series of Discrete Particles."[§] In his discussion, allusion was made to an observation he had frequently made in connection with his experiment of the Syntonic Leyden jar; viz., to the effect that if the two metal knobs of the receiver were very close together, a battery and electric bell being in series, the occurrence of an electric oscillation in the circuit caused the knobs to make a good contact and cause the electric bell to ring. This action was produced entirely by electric radiation.

In June, 1894, Lodge gave a lecture at the Royal Institution, entitled "The Work of Hertz."[‖] In this lecture, the Branly tube was again described and several were exhibited. Lodge was the first to give the name Coherer to the Branly tube, as follows: "*A coherer is a device in which a loose or imperfect conducting contact between pieces of metal is improved in conductivity by the impact on it of electric radiation.*" Lodge's lecture caused widespread interest in Branly's discoveries and pointed out more forcibly that a new and highly sensitive means of detecting electric radiation had been evolved. The coherer used by Lodge consisted of a glass tube 1 cm. or less in diameter and about 7 cm. long,

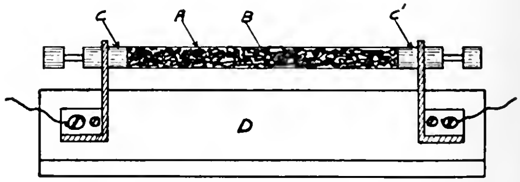

Fig. 2. Lodge Coherer. ***A*, Glass Tube; *B*, Iron Filings or Borings; *C* *C*¹, Metal Plugs; *D*, Insulating Base**

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[*] See Dr. Dawson Turner, *The Electrician*, 1892, vol. 29, p. 432, "Experiments on the Electrical Resistance of Powdered Metals".

[†] See W. B. Croft, Proc. Phys. Soc. Lond., vol. 12, p. 421.

[‡] See Prof. Minchin, Proc. Phys. Soc. Lond., Nov. 24, 1893, vol. 12, p. 455.

[§] See Proc. Phys. Soc. Lond., 1893, vol. 12, p. 461. Also Phil. Mag., Jan., 1894, vol. 37, p. 24.

[‖] See Proc. of the Royal Institution, 1894, vol. 14, p. 321.

filled loosely with coarse iron filings between two metal plugs. A diagram of this tube is shown in Fig. 2. He also tried brass borings and various other metals, filling the tube with air, hydrogen and even sealing it off at a vacuum. Lodge also experimented with various forms of light contact coherers, such as a steel sewing-needle resting lightly on an aluminum plate, and also slightly oxidized steel rods in light contact.

Up to this time the coherer was found to be a very capricious instrument; in instances highly sensitive to electric sparks, and then, all conditions being apparently the same, it became far less sensitive. The metals forming the most reliable coherers were iron, steel, nickel, copper, brass, and zinc, while the noble metals were much less reliable.

The man who really made the coherer famous, G. Marconi, began his work in Italy in 1894 and devoted his attention to the further development of the Branly coherer. He made a systematic and scientific study of the relative advantages of various metals as coherer material and selected for his work a mixture of 95 per cent nickel and 5 per cent silver filings carefully sifted to the same degree of fineness. He also modified his coherer tube, Fig. 3, very greatly from that previously used by other experimenters.* Instead of a long tube of large diameter as used by Lodge, he used a tube, *A*, 3 or 4 cm. long, having an internal diameter of 4 or 5 mm. He placed in this tube two silver plugs, *B*, *B′*, with edges beveled, highly polished, and slightly amalgamated with mercury. This gave to the interspace a wedge shape, the large part being at the top of the tube and about 2 or 3 mm. wide. This interspace was about half-filled with the nickel-silver granules, *E*. The tube was then exhausted and sealed at *C*, platinum wires, *D*, *D′*, being fastened to the silver plugs and brought out at either end. This tube was much more sensitive and reliable as an electric wave detecting device than anything that had previously been designed.

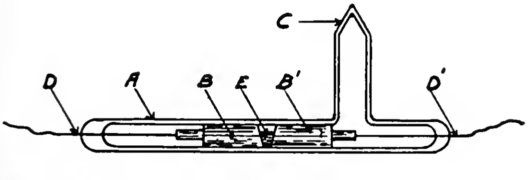

Fig 3. Marconi Coherer. *A*, Glass Tube Exhausted; *B*, B^1, Metal Electrodes; *C*, Side Tube for Exhaustion; *D* D^1, Platinum Terminal Wires; *E*, Nickel-silver granules

Marconi then proceeded to work out devices for employing his improved coherer as a relay upon a relay in a telegraphic outfit for receiving wireless messages. This last application caused world-wide interest in the coherer and numerous experimenters began work upon it.

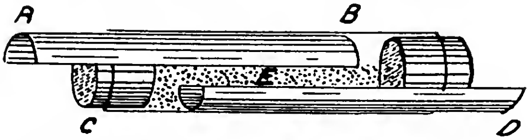

Fig. 4. Popott Coherer. *A*, *D*, Platinum Strips; *B*, Glass Tube; *C*, Cork; *E*, Iron Filings

Prof. A. S. Popoff, of Russia, in 1896 used his filings coherer to study the phenomena of atmospheric electricity, and also used it to detect and make records of lightning discharges at a distance. His coherer, a diagram of which is given in Fig. 4, was made of a glass tube, *B*, with two platinum leaves, *A* and *D*, down opposite sides, the intervening space being loosely filled with iron filings, *E*. The tube was then corked up at *C*.

Toward the close of 1896 Guglielmo Marconi left Italy for England and there explained his wireless coherer apparatus to Sir W. H. Preece, then the Engineer-in-Chief of the British Government Telegraph Department of the Great Post Office. Preece delivered a lecture before the Royal Institution on June 4, 1897 at which he exhibited Marconi's apparatus and stated that: "Marconi has produced from known means a new electric eye, more delicate than any known electrical instrument, and a new system of telegraphy that will reach places hitherto inaccessible."†

After this, many well-known scientists constructed various forms of coherers, most of which were designed for more rapid operation so as to be more adaptable for wireless work. Some were made of steel and mercury, copper and mercury, carbon and mercury, ball coherers, single contact coherers, etc. These were all low-voltage coherers, having a critical voltage of from 0.3 to 3 volts.

De-coherence was produced in the metallic filings coherer by tapping, slowly revolving the coherer tube, attaching the coherer to the armature of a relay, by clock-work

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* See British Patent Specification of G. Marconi, No. 12039, June 2, 1896.

† See *The Electrician*, vol. 39, p. 217.

tappers, etc. Marconi's scheme for producing de-coherence is shown in Fig. 5. It seems T. Tommasina was the first to use electromagnetic means directly for producing de-coherence*. He placed an electromagnet over the tube and in series with the coherer so that when the tube became sensitive the magnet was energized and lifted the granules to the top of the tube, thus producing de-coherence. This was applied to iron, nickel, and cobalt coherers.

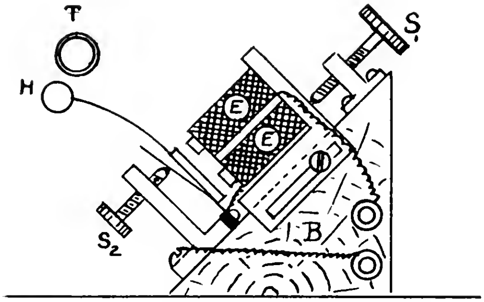

Fig. 5. Marconi's Electromagnetic Tapper for tapping his Sensitive Tube to a Receptive Condition. *E*, *E*, Electromagnet; *H*, Hammer; *T*, Sensitive Tube shown in Cross Section; S_1, S_2, Adjusting Screws

Various ingenious schemes have been developed for varying the sensitiveness, or critical voltage, of these coherers. Marconi made use of the wedge-shaped electrodes, *B*, *B'*, Fig. 3, in his coherer tube to produce this change. By taking hold of the sealed-off glass projection, *C*, the tube can be turned on its axis into various positions, so that the filings lie in a broader or narrower portion of the gap between the bevelled silver electrodes.

M. Blondel made a coherer with a side pocket into which some of the granules could be shaken from between the electrodes, or vice versa. This coherer is illustrated in Fig. 6.

In the various types of single-contact coherers the degree of sensitiveness was altered by changing the number of such coherers in series.

When the Consulting Engineering Laboratory of the General Electric Co. took up the development of a coherer to be used in connection with discharge alarms for lightning arresters, high-frequency alarms, etc., the problem had previously been the design of a coherer that would be as sensitive as possible and yet act reliably. The alarm coherer presented an entirely different problem. The task now was to make the coherer less sensitive and to shield it from all wireless effects so it would only respond when voltage was present, not due to Hertzian waves but due to direct contact with an energized source of voltage.

As the result of exhaustive experiments with aluminum, copper, magnesium, cobalt, iron, nickel-plated lead shot, tungsten, molybdenum, nickel, silver, and various other metals, 40-60 mesh pure nickel granules were selected. These were oxidized and sealed off in a tube containing a sufficient amount of gas to stabilize the oxidization of the granules. This residual gas thus prevents a rise in the critical voltage. The tubes may have a critical voltage of from 10 to 700 volts, depending upon how far the oxidization of the granules is carried.

After experimenting with tapping, rotating, and electromagnetic means of de-coherence, it was decided to use a tube shaped as shown in Fig. 7 and surrounded by a solenoid. This construction serves a double purpose in de-cohering the tube, for it lifts the granules away from the electrodes sealed in the bottom of the tube, thus breaking the circuit through the coherer, and then shakes up the granules and rearranges them by dropping them back when the solenoid is de-energized. Only one operation of this de-cohering device is necessary to produce perfect de-coherence in every case; while by the tapping method current continues to flow through the granules while being tapped and it often requires a number of operations to produce like results.

The sensitiveness of this coherer may be fixed by the amount the granules are oxidized and by the length of the "pantlegs" on the coherer tube.

To prevent the coherer from operating due to wireless effects, a high critical voltage coherer has been developed and in each lead running to it is placed a spark-gap which is set at such a value as to prevent any accumulation of static voltage from jumping over and reaching the tube. The coherer circuit is also operated by means of dry cells placed

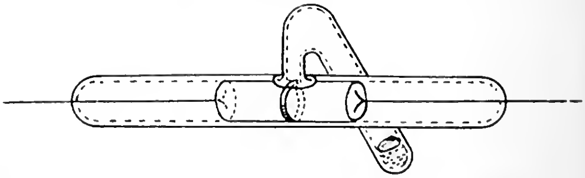

Fig. 6. Blondel Side-Pocket Metallic Filings Coherer

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* See *Comtes Rendus*, 1899, vol. 128, p. 225

close to the coherer to cut down the antennae effect of the leads. The contact on the armature of the small relay in series with the coherer tube has been insulated from the armature, so as to prevent surges being set up in the relay winding by current flowing through the armature and core of the relay.

These combined precautions make the present form of coherer very reliable and quite free from wireless effects.

In the best of former coherers a very slight leakage current was always noticeable; in the present coherer no deflection of a micro-ammeter needle can be observed when 100 volts is applied to the terminals of a coherer having a critical voltage of 150 volts, while the operating voltage of the coherer circuit is only 6 volts. This demonstrates the great factor of safety as to leakage current.

The volt-ampere characteristics of one of these coherers is shown in Fig. 8.

Theories of Coherer Action

A few of the theories that have been advanced to account for the phenomenon of coherence under the impact of electromagnetic waves will be briefly dealt with.

It is clear that the agency which actually causes coherence is electromotive force, and that the problem to be explained is the reason why electromotive force when acting on certain materials which are in light, or imperfect contact, brings the contact surfaces into a better conducting state while with a few other substances the action reduces the conductivity.

Fig. 7. Coherer which Forms a Part of Discharge Alarm and High-frequency Alarm Devices

At an early date Lodge advanced the opinion that coherer action was due to the welding together of the metallic surfaces in light contact. Many observers claim this process can be witnessed through the microscope. This theory of welding, however, does not explain how highly oxidized granules or carbon dust coheres, as it is impossible to weld either of these at such temperatures as are present in these cases.

T. Sundorph[*] claims that in the filings coherer the action is due to the formation of conducting chains of particles stretching between the electrodes. T. Tommasina supports this theory and says these chains are more easily formed when the surrounding medium is distilled water, or some dielectric other than air.[†] In these experiments it seems that a considerable potential difference must have been employed, far in excess of that necessary to cause coherence.

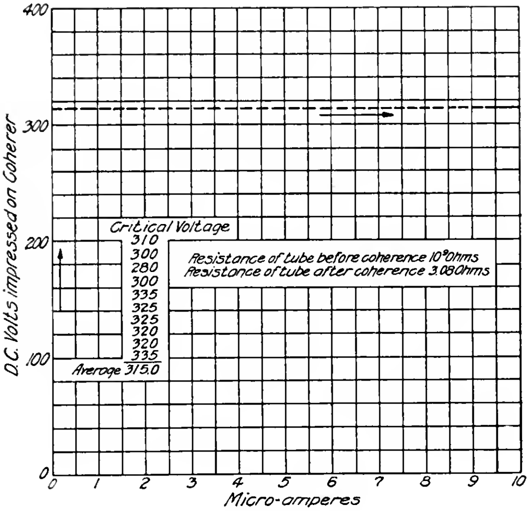

Fig. 8. Volt-Ampere Characteristic Curve of G-E Coherer No. 1065

This theory of conducting chains does not show why some substances, such as potassium, arsenic, lead and lead peroxide etc. become less conductive, and therefore does not satisfy the requirements.

Lodge has shown that two conductors separated by a film of air one ten-thousandth of a millimeter thick, and having a difference in potential of 1 volt, are drawn together by electrostatic attraction with a force of 646.8 pounds per square centimeter of contact surface.

He claims this force squeezes out the gaseous dielectric film separating the granules and thus causes coherence. This, however, also fails to show why other substances exhibit the negative conducting qualities under similar conditions.

Another theory of coherer action is based on the electronic theory of electricity. According to this theory, the conduction of electricity in conductors is due to the motion of free electrons, or negative ions, in them. In each conductor there is a certain number of these free ions per unit mass. The following is taken from Fleming's "Principles of

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[*] See *Wied Annelen*, 1899, vol. 68, p. 594.

[†] See *Comtes Rendus*, 1899, vol. 129, p. 40.

Electric Wave Telegraphy and Telephony," second edition, page 445.

"Sir J. J. Thompson has shown that an ion cannot fly off spontaneously and leave the conductor in which it is located*, since the instant it attempts to depart from the surface it is subjected to a force which is numerically equal to $\frac{e^2}{4\,d^2}$, where e is the ionic negative charge, (viz., 3.4×10^{-10} electrostatic units) and d is the distance from the surface. Now suppose that two metal surfaces are very near together, and at a difference of potential of V volts, or $\frac{V}{300}$ electrostatic units. Let the distance between these surfaces be microscopic, and equal to X cm. Then the electric force in the intervening space is $\frac{V}{300\,X}$ electrostatic units, and if this is equal to or greater than $\frac{e^2}{4\,X^2}$ then negative ions may pass from one mass of metal into the other and thus cause current to flow.

For example, if there is such a value of X and V that $\frac{V}{300\,X}=\frac{e^2}{4\,X^2}$ or $X=75\,\frac{e^2}{V}$, this transference of ions can take place. Moreover, when this transference of ions begins, it increases the potential difference between the two masses and this causes them to be drawn still closer together by electrostatic attraction.

When very great differences in conductivity exist between the two surfaces in contact, the action may result in the accumulation of negative ions at the bounding surface in such a manner as to stop the flow of current across the junction. This would explain the decreased conductivity between lead and lead peroxide."

Some of the latest experimenters claim that there can be no passage of ions from one conductor to another unless the surfaces are really in contact, so it seems the real way in which coherence occurs is still a problem to be solved.

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* See "Conduction of Electricity Through Gases," p. 144.

THE COMMERCIAL ENGINEER

By George P. Baldwin

Manager Philadelphia District, General Electric Company

This article and that of R. G. Clapp in this issue furnish valuable instructions to commercial engineers, particularly those of the near future who are now in college. In the opening paragraphs, Mr. Baldwin makes reference to the vital connection between the commercial engineer and the world's welfare and progress, and then shows how the ideas and policies of the "old school" of salesmanship are being superseded in the modern practice of commercial engineering. The remainder of the article is devoted to an analytical discussion of the fundamental requisites of the modern successful salesman.—Editor.

In America's industries there is a large and increasing demand for more electrical equipment, more expert service, more elaborate improvements to obtain increased output and efficiency, and still more delicate refinements in the various processes. The demand is growing because it has been proven that electricity permits easier, more rapid, and cheaper production in old processes, and that it has also endowed the world with new products which would otherwise never have been discovered or would have been impossible to produce.

A detailed list of the thousand-and-one fields of commercial activity on the part of electrical engineers could not be furnished here. There is hardly a commodity known to civilized man—be it derived from the animal, vegetable, or mineral kingdom but what is worked upon by electricity in some form between the raw material and the finished product.

Consequently, there is an unfilled demand for skillful commercial engineers to introduce the products of the central station and the electrical manufacturer into these thousands of industries. The question of opportunity in the electrical engineering profession is quite beside the point; what the young man of to-day has to consider, particularly the undergraduate in college, is how best to fit himself that these opportunities will be within his grasp.

The engineers and executives of America's greatest corporations of to-morrow are in college to-day. They will change and control the habits of a nation. The intelligent young man in college to-day can map his career more successfully if he appreciates what the future holds. The writer will dwell specifically upon the human requisites for grasping what the future holds in the field of commercial engineering.

A well known engineer described how his conception of engineering developed as time went on. In the early stages of his college career his idea of engineering was limited to operation and maintenance, so he spent a vacation period in a central station. This experience developed in his mind the belief that construction was more interesting than operation. He next took a position with a construction gang. This developed in his mind an interest in manufacturing. He finally entered the employ of a large manufacturer, in the Engineering Division. From designing details he was promoted to a position where he was assisting in the complete layout of large installations.

One afternoon on glancing up from his drafting board he noticed a party of visitors inspecting the works. It was a committee of business men being conducted through the plant by one of the commercial engineers, in order that they could observe the manufacturing facilities of the company. Then it dawned upon this young man that great installations must be sold before they are designed, just as they are designed before they are manufactured, erected, and operated. Then, also, for the first time it occurred to him that the activities of the commercial engineer were essential and important.

Now, of course, this is only the conception of one man. He was quite well grounded in practical experience—in the plant, on the road, in the shop, and in the drafting room—before his mind turned to the commercial phase of the engineering profession. That man now holds a highly responsible position in one fo our great corporations. He has found that what is commonly known as "salesmanship" requires just as intense and involved a study as does engineering, and also that successful salesmanship requires a mental layout and a scheme of operation that are as profound as engineering in its broadest sense.

Not long ago, many believed that salesmanship was an individual talent that would enable a man to sell anything—candy or electrical machinery. Salesmen used to make the statement that they could sell *anything*, but to-day there are not many of these candy salesmen trying to sell electrical machinery. The universities of this country, with the assistance of the manufacturers, are devoting considerable thought towards training men for the commercial side of the professions.

The first requisite for a successful sales transaction is a scientifically designed and well manufactured product. The next element is the salesman's intimate knowledge of this product and its application; and the third and most important feature as far as the commercial engineer is concerned is his ability to establish and maintain favorable relations with the people with whom he is brought into contact. It is this ability to establish favorable relations and maintain them that produces results and for which the engineer who desires to enter the commercial field must train himself. He must have not only sound engineering knowledge, but must also supplement this with a well-rounded-out knowledge of men, and affairs in general; this latter feature is important and, strange to say, is often lost sight of by the young man.

A man who is now a prominent executive in one of our engineering organizations nearly marred his career because of his neglect to realize this. The great turning point came when he was offered the position of Treasurer of his company. He hesitated. He considered it unfortunate. He feared he would no longer remain an engineer. Yet he finally yielded to exterior pressure and accepted the position. Later developments proved, without question, that this was the best step he could have made for it broadened his vision. Since he has crossed the threshold into the commercial world he has been able to make use of his engineering knowledge in a vast number of diverse fields. To-day he is amazed at the ignorance which caused him to hesitate.

His successful career is an example of what can be done to-day in commercial engineering. The old school salesman has passed. The salesman of to-day must thoroughly know his subject. If he does not have a deep knowledge of engineering principles and their application as well, he may try to get business by means of guessed-at statements; or should he not yield to this temptation, he will find himself often in the position where he must confess his ignorance in the presence of the prospective customer and offer to send to the home office for an engineer. The doctrine of the survival of the fittest is rapidly eliminating this type. To-day, the great manufacturers realize that the man to get the business should really be an engineer and be able to discuss intelligently the topics under consideration in all their phases. It has been proven that the old method was an economic waste; the new method is modern business.

But, the securing of this high type of commercial engineer involves a process of elimination. Experience has shown that out of one hundred engineers of high order by no means all of them developed sound commercial judgment and are capable of quick, accurate business decisions. And of those who have this accomplishment, not all of them possess the requisite knowledge of human nature, the tact, the ability to form acquaintanceships, and those qualities which are summed up in the word "personality." If exact figures were produced, it would be surprising how few good engineers possess these first two requisites for a commercial career—judgment and personality.

And still one more requisite must be fulfilled in order that a first-class engineer may make a successful commercial engineer, and that is language. He must make a clear, logical arrangement of his engineering facts; and both in personal interviews and in writing he must submit these facts in concise, impelling, language. A great author made the statement:

> "If I had more time I would write you a shorter letter."

Thus did he emphasize the fact that concise expression is a difficult and rare accomplishment. So difficult is logical, simple, attention-rivetting language that of the engineers who possesses judgment and personality surprisingly few will be found who possess this last qualification essential for a successful commercial career. And the fact should be further emphasized that the best place and practically the only opportunity for language training is during college days. After graduation, one's mind will be intent on what he says—not on how he says it.

The greater one's solid, practical, engineering knowledge, the greater will be his future in the commercial field, provided he possesses a clear, definite knowledge of human nature and the world in general, and is able to express his thoughts in concise convincing language.

To add a commercial training does not make one any less of an engineer. A bar of fine steel can be finished, tempered, ground to a fine edge, and yet it is still, steel. Just so, a commercial engineer is still an engineer. But he must be more than an engineer. To illustrate. You call on the President of a great railroad with the object of interesting him in electrification. You explain in detail, from the point of view of railroading, the savings that can be effected. The President is interested. Then you start to talk about kilovolt-amperes, power-factors, diversity-factors, and the like. The President has been brought up in the profession of steam railroading and he is not familiar with electrical terms. His distress is shown when his eye wanders to the pile of unanswered correspondence on his desk. Unknown to you, you have lost his attention. Then he sagely remarks:

> "Very interesting—I want you to explain these points to Mr. Thompson on the third floor,"

and he politely bows you out, shunting you off to a subordinate. It then occurs to you that you have not been given an invitation to call again. Your mind and that of the President's have not met because of your foreign tongue. An interpreter was needed. You had engineering knowledge and engineering skill, but you did not possess the judgment to know when you were in danger of losing the President's attention. Moreover, you lacked the tact to regain his attention or to obtain another interview.

Knowledge and language are the two master tools of business—the language that you used was not adapted to the work. It was as though your were trying to cut diamonds with a saw. To be sure, you were articulate—sounds emanated from your mouth—but they were not sensed by the commercial ear. Truthful and accurate as your statements may have been, they were not comprehended.

It cannot be impressed too forcibly upon the young men of to-day that they fully avail themselves of the manifold advantages offered by the Universities; that they beware of the habits which have been the undoing of the old school commercial men now almost entirely displaced; that they remember, as Francis Bacon wrote,

> "Reading maketh a full man, writing an exact man, and conference a ready man,"

and that upon graduation they decide to build their careers upon the rock of sound engineering experience and practice. By so doing they will automatically find themselves associated with real men—men who are doing things in the world today. Such association and practice will undoubtedly develop a mind capable of meeting other minds on equal terms and swaying them.

And finally, every man who has succeeded and has come to the front has had one axiom: He tried to do a little more than the other fellow, and he tried to do it a little better."

THE ELECTRIC VEHICLE AS A LOAD FOR THE CENTRAL STATION

By C. A. Rohr

New York District, General Electric Company

The desirability of the electric vehicle business to the central station lies in the fact that it is practically all off-peak long-hour service, with a load factor of 30 to 35 per cent in comparison with a probable 10 per cent load factor for the electric motor. The author seems to favor the car-mile system of electric service charges, as by this system the customer with a little observation can foretell within narrow limits his electric vehicle service bill month by month. The scale of charges may be expected to vary for different sections of the country, depending upon the items that make up the cost of power production such as local coal prices; and in some cases a careful record of this business for say one year may show the need for a revision of the scale. In order to make the system as serviceable as the kilowatt-hour system, it might be well for the power companies to provide rates for any standard battery in any standard vehicle, rather than to restrict the rates to a certain make of battery in certain makes of vehicles as is the practice at present.—Editor.

In discussing whether any particular industry might afford a desirable load for the central station it is necessary to look at the matter from two view points, viz., the advantage to the public and the profit to the central station.

The electric vehicle is cheaper than any form of animal transportation, irrespective of the load and haul. This statement is made unqualifiedly and is susceptible of proof in all cases. Reports of the Department of Agriculture show that in New York City there are 128,122 horses, in Chicago 68,050 horses, in Philadelphia 50,461 horses, and in St. Louis 27,182 horses. At a three cent rate each horse means a minimum annual income to the central station of between $80 and $100, if replaced by an electric vehicle. This means that in New York alone there is a minimum of something over $10,000,000 annually to be derived from the substitution of electric vehicles for horses.

Regarding the comparative cost of operation of gasoline trucks and electric trucks, it is impossible to say which is cheaper until it is known just what the cycle of duty is that must be performed.

Generally speaking, the electric vehicle should be selected in all cases for city delivery work for total mileages of 50 or below, where the stops are comparatively frequent or of long duration. Then there are cases of specific application, such as the industrial truck and baggage truck, where a gasoline-propelled vehicle cannot be considered at all, irrespective of cost of operation, because of the fire risk.

The future of the electric industrial truck is almost unlimited. There is hardly a manufacturing town in the country where there are not numerous opportunities for the sale of these trucks. They have demonstrated in hundreds of instances their ability to very materially cut the costs of haulage, as well as to accomplish much more work in the same time and to materially aid in establishing higher standards of efficiency.

I will not go into the question of electric pleasure cars, except to say that it is the ideal car for salesmen in visiting their trade. To see the representatives of a central station or electrical manufacturer visiting their trade in a gas car, and then go in and shout "do it electrically," seems incongruous.

From the central station standpoint the electric vehicle is desirable business because it is off-peak business and long-hour business. It is difficult to remember when the central station did not favor the long-hour business—it was this business which first attracted the central stations to the industrial motor load. Electric vehicles are on charge 6 to 8 hours every night and the load factor is uniform at 30 to 35 per cent.

Next, I would draw your attention to the low demand of the electric vehicle. For the same amount of plant equipment needed to operate it the electric vehicle has 8½ times the earning capacity of the electric flat iron. While it takes 86 irons to equal the annual income from a two-ton electric, the irons demand 51.61 kw. against 6 kw. for the electric vehicle.

The following table is submitted for consideration:

ANNUAL INCOME PER KILOWATT OF PLANT EQUIPMENT FROM TWELVE DIFFERENT CLASSES OF INSTALLATIONS

Installations	Annual Income per Kilowatt
One 2-ton electric truck	86
Small residence	15.22
Small retail store	31.75
1 motor	43.16
2 motors	41.18
3 motors	19.61
8 motors	50.96
20 motors	35.11
Large residence	63.04
Drug store	118.40
Saloon	191.51
Church	32.57

The next pertinent question that might be raised is what is the best way to sell electric power for use on electric vehicles or what rates shall we charge. It is considered by some that the best way to sell the power is on a car-mile basis; and in this connection a brief description of the battery-service plan will be of interest. Under this plan the consumer buys the car less the battery, which is furnished by the central station. When the battery is exhausted it is exchanged for a fully charged one at the central station. This plan was first tried out in Hartford, Conn., and has been in force there for two and one-half years.

A table of the rates charged by this company follows:

SCALE No. 1

Monthly scale of charges under the battery service system as furnished by the Hartford Electric Light Company, for standard wagons and trucks. No charging apparatus or garage required.

750 POUND WAGON

Fixed charge per month		$14
Rate per mile	0 to 500	2½ cents
Rate per mile	501 to 750	2¼ cents
Rate per mile	751 to 1000	2 cents
Rate per mile in excess of	1000	1½ cents

1000 POUND WAGON

Fixed charge per month		$18
Rate per mile	0 to 500	3 cents
Rate per mile	501 to 750	2½ cents
Rate per mile	751 to 1000	2¼ cents
Rate per mile in excess of	1000	2 cents

2000 POUND WAGON

Fixed charge per month		$27
Rate per mile	0 to 500	3½ cents
Rate per mile	501 to 750	3 cents
Rate per mile	751 to 1000	2½ cents
Rate per mile in excess of	1000	2 cents

4000 POUND WAGON

Fixed charge per month		$32
Rate per mile	0 to 500	4½ cents
Rate per mile	501 to 750	4 cents
Rate per mile	751 to 1000	3½ cents
Rate per mile in excess of	1000	3 cents

7000 POUND TRUCK

Fixed charge per month		$40
Rate per mile	0 to 500	6 cents
Rate per mile	501 to 750	5 cents
Rate per mile in excess of	750	3 cents

10000 POUND TRUCK

Fixed charge per month		$48
Rate per mile	0 to 500	7 cents
Rate per mile	501 to 750	6 cents
Rate per mile	750 to 1000	4 cents
Rate per mile in excess	1000	4 cents

SCALE No. 2

Monthly scale of charges under the battery service system as furnished by the Hartford Electric Light Company; battery charged in wagon at night, where the customer furnishes charging apparatus on premises approved by the Hartford Electric Light Company.

750 POUND WAGON

Fixed charge per month		$10
Rate per mile	0 to 500	2½ cents
Rate per mile	501 to 750	2¼ cents
Rate per mile	751 to 1000	2 cents
Rate per mile in excess of	1000	1½ cents

1000 POUND WAGON

Fixed charge per month		$13
Rate per mile	0 to 500	3 cents
Rate per mile	501 to 750	2½ cents
Rate per mile	751 to 1000	2¼ cents
Rate per mile in excess of	1000	2 cents

2000 POUND TRUCKS

Fixed charge per month		$19
Rate per mile	0 to 500	3½ cents
Rate per mile	501 to 750	3 cents
Rate per mile	751 to 1000	2½ cents
Rate per mile in excess of	1000	2 cents

With this arrangement the customer's unknown factors are reduced to a minimum, and therefore his doubts are reduced to a minimum and the sale of electric transportation is made easier. The customer buys his cars without batteries, which means less investment. If he knows how many miles long his delivery routes are, he knows what it will cost him to make deliveries.

This system was devised to relieve the customer of all uncertainties and to place the burden of variables upon those best able to control them. At the present time this system is effective in Hartford, Spokane, Boston, Baltimore, Harrisburg, Los Angeles, Worcester, Fall River and Wichita.

TABLE A

Amperes Essential for Charging	Kilowatt-hour Full Charge	Type
1000 lb.	18.0	22
2000 lb.	22.9	28
2 ton	30.7	40
3½ ton	36.3	45
5 ton	40.3	50

The other method of selling power for electric vehicles is the common one of charging so much per kilowatt-hour. This is the way it is done by all companies not using the battery service system. In Chicago an off-peak schedule has been arranged, applying to installations having a maximum demand of 50 kw. or above, which brings the rates used by the larger garages handling from 75 to 150 cars down to between $1\frac{3}{4}$ and 2 cents per kilowatt-hour.

The requirements of this service are shown in Table A on preceeding page.

The most important thing to remember is that the load factor is 35 per cent as compared to a 10 per cent load factor for the industrial motor.

DEVELOPMENTS IN SWITCHBOARD APPARATUS

Under this heading we shall publish from time to time descriptions of new or modified apparatus and practice in switchboard engineering. In this issue are described a line of solenoid operated field switches, a temperature indicator for use with exploring coils inserted in the winding slots of motors and generators or other electrical machinery, and some safety features in switchboard construction.—EDITOR.

SOLENOID OPERATED FIELD SWITCHES

On benchboard equipments and on large capacity vertical boards where remote control of the field is desirable solenoid operated field switches are usually employed. These are similar in construction to the non-automatic (CP) self-contained solenoid-operated air circuit breakers, with the addition of a discharge switch. A solenoid control relay is required only with the double pole switches which have a common closing and a common opening coil for both poles.

Solenoid operated field switches for synchronous motors started from the alternating current source with the field open, as is usual with motors of 125-volt excitations, are made ordinarily of two single-pole elements with independent closing and opening coils. Both poles are closed simultaneously and connect the discharge resistance across the field; but one pole precedes the other a short time in opening. When the other pole opens the discharge circuit is interrupted.

Solenoid-operated field switches for synchronous motors started with the field short-circuited, as is usual with motors of 250 volt excitation, are double-pole with common closing coil and common opening coil. No provision is made for automatically interrupting the discharge circuit after the switch opens, although the discharge blade can be opened by hand.

Switches are not made double-throw. When required for this service two sets of single-throw switches can be applied.

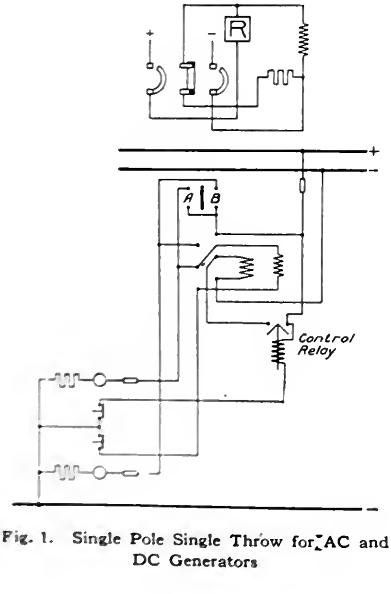

Fig. 1. Single Pole Single Throw for AC and DC Generators

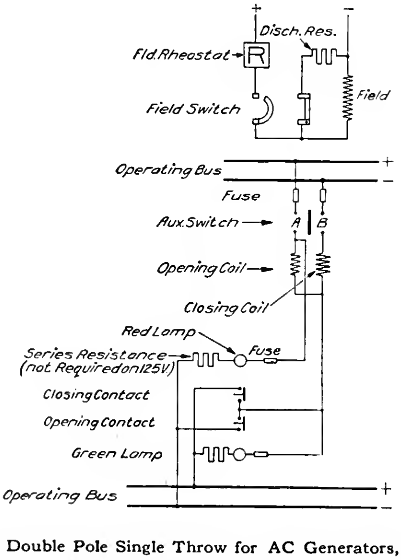

Fig. 2. Double Pole Single Throw for AC Generators, and for Synchronous Motors Started with the Field Short Circuited Through a Resistance

Solenoid-operated field switches are usually mounted on a base near or attached to the field rheostat, or they may be located on the exciter board remote from the main alternating current control board.

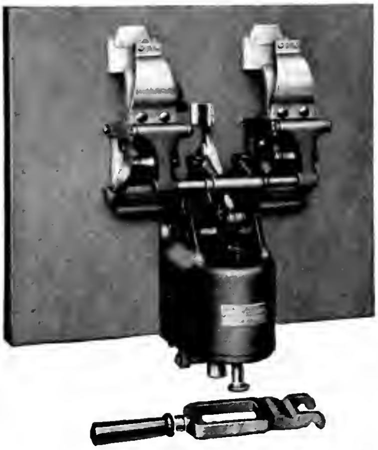

Fig. 3. Double Pole Single Throw Solenoid Operated Field Switch—Also Handle for Hand Closing.

TEMPERATURE INDICATORS

A temperature indicator equipment affords a convenient and rapid means of indicating continuously, at the switchboard, the temperature of various portions of the windings of electrical machinery under operating conditions.

The operation depends on the variation of resistance of a copper resistor placed in a slot of the machine stator in contact with the insulation of the winding, or in any other location external or internal where the resistor may be protected by suitable insulation from the conductors. The increase or decrease of temperature of the windings causes a corresponding change in resistance of the coil. This change of resistance is indicated by a sensitive instrument, the scale of which is graduated in degrees Centigrade and indicates directly the temperature of the windings.

It is now standard practice in accordance with A.I.E.E. recommendations to furnish temperature coils with all alternating current machines having a stator core of 20 inches or more in width, or voltage of 5000 or higher, 500 kv-a. or greater.

Equipment

For machines from 500 to 3125 kv-a., four coils are used, two of which are considered as spares. Above 3125 kv-a., six coils are used, three of which are spares. Some engineers require that all coils be connected with the instruments. When two machines are

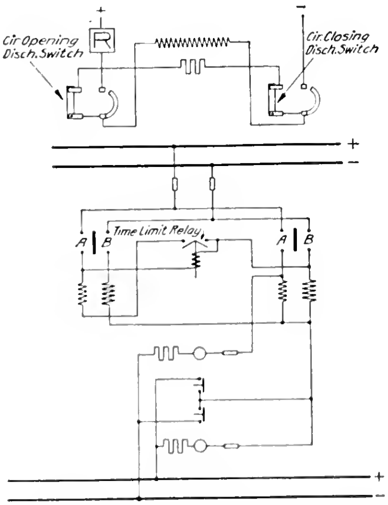

Fig. 4. Double Pole, Double Throw for Synchronous Motors Started From the AC End With the Field Open

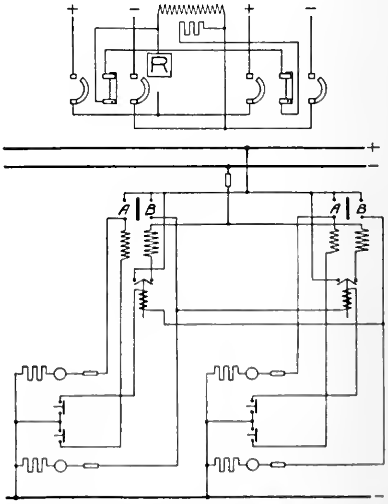

Fig. 5. Double Pole, Double Throw for Same Service as Fig. 4 Except for Use With two Sources of Field excitation.

AUXILIARY SWITCH REPRESENTATION

A = Open when field switch is open.
B = Closed when field switch is open.

furnished in a frequency changer set, and one machine requires temperature coils, coils will also be furnished for the other machine.

Orders are received for standard equipments mounted on small panels with wall brackets, or without the panel as shown by Fig. 7 to be mounted either on a switchboard which the customer has installed or on new main switchboards included in the same order.

A sample specification for equipment for use on a 125-volt d-c. operating circuit follows: Equipments may also be supplied for use on 250-volt d-c. circuits.

1 Temperature indicator, 20°-120° C. scale.
1 Variable resistance for 100-130 volts d-c. range.
1 Operating mechanism for variable resistance.
1 D-p.s-t., 250-volt, 30-amp. D-12, lever switch for supply circuit.
1 S-p.s-t. pull button test switch.
* 3-pt. receptacles.
1 3-pt. plug.

Fig. 6. Temperature Indicator Panel (Wall Brackets not Shown)

A 3-conductor lead for each 3-pt. receptacle to connect the instrument to the terminal box on the machine is furnished when requested.

Temperature Coils

The temperature coils are made up of copper wire wound on a thin form and pressed flat so as to be non-inductive. The temperature coils in the machine windings are connected to a combination terminal and cutout box mounted on the machine frame, by means of a 3-conductor armored cable.

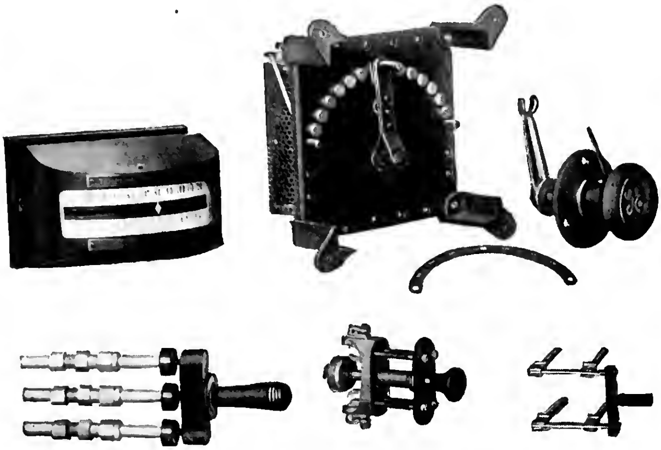

Fig. 7. Parts of Equipment for Mounting on Panel

Protective Device

Mounted on the frame of the machine is a small box carrying six rows of terminals for attaching the leads from the coils and for connection to the extension leads to the instrument. The protective device mounted in this terminal box consists of six pairs of film disk cutouts supported by spring clips with a ground connection between them; the spring clips being connected to the terminals of the coil. The cutouts serve as protection to the operator in case a coil becomes grounded to the power winding. Should the pressure between any temperature coil and ground exceed about 400 volts the insulation in the corresponding film will break down, removing the higher potential from the temperature coil, although bringing the machine winding to ground.

Temperature Indicator

The temperature indicator is a direct current differential voltmeter with three terminals. One of the windings of the temperature indicator is in series with a coil of manganin, having a resistance equal to that of the temperature coils, usually at 80 degrees C., and the other winding is in series

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* 1 for each pair of machine coils.

with the copper temperature coil itself. When the temperature in the copper coil rises, the current in the branch of the circuit carrying the temperature coil decreases, causing a corresponding deflection toward higher temperature marking on the scale of the indicator. The reverse occurs when the temperature of the temperature coil falls. The scale of the standard instrument is adjusted with a range of 20-120 deg. C. or 0-90 deg. C. and marked in 1 degree divisions.

Variable Resistance

The whole indicator outfit is connected through instrument fuses across a 125 or 250 d-c. source. A variable resistance with dial switch and index is furnished, to make up for variations of the voltage of the supply circuit, especially when voltage regulators are used with the exciters. In some instances it is desirable to use a fixed resistance, but this should be recommended only when investigation shows that the d-c. voltage does not vary more than 2½ volts for 125 volts and 5 volts for 250 volts either side of normal. A greater variation in supply voltage introduces serious error in the indicator reading. It is therefore desirable, in order to obtain the best accuracy, to always set the resistance to the nearest 5-volt step on a 110-volt circuit and to the nearest 10-volt step on a 220-volt circuit corresponding to the voltage of the exciting circuit.

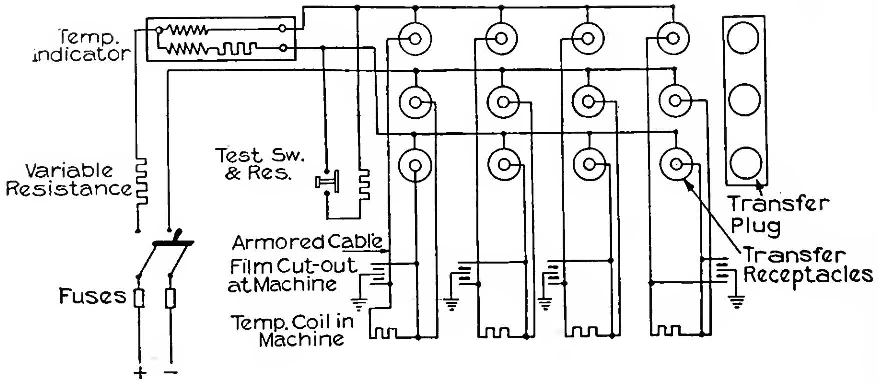

Fig. 8. Connections

Disconnecting Switch

For convenience in disconnecting the indicator outfit from the supply source a double-pole, single-throw switch is supplied to be mounted on the front of the switchboard.

Test Switch for Checking Indicator

A single-pole, single-throw, pull-button, test switch is provided on the switchboard to connect occasionally a resistance in multiple with any of the temperature coils. If the outfit is in proper working order, closing this switch will cause the instrument to show a reduction in the reading of about 12 degrees.

Transfer Plug and Receptacle

Special 3-point receptacles and 3-point plug at the switchboard are used for transferring the temperature indicator to any of the coils in the machine winding. One-half of the temperature coils are connected from the terminal to the switchboard, requiring 3 leads per coil. One 3-point receptacle is required for each coil, the temperature of which is to be read. One 3-point plug is required for each indicator.

The center point of the plug is made shorter than the other two, thus insuring that the circuit of the supply is broken before the instrument is disconnected from the coil. From Fig. 8 it can be seen that if either of the other leads were broken first an unbalanced condition would exist and cause the needle of the differential instrument to be thrown violently to one side or the other.

Leads

Since the indicating instrument is mounted apart from the machine, either on the main switchboard or on an auxiliary panel, it is necessary to run cable leads from the terminal box on the machine to the transfer receptacles on the switchboard. Three conductors are necessary for each 3-point transfer receptacle used. For distances up to 200 ft., each conductor may consist of 19 strands of No. 25. For greater distances conductors consisting of 19 strands of No. 22 wire are recommended. Ordinarily 3-conductor cables are used, although one 6-conductor or 9-conductor cable could of course be substituted.

SAFETY FEATURES IN SWITCHBOARD CONSTRUCTION

The switchboard panels illustrated on this page embody several features which in many cases are desirable from the standpoints of safety and convenience. All live parts, except current and potential receptacles, are inaccessible from the front of the board and the live parts of the receptacles are recessed so that accidental contact with them is difficult.

Grillework screens afford protection against accidental contact with live parts in the rear of the board, and prevent tampering with apparatus. Disconnecting switches are used between all oil circuit breakers and busbars and provide convenient and rapid isolation of the breakers from the bus for inspection, changing oil, or repairs, without hazard. Instead of the usual calibrating switches back of the panel, this board is equipped with front of board calibrating receptacles which permit safe and convenient calibration of instruments and meters from the front.

Insertion of plugs in the calibrating receptacle connects the testing instrument in series with the instrument under test.

The live parts of the field switches are mounted on a slate base, back of the panel, and are connected to an operating handle on the front of the board by a rod and bell crank. This method of mounting field switches is a development of great importance, and is strongly recommended. It is impossible for the switchboard attendant to be injured by the arc or to come in contact with live parts of the switch when operating. Also instruments and other adjacent equipment are safe from damage by burning, which sometimes happens with the front of board type of field switch.

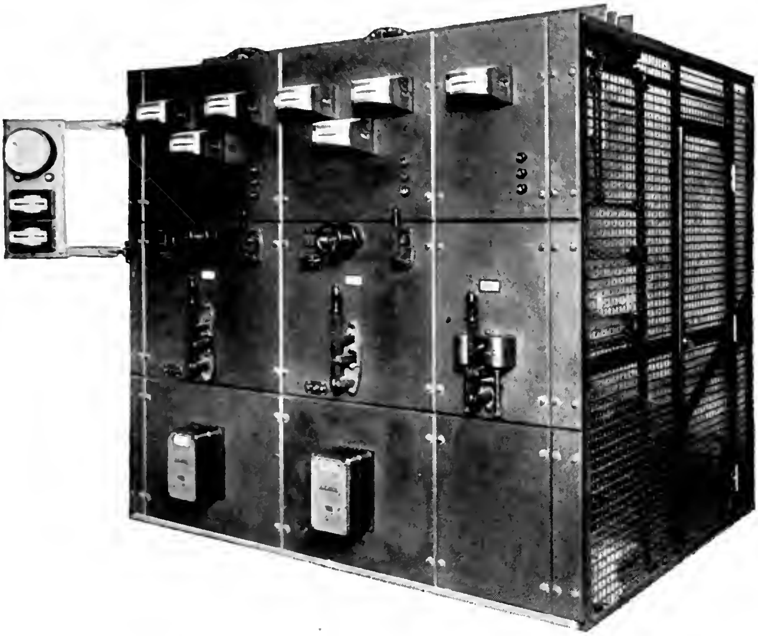

Fig. 9. A-c. Switchboard with New Safety Features

When switches are required for arc or incandescent circuits, the switches are of the dead front plug type. All live parts are entirely back of the panel and cannot be touched from the front. This result is obtained by using two tubular receptacles and a two-point double-break switch plug, per pole. The entrance bushings for receptacles are of moulded material, and extra large in size.

The panels described are for general power and lighting service up to 3500 volts, 25 to 60 cycles.

ELECTRICITY IN THE PULP AND PAPER INDUSTRY

By W. W. Cronkhite

Power and Mining Department, General Electric Company

The advantages of electric drive for pulp and paper machinery have been so thoroughly demonstrated and are so well appreciated by the industry that it is unnecessary to discuss this matter at length. In this article the various machines are considered separately, and especially with respect to the approved method of driving and the power requirements. The illustrations will indicate the adaptability of the electric motor to this service, and the large extent to which it is employed in the industry.—Editor.

The paper and pulp industry was one of the pioneers among large manufactures to realize the benefits of electric drive. The use of the electric motor in the paper and pulp industry has grown so rapidly that at the present time a conservative estimate of the motors installed in these mills in the United States is close to 300,000 h.p. Electricity is the only practicable power distributing agent that allows the centralization of the power generating apparatus in one efficient station and, at the same time, affords the flexibility of distribution necessary to allow the layout of the plant to be made entirely with a view to its manufacturing efficiency. However, electricity is more than a convenient agent for distributing power; its assistance in the economical application of power direct to the machines is also of great importance.

There are many special applications of motors to pulp and paper making machinery that enable the manufacturer to get the maximum production from his mill. In applying motors, both group and individual drive must be considered and the choice determined by the conditions. Motor drive assists the manufacturer in re-arranging or adding machinery to take care of an increasing business.

To cover the complete engineering end of the industry would involve much technical data; therefore this article will make only general recommendations and in the briefest manner.

Wood Conveyor

Fig. 1 is of a wood conveyor which is driven by an induction motor located in the frame building to the left of the picture. Tests which have been made would indicate that wood conveyors take 1½ h.p. per 100 feet of length when running at 100 feet per minute. Some paper and pulp companies, however, make a practice of running their conveyors up to nearly 200 feet per minute and allow 5 h.p. per 100 feet of length. This may result in a motor that is a little larger than necessary, but it is an insurance against trouble due to high peak loads that may be encountered if the wood jams in the trough; it also insures ample starting torque if the conveyor is started with the trough full of wood.

Barkers

Individual drive is an ideal method for driving barkers. Fig. 5 shows an induction motor on a 5-foot barker installed in a Wisconsin mill. The power consumption varies somewhat with the material, and of course with the speed. Tests which have been taken on a 5-foot barker driven by a 15-h.p., 720-r.p.m. direct-connected motor show a maximum requirement of 12 h.p. and a minimum of 7 h.p. Squirrel-cage motors are to be recommended, but inasmuch as starting conditions are severe, due to heavy loads to be accelerated, it is important that an indestructible type of rotor construction be used. There may be conditions when group drive would be best. Fig. 2 shows such a drive in a pulp mill in Maine.

Grinders

Motor-driven grinders are finding an increasing field when it is desired to locate the pulp mill at a distance from the water power, or where power is purchased. Also, motor-driven stones can be used to supplement the work of the water-wheel driven stones at time of low water.

Fig. 3 shows 1200 h.p. motors each direct-connected to two four-pocket grinders, one on each end of the motor. This same arrangement with two stones on each end of the motor has been adopted in some mills. The reason for placing half of the stones on one end and half on the other is that in case of accident to a stone the coupling can be opened at that end of the motor and the stone or stones on the other end operated. This arrangement may not be of very great practical importance, and many installations are being made with all the stones on one end of the motor. This latter arrangement

Fig. 1. Motor-operated Wood Conveyor, Finch, Pruyn Company, Inc. Glens Falls, N. Y.

Fig. 2. Barking Room in Pulp Mill, Great Northern Paper Company, Millinocket, Me.

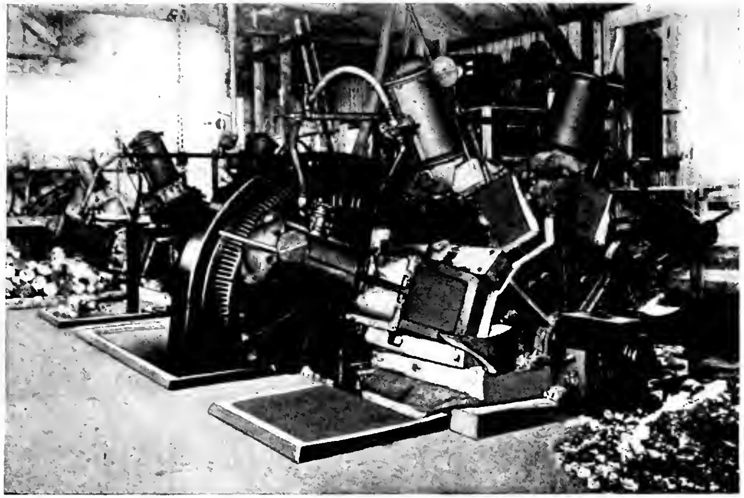

Fig. 3. Two 1200-h.p., 240-r.p.m., 440-volt Synchronous Motors, each motor direct-connected to two 4-pocket grinders. Inland Empire Paper Company's Plant, Spokane, Wash.

Fig. 4. Screen Room in Pulp Mill, Great Northern Paper Company, Millinocket, Me.

allows the motor and controlling apparatus to be placed in a separate room, free from dirt and slush, and also permits of easier handling of the wood. The power required to drive grinders varies considerably with the pressure. Tests taken on a 1200 h.p. motor, driving four three-pocket grinders with 54-in. diameter by 27-in. stones at 255 revolutions full-load speed, and with a water pressure of about 55 pounds per square inch in 18-in. diameter cylinders, showed that 104 h.p. was required to drive the four stones light with no wood in the pockets; and, as each pocket was filled with wood and the pressure applied, the power was increased by an average of 105 h.p. per pocket. On this basis, allowing 26 h.p. for windage and bearing friction, a three-pocket grinder should require 341 h.p. The power consumption would increase or decrease proportionately as the speed and pressure increased or decreased. It must be borne in mind, however, that in driving a group of grinders it is seldom that all the pockets are full at one time; in the test referred to it was found that it took 40 to 50 seconds for the attendant to fill a pocket with wood, and that the time between successive fillings was sometimes as low as four or five minutes. During this period the power consumption drops off. Therefore, instead of 1364 h.p. being required to drive four three-pocket stones, the average load actually would not exceed 1250 h.p. because there would be an average of more than one pocket empty all the time.

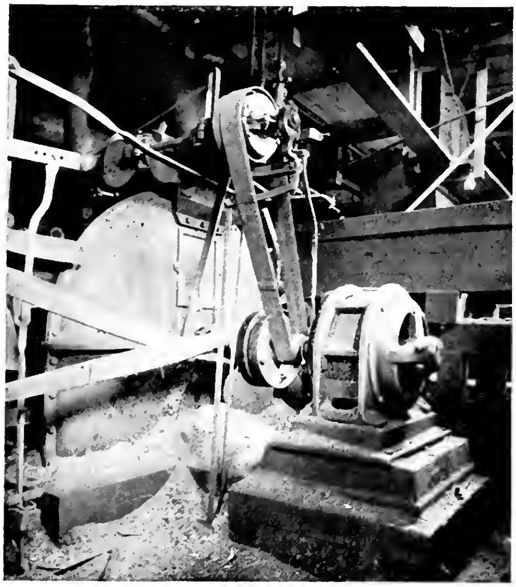

Fig. 5. 15-h.p., 750-r.p.m., 440-volt Form K Induction Motor driving 5-ft. barker. Kimberly-Clark Company, Kimberly, Wis.

There seems to be some uncertainty, even among the manufacturers, about the best speed for grinders. We have motors on this work, ranging in speed from 214 to 257 r.p.m. Some paper mill engineers believe that 257 r.p.m. is too high, and a few even advocate speeds as low as 210 r.p.m. Others believe that 257 is not only satisfactory but gives increased production.

Both slip ring type induction and synchronous motors are operating successfully on grinders. In certain sizes the synchronous motor will work out a little lower in cost and better in power factor than the induction motor.

Screens

Screens require such small amounts of power that we will not dwell long on them. The flat bed screen, by test on a group of three eight-plate screens, showed a power consumption of about 6 h.p., or ¼ h.p. per plate. This we believe is a fairly accurate estimate for figuring motor capacity.

Group drive is the proper thing for flats. (See Fig. 4.) Rotary and centrifugal screens consume more power. We find that power requirements vary for the different makes from 12 to 20 h.p., and for one centrifugal, which is somewhat larger than the others, 30 h.p. is required. Centrifugals may be belt driven, using a quarter turn belt, or a vertical motor may be direct-connected to the screen shaft at the top.

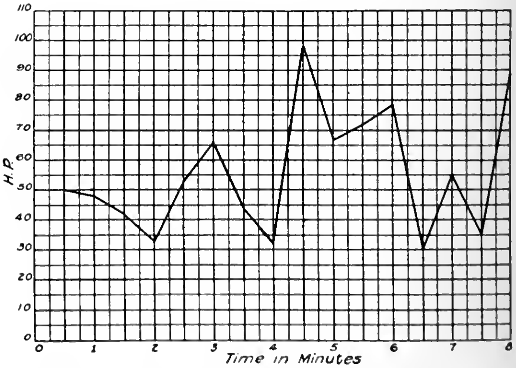

Fig. 6. Test on 5-ft. Chipper Working on Spruce—2-ft. lengths

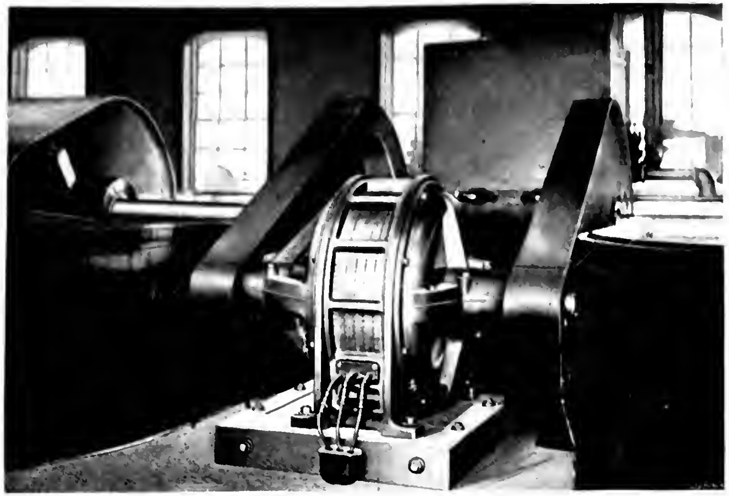

Fig. 7. 150-h.p Induction Motor Driving Two Beaters through Chain Belts. Kimberly-Clark Company, Kimberly, Wis.

Fig. 8. Group of 6 100-h.p., 480-r.p.m., 550-volt Slip Ring Induction Motors, each driving two Jones Type Beaters. Fenimore Mill, Union Bag and Paper Corporation, Hudson Falls, N. Y.

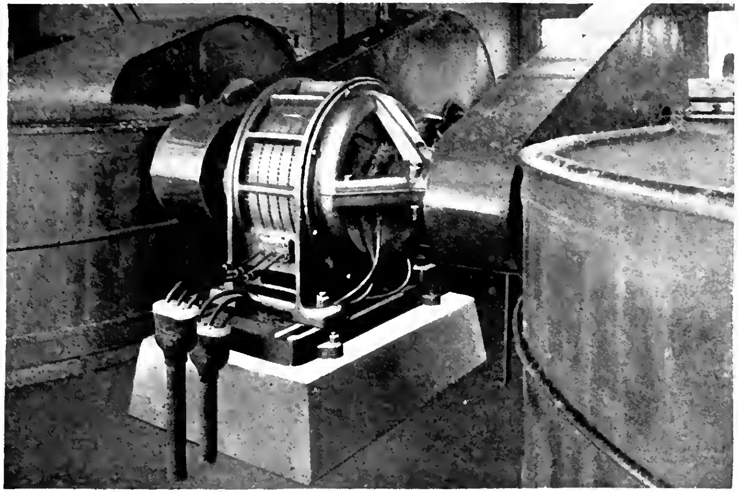

Fig. 9. 100-h.p., 480-r.p.m., 550-volt Slip Ring Induction Motor Driving Two Jones Beaters. Fenimore Mill, Union Bag and Paper Corporation, Hudson Falls, N. Y.

Fig. 10. 175-h.p., 600-r.p.m. Induction Motor Driving four 800-lb. Beaters, one Jordan, two Stock Pumps and one Agitator. Allen Mill Bag and Paper Co., Hudson Falls, N. Y.

Chippers

Fig. 6 shows test results on a 5-foot chipper working on spruce in 2 foot lengths. The average load was 56 h.p. Evidently a 75 h.p. motor would be ample to drive a chipper of this size. The load fluctuates and the motor is subject to high peaks due to irregularities in the size of the wood fed into it. Tests on an 87 in. chipper show a maximum peak of 115 h.p. and an average of 75 h.p. Chippers should never be direct-connected to motors.

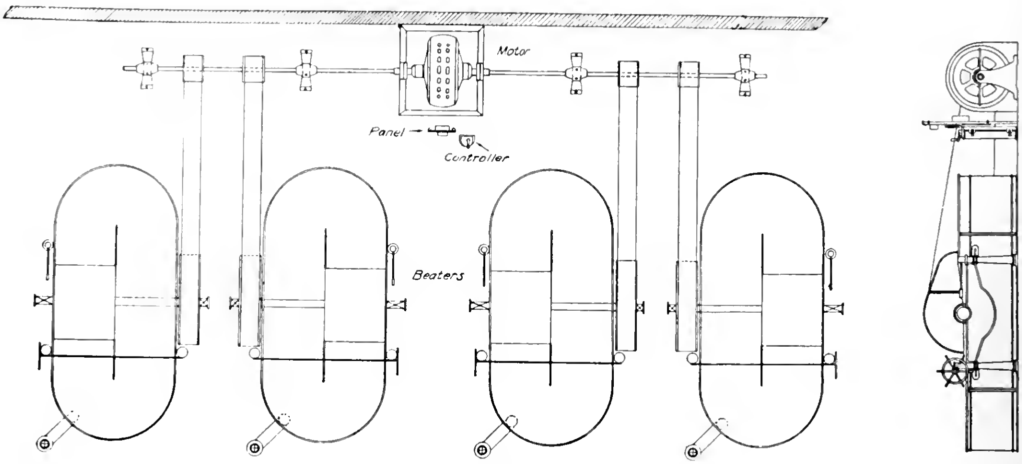

Fig. 11

Beaters

These machines may be driven in groups, in pairs, or singly. Fig. 7 shows the motor mounted between the two beaters. This arrangement is not always practical, as the distance between beaters may be such that it is impossible to install the motor.

Another arrangement for group drive is suggested in Fig. 11. The motor is direct-connected to a jack shaft and belted to the beater pulley. Both squirrel cage and slip ring motors are used on beaters, but in general the slip ring motor is to be recommended, as it will take care of the most severe starting conditions. Fig. 8 shows a beater room using chain drive, with the motor mounted between two beaters. Fig. 9 is a close-up view of the motor arranged for chain drive from each end. Fig. 13 shows one motor driving two beaters, the motor being placed in the basement and belted to the beater pulleys. The choice between these arrangements depends upon local conditions. The power consumption of beaters varies considerably. Fig. 12 is from tests on a 1500-lb. beater having a roll with 54-in. face and 65-in. diameter.

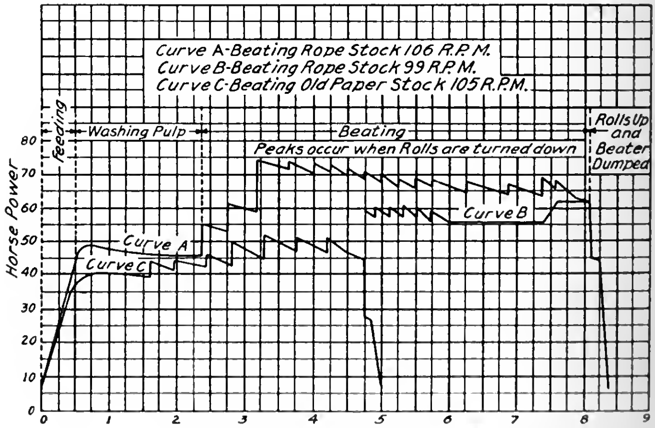

Fig. 12. Power Required by 1500-lb. Beater. Roll 54-in. face by 65-in. diameter. Capacity of Beater about 1200 lb. Rope Stock, 1300 lb. Sulphite

Curve A is for beating rope stock at 106 r.p.m. The first period is "feeding," and the maximum horse-power is about 48; the second period is "washing," and the power consumption gradually goes down; the third period is beating, and the load goes up to

Fig. 13. Direct-connected Jordan Driven by 150-h.p. Motor and 1000 lb. Beaters Belt-driven from Line Shaft Direct-coupled to 400 h.p. Motor Located on Floor Below—Beater Room Strathmore Paper Company

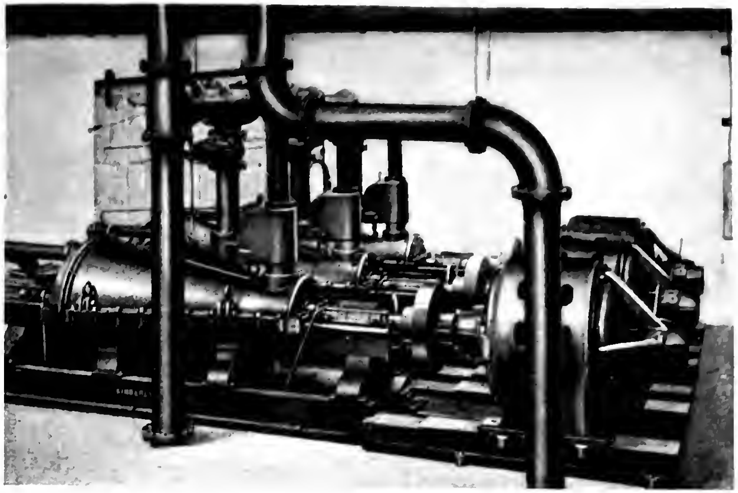

Fig. 14. Three 150-h.p. Induction Motors Driving Jordans. Kimberly-Clark Company, Kimberly, Wis.

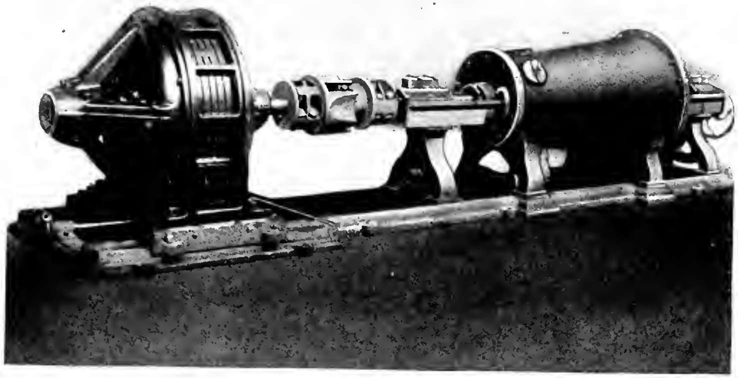

Fig. 15. 150-h.p., 400-r.p.m., 440-volt Slip Ring Induction Motor driving Mammoth Jordan. Inland Empire Paper Company, Millwood, Wash.

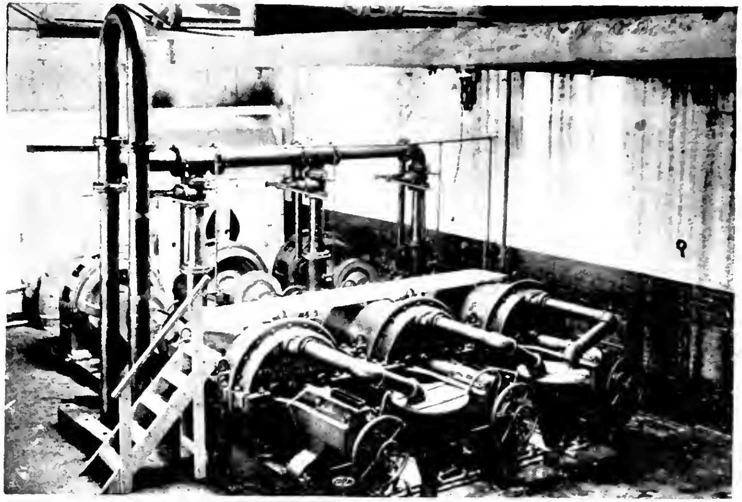

Fig. 16. 3 125-h.p., 104-kv-a., 300-r.p.m. Synchronous Motors Driving Jordan Engines. Kimberly-Clark Company, Kimberly, Wis.

approximately 75 h.p. The peaks occur when rolls are turned down. This test is over a complete cycle.

Curve B is similar to curve A, except that it shows the difference in power consumption due to the lower speed. In both cases the beater was working on rope stock.

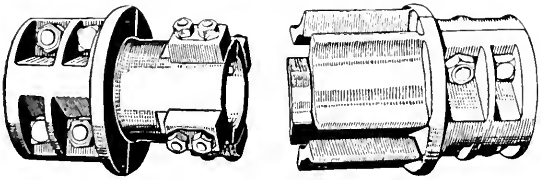

Fig. 17. Flexible Telescoping Coupling for use with Motor-driven Jordan Engines

Curve C is a similar test except that old paper stock is used and the beater is operated at 105 r.p.m.; naturally the power is less—a trifle over 50 h.p.

Some mill engineers recommend 1 h.p. per inch width face of beater-roll in estimating power required, but on very tough material and high peripheral speed the requirements go higher than this. We believe, however, that for work on light stock such as ground wood, sulphite, old papers, etc., with peripheral speeds not exceeding 1700 feet, three-quarters of a h.p. per inch width face is ample.

Jordans

The advantage of the direct-connected motor for driving jordans and similar refining engines is its compactness, freedom from belts, and long life of bearings and linings. Fig. 14 shows three-150 h.p. induction motors with sliding base arranged to take up the movement of the jordan plug. This movement can also be taken care of by the use of a telescopic coupling, as shown in Fig. 15. Fig. 17 shows a close-up view of a G-E. telescopic coupling for use between the motor and the jordan, by the use of which the plug movement of the jordan is taken care of, allowing the motor to remain stationary.

Synchronous motors are also used for driving jordans, and Fig. 16 shows this type of motor direct-connected to Jones jordans.

Some mills prefer to use a motor having internal resistance. Fig. 18 shows such a motor. A squirrel-cage motor direct-connected to a mammoth jordan through telescopic coupling is shown in Fig. 19.

Jordans do not require high starting torque unless the machine is shut down and allowed to stand with the stock in it and with the pressure of the plug not relieved. This practice is not customary, of course, as the jordan is generally allowed to clear itself before shutting down, and the pressure of the plug is relieved upon starting up.

There are so many conditions that enter into the operation of jordans to affect the power consumption that it is hard to do other than fix the extreme limits. Motor capacity will depend upon the size of the jordan, the speed, character of pulp, and the position of the plug. The different mills may obtain considerably different results as regards power consumption, even though they may be using the same size jordans and working the same class of pulp, as one mill may have a large beater equipment and depend upon the jordan only for brushing the stock, while another mill may have a limited beater capacity and use the jordan to reduce the stock. Many tests have been made on the different sizes and makes of jordans, but each case should be considered separately before making recommendations for size of motor.

Paper Machines

Electric drive for paper machines has engaged the attention of engineers for years, and a great many successful installations are now in operation. This form of drive eliminates mechanical speed changing devices and variable speed engines. It confines the power generating apparatus to one central plant, and in cases where power is purchased, it does away with the high operating cost and trouble incident to maintaining a few small engines on the machines alone. Bear in mind that there are many cases where it is not economy to employ motor drive on paper machines, for instance, steam engines exhausting into the driers may give an overall fuel economy higher than can be obtained by using motors supplied with central station power and using live steam for drying. In new mills this can be taken care of by using steam turbines in the power station and extracting the low pressure steam for drying. This problem, above all others, should be thoroughly studied, since the steam demands of paper mills vary greatly with the class of product. A scheme that would be economical for one mill might fail utterly for another.

On account of the fairly wide range of operating speeds of paper machines, direct current motors should be used. Conse-

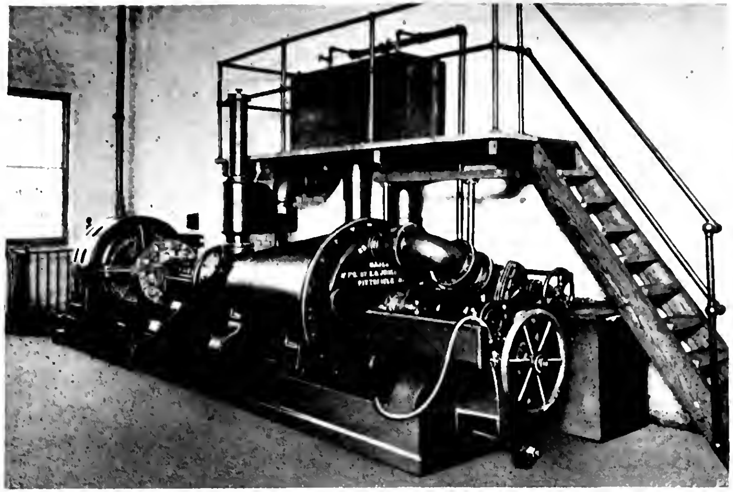

Fig. 18. 225-h.p. Induction Motor Driving Jordan. Fenimore Mill, Union Bag and Paper Corporation, Hudson Falls, N. Y.

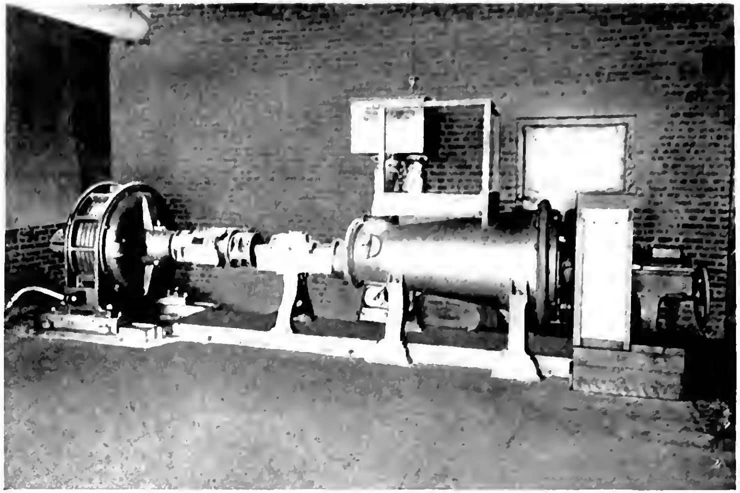

Fig. 19. 75-h.p., 345-r.p.m., 2200-volt Squirrel Cage Induction Motor Direct Driving Mammoth Jr. Jordan. Walloomsac Paper Company, Walloomsac, N. Y.

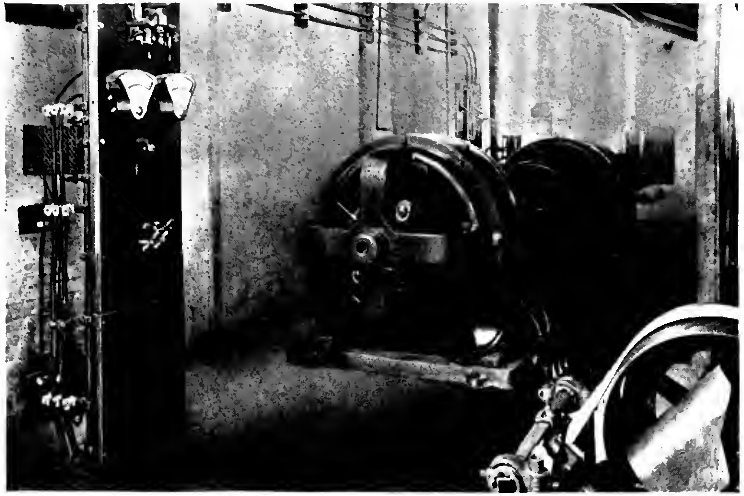

Fig. 20. Motor-generator Set for Operating Variable Speed end of Paper Machine

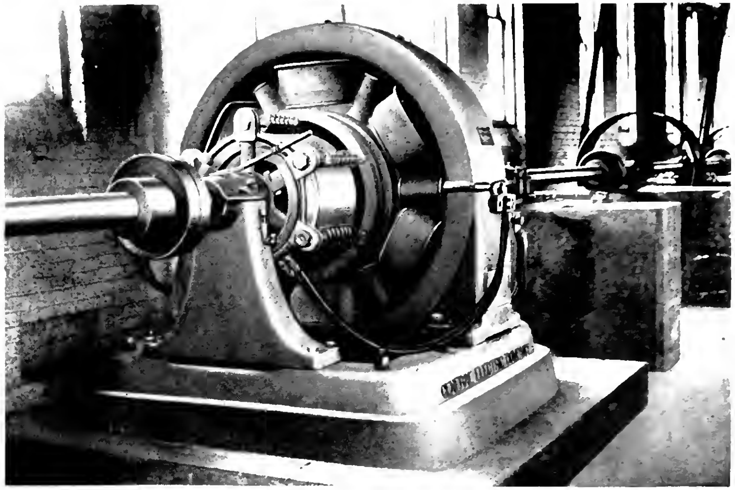

Fig. 21. One 100/225-h.p., 275/500-r.p.m., 220-volt Variable Speed Direct Current Motor direct-connected at both ends to line shafting driving variable speed end of paper machine. Consolidated Water Power and Paper Company, Grand Rapids, Wis.

quently, when the power supply is alternating current, a motor-generator set must be used to convert the power to direct current for the paper machine motors. Fig. 20 shows a motor-generator set and a 125 h.p. d-c. motor driving a cylinder board machine.

Fig. 21 is an illustration of a 225 h.p. motor direct-connected to the back line of a Fourdrinier machine. The motor may be coupled in the middle of the line or at one end. With this method a very wide speed range, 8 or 10 to 1, can be secured. Push button stations can be placed at convenient points around the machine.

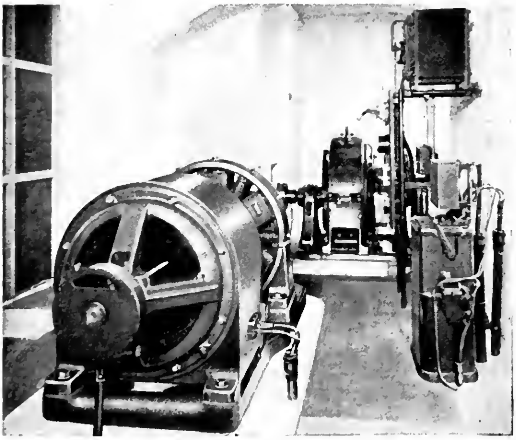

Fig. 22. 215-h.p., 300/380-r.p.m., 270-volt Motor Direct-connected to variable speed line shaft of 110 in. paper machine with 183-kw. motor-generator set and control panel. Total speed range, 160 to 380 r.p.m. by voltage and field control. Malone Paper Company, Malone, N. Y.

Fig. 22 shows a drive installed at Malone, N. Y. It will be noted that the motor is direct-connected to the end of the variable speed shaft instead of in the middle.

Another method that has worked out satisfactorily in some cases and that is well adapted for large machines requiring a wide speed range, is to drive the constant speed line shaft direct from an engine which is also connected to a generator of sufficient capacity to furnish power for the variable speed section, the latter being driven by a motor coupled to the back line and controlled from the machine room. This method gives an easily controlled and reliable method of obtaining a wide speed range, and leaves the engine exhaust for drying.

An analysis of tests made shows that in Fourdrinier and single cylinder machines the power required to operate the entire machine (including both constant and variable speed ends) can be arrived at by this formula:

Horsepower = 0.004 to 0.0045 × width in inches × speed in feet per minute.

The power for the variable speed end alone runs from about 0.0023 to 0.003 h.p. per inch width per foot per minute speed.

For multi-cylinder board machines, the power is very much higher, ranging from 0.012 to 0.015 h.p. per inch per foot per minute for the entire machine, and from 0.0069 to 0.0088 h.p. per inch per foot per minute for the variable speed end alone.

These figures are in actual brake horsepower, and should be increased 10 per cent when comparing with tests of indicated h.p.

Super Calenders

Several arrangements of motors for driving super-calenders have been installed. The one motor drive, depending upon resistance in the secondary circuit for threading, gives an unstable threading speed and also consumes considerable power. Super-calenders work from 20 to 30 per cent of the time at the low speed. It is therefore apparent that a motor large enough to drive the calender at calendering speed, if operated at one-tenth speed for threading 30 per cent of the time, is a very inefficient equipment.

However, single motor drives have been installed, and Fig. 23 shows a 75 h.p., slip ring motor geared to calenders in a Massachussetts mill.

Fig. 24 shows a group of calenders, each driven by a 75 h.p. motor geared to the bottom roll of the stack.

With single motor drive the threading speed is obtained by inserting resistance in the rotor circuit. After the paper is threaded through the stack, the motor is gradually brought up to the desired speed by cutting out resistance by means of the dial controller. From an engineering viewpoint this method is open to serious objection, as the low speed requires a speed reduction of about 90 per cent below normal. This makes the threading speed very unstable and requires care on the part of the operator while threading. In fact, single motor alternating current drives have proven unsuccessful in some plants.

With direct current motors the threading speed can be made somewhat more stable, as a certain amount of field control can be used and a shunt resistance connected around the armature to hold the speed down during threading. Even this method is not entirely

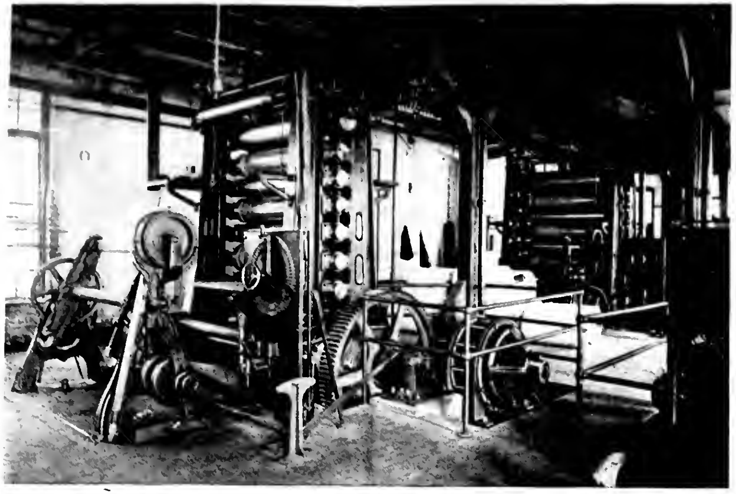

Fig. 23. 75-h.p., 514-r.p.m., 550-volt Slip Ring Induction Motor and Controlling Panel Geared to Finishing Calenders. Louis DeJonge Company, Fitchburg, Mass.

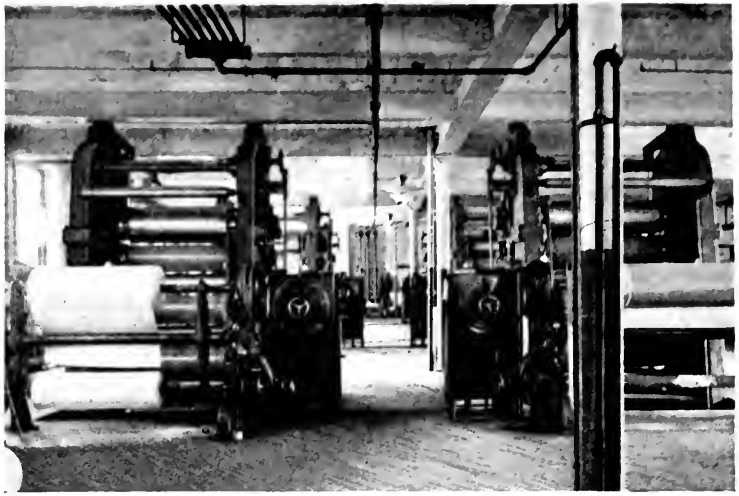

Fig. 24. Group of Six 9-roll Finishing Calenders with Motor Controlling Panels. Calenders are individually driven by 75-h.p., 514-r.p.m., 550-volt slip ring Induction motor geared to lower roll. Motors located in basement. Louis DeJonge Company, Fitchburg, Mass.

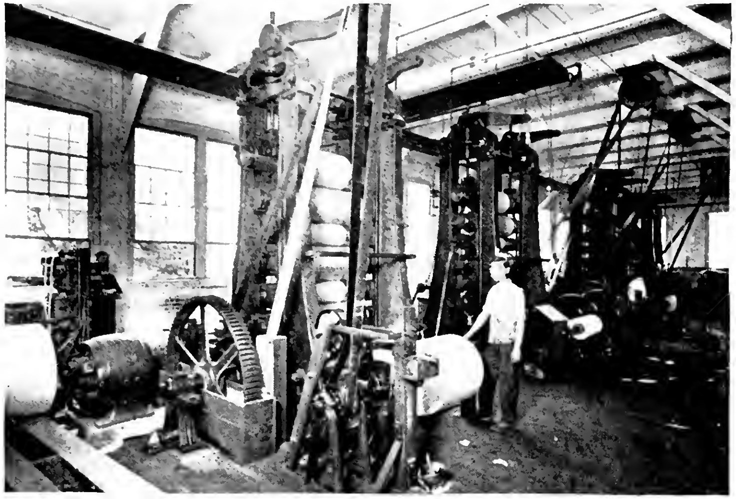

Fig. 25. Finishing Calenders Driven by Individual Motors. Lowe Paper Company, Ridgefield, N. J.

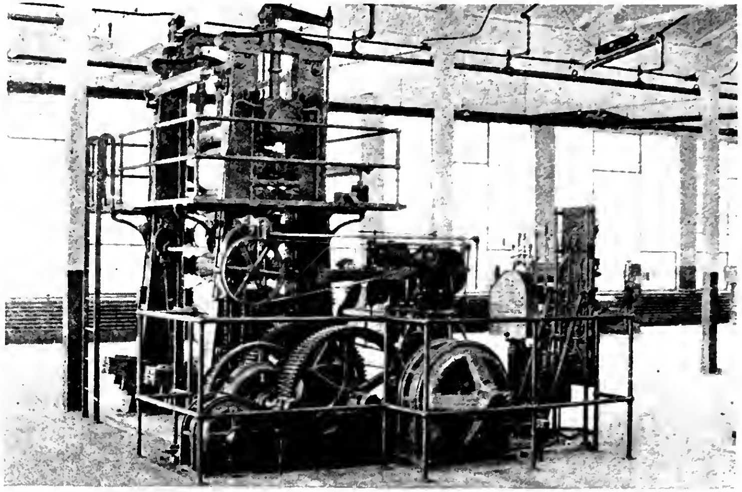

Fig. 26. 75-h.p. Slip Ring Induction Motor and 7½ h.p. Squirrel Cage Motor driving 50-in. 9-roll stack paper calender, Strathmore Paper Company, Woronoco, Mass.

satisfactory unless the load is uniform during threading, and this condition seldom exists. Further—the power consumption on a one motor drive (either a-c. or d-c.) is excessive at low speeds.

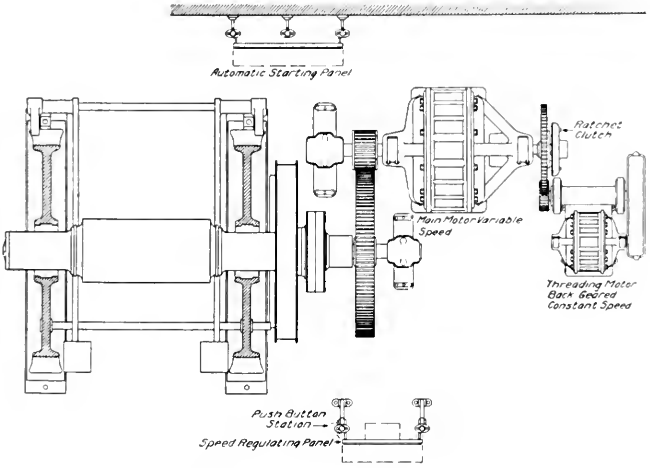

Fig. 27. Automatic Super-calender Drive for Paper Mill

Fig. 25 shows 4 stacks with single motor (direct current) equipment. These drives were installed several years ago.

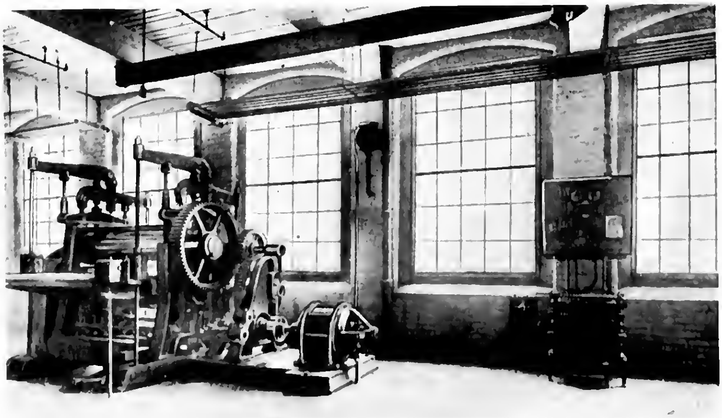

Fig. 28. 15-h.p., 600-r.p.m., 550-volt Slip Ring Induction Motor and Panel for Plater

We will now consider the two-motor alternating current equipment. In the first place, most mills have alternating-current available. Next, we know that super-calenders are constant torque propositions and the power goes down with the speed. The two-motor drive is therefore to be recommended. It has been developed and installed with a number of modifications to meet varying conditions. The small or threading motor shown in Fig. 26, which gives one-tenth speed, is controlled by push buttons placed at convenient points on the calenders, so this motor can be started and stopped by the men handling the paper. When the paper is threaded through the calenders, the large motor is thrown in and brought up to speed by a drum controller.

This motor is fitted with a magnetic switch for connecting its primary to the line, so that it can be stopped from any of the push button stations.

Fig. 29 shows four super-calenders at the Glatfelter Mills which are driven by complete automatic equipment. In this installation the large motor is brought up to speed automatically instead of by hand controller. A diagram of this drive is shown in Fig. 27.

Each push button station, of which there can be as many as desired, contains three buttons, one marked "slow," one "fast" and one "stop." Pushing the "slow" button in any station starts the small motor and drives the calender at threading speed. Pushing the "fast" button starts the large motor and automatically brings it up to whatever speed the controller is set for, and at the same time shuts down the small motor. Pushing any

Fig. 29. Group of Four Motor-driven Super-calenders. P. H. Glatfelter Company, Spring Grove, Pa.

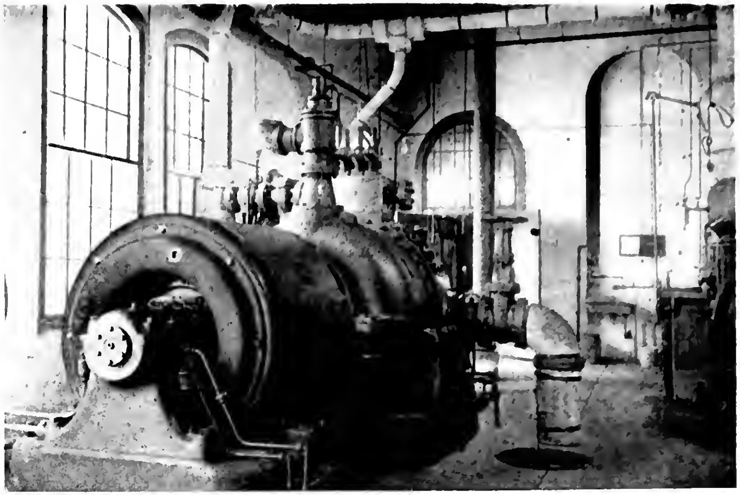

Fig. 30. 600-kw., 1800-r.p.m. Mixed Pressure Turbo-generator Set installed for the Parsons Paper Company, Holyoke, Mass.

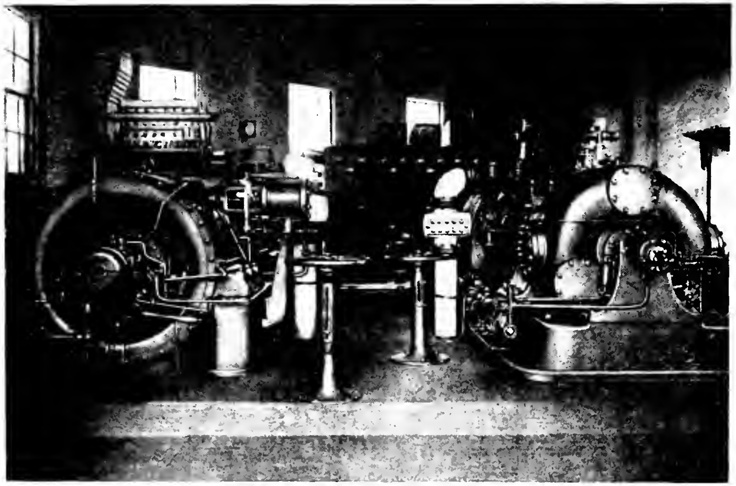

Fig. 31. 500-kw. and 750-kw. High Pressure Condensing Turbines Arranged for Steam Extraction at about 10 lb. pressure for drying. Claremont Paper Company, Claremont, N. H.

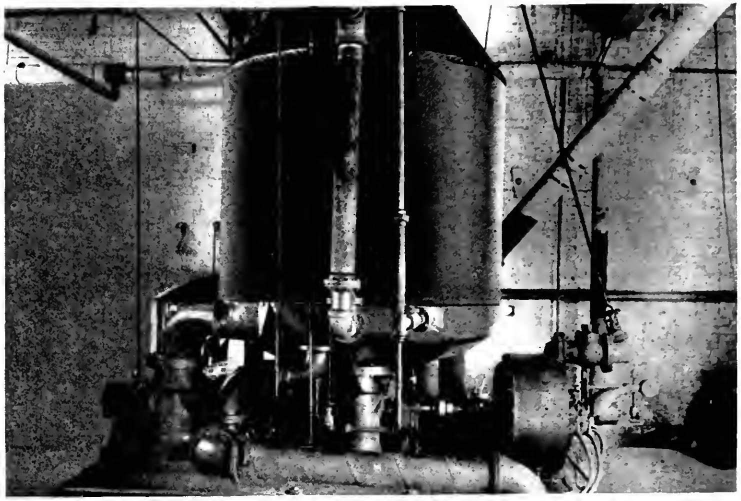

Fig. 32. Type L Two-stage 50-h.p., 1800-r.p.m. Turbine Driving Winestock. De-fibering and De-inking Machine. Stevens and Thompsons Paper Company, N. Hoosick, N. Y.

of the "stop" buttons shuts down either motor that may be driving the stack, and electrically brakes so that the calender will come to rest instantly. This particular arrangement allows a range of calendering speed from 300 to 600 feet per minute and permits slowing down for bad spots in the paper. This equipment is absolutely foolproof and completely automatic with push button control.

Platers

Fig. 28 shows the first of four plater equipments installed in a New England paper mill. These direct-connected motors are built to stand the jar of frequent reversals. The plater in the picture is a Norwood, with 42 in. face and 18 in. diameter rolls revolving at about 17 r.p.m. when the motor is running at full speed. The ordinary reversals are about 10, or 5 complete trips of the book, but when working on a corner of the book the reversals are as high as 30 a minute. The controller is mounted on a bracket attached to the plater table convenient to the operator. An enclosed contactor panel is mounted near the plater, containing switches for reversing the motor. These are controlled by the drum controller previously mentioned.

Steam Turbines

Electricity has been responsible for the modern steam turbine. Paper manufacturers are interested, as their power and heating problems are closely related, and the steam turbine gives ideal flexibility with respect to steam utilization.

Fig. 30 shows a 600 kw. mixed pressure unit. This machine is designed for mills whose supply of exhaust steam from existing engines considerably exceeds the drying and heating requirements, and where the engines are consequently operating condensing, or if non-condensing, are exhausting into the air. This turbine takes this exhaust steam at slightly above atmospheric pressure and expands it down to 28 in. vacuum, producing practically as much additional power as given by the engines themselves. The engines will take somewhat more steam than if they were operating condensing, but the increase is far less than the gain in power, and no change in the boiler room or boiler room force has been necessitated by the addition of this turbine.

Another demand may be made on the turbine by the paper mill that operates under a different condition. For instance, when the need for low pressure steam for manufacturing purposes is moderate compared with that required for power, an extraction turbine can be used to advantage. This type is designed to operate condensing and uses high pressure steam, but low pressure steam can be extracted from one of the stages. The extracted steam is automatically regulated so as to remain constant under variable load and steam flow conditions. Paper mills differ widely in their steam requirements and it is better that each proposition be carefully studied. Fig. 31 shows two turbines, a 500 and a 750 kw. high pressure machine, arranged for steam extraction.

A recent use of the steam turbine is its application to the Winestock de-fibering and de-inking machine, as shown in Fig. 32. In this installation the turbine not only drives the machine but furnishes steam to heat the stock for the next charge.

The many possibilities of electric drive in paper and pulp mills are partly indicated in the illustrations. These pictures are typical and constitute a strong argument for the general adoption of motors throughout the industry.

THE STRUCTURE OF THE ATOM

PART II

BY DR. SAUL DUSHMAN

RESEARCH LABORATORY, GENERAL ELECTRIC COMPANY

Part I of this article appeared in the March issue and contained a discussion of the experimental observations upon which the modern theories of the structure of the atom have been formulated. In Part II below the author discusses the theories of the structure of the atom suggested by Bohr, J. J. Thomson, Nicholson, Lewis, and others; and he shows in what respects each theory agrees or disagrees with observed physical and chemical facts.—EDITOR.

Introductory

It is self-evident that in dealing with a general problem such as that of atomic structure, the physicist and chemist would differ a great deal in their points of view. The former naturally considers questions of stability and energy emission or absorption; on the other hand, the latter believes that the atom models postulated by the physicists must also possess the chemical and physical properties suggested by the periodic arrangement, and to him the purely dynamical considerations of the physicist are of much less importance than the fact that there must be some necessary relationship between any postulated atomic models and their chemical properties.

We are thus led to divide the different theories of atomic structure which have been suggested in the past few years (and these are the only ones worth while considering in the light of our present knowledge) into two groups: Firstly, those which are based on the application of the laws of classical dynamics and the more recent modifications involved in the quantum theory; secondly, those theories which are based largely on purely chemical and electrochemical considerations, but which may be so modified as to agree qualitatively at least, with atomic models of the first class. Such a division must confessedly be more or less arbitary. All classification in science always possesses this great disadvantage. Nevertheless, it is necessary to emphasize the essential fact that the physicist and chemist have approached this problem of the structure of the atom from two different points of view.

In the previous section, we discussed the experimental observations which have been made in recent years and upon the basis of which some theory can be built up of the structure of the atom. These experimental facts may be summarized briefly as follows:

(1) The atoms of all elements may be penetrated by alpha particles and electrons travelling with high velocity.

(2) The atoms of all the elements but those of the radio-active series are extremely stable.

(3) The atoms contain electrons which emit practically undamped oscillations in the form of spectral lines. The different spectral lines can be arranged in the form of series which follow relations of the general form

$$\nu = K\left(\frac{1}{\tau_2^2} - \frac{1}{\tau_1^2}\right)$$

where τ_1 and τ_2 are integers and τ_1 can assume all integral values greater than τ_2. The electrons which are active in the production of spectral lines are probably the same as those which take part in the chemical combination of atoms to form molecules.

(4) There exists a relation between the frequency of characteristic X-rays emitted by an element and the order (N) of this element in the periodic table. This relation has the form

$$\sqrt{\nu} = a\,(N - N_o)$$

where N_o and A are constants for any characteristic radiation.

(5) The number of electrons in an atom can be determined by observations on the scattering of X-rays. The results obtained by this method are the same as those obtained by means of observations .on the high frequency spectra.

As already stated, this experimental evidence warrants us in concluding that the atom consists of a positively charged nucleus of extremely small dimensions situated at the center of the atom and a number of electrons arranged around this nucleus. Also the actual number of electrons in each atom corresponds to the place which the corresponding element occupies in the periodic arrangement. The atom thus resembles a sort of Saturnian system. We have, furthermore, good reasons for believing that valency

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H. S. Uhler (Proc. National Acad. Sc., 3, 88, 1917) has drawn attention to the fact that Moseley's law is not quite in accordance with the more recent observations of Siegbahn, Firman, and others. For large ranges of N, there are systematic deviations from the above relation.

and chemical properties in general are due to to electrons situated on the outermost surface of the atom, while the innermost electrons are those which are effective in producing X-ray spectra.

These are the fundamental facts upon which are based the most recent theories of atomic structure. The first atom model which represented a serious attempt to correlate the structure of the atom with its chemical and physical properties was due to J. J. Thomson. Assuming the atom to "consist of concentric rings of negative electrons in a sphere of homogeneous positive electricity of the size of the atom," Thomson was able to show that such a model would "explain" the known periodic properties of the elements.

The observations on scattering of alpha and beta particles led Rutherford to discard this model and to assume a nuclear structure such as has already been described. It was also shown by Darwin that the only law of force which could be assumed to act between the positive nucleus and the alpha particles and which would be consistent with the observed facts is the inverse square law. Lastly, Moseley's work on the high frequency spectra led not only to increased confidence in Rutherford's theory, but also to an actual determination of the magnitude of the positive charge on the nucleus, so that at the present time we can regard the model suggested by Rutherford as the nearest approximation that we have to the real structure of the atom.

Now a similar atom model had been suggested some years ago by Nagaoka, but at that time the objection was raised that such an arrangement of electrons rotating around a positively charged center would be dynamically unstable. On the other hand, no such objection could be raised against the model of J. J. Thomson. Thus arose a strange situation in scientific speculations, that the actual observations led to conclusions which were apparently at variance with the classical laws of dynamics.

Atom Model of Bohr

The most successful attempt to bridge this difficulty has been made by N. Bohr. In a series of classical papers which appeared in 1913 in the Philosophical Magazine, he showed that by introducing certain reasonable assumptions on the nature of the forces between the electrons and the positive nucleus, it is possible to deduce a very definite picture of the structure of atoms and molecules.[*]

After stating the nature of the difference between the atom-models proposed by Thomson and Rutherford, and the objections raised against the latter, Bohr continues as follows:

"The way of considering a problem of this kind has, however, undergone essential alterations in recent years, owing to the development of the theory of energy radiation, and the direct affirmation of the new assumptions introduced in this theory, found by experiments on very different phenomena, such as specific heats, photoelectric effect, Roentgen-rays, etc. The result of the discussion of these questions seems to be a general acknowledgment of the inadequacy of the classical electrodynamics in describing the behavior of systems of atomic size. Whatever the alteration in the laws of motion of the electrons may be, it seems necessary to introduce in the laws in question a quantity foreign to the classical electrodynamics, i.e. Planck's constant, or as it is often called, the elementary quantum of action. By the introduction of this quantity (h) the question of the stable configuration of the electrons in the atoms is essentially changed."

In other words, Bohr reasons that just as it has been found necessary to introduce a quantum theory of energy emission in order to account for the observed laws of distribution of energy in the spectrum of a black body, even so it is reasonable to assume that in the case of electrons vibrating in the atom, there exists some sort of discontinuity in the emission and absorption of energy. In this manner, Bohr is able to give a mechanical basis to the atom-model proposed by Rutherford.

The principal assumptions made by him are as follows:

(1) That the electrons revolve in circular orbits about the positive nucleus, with an angular momentum which is the same for all the electrons in the atom, and that during such revolutions the electrons do not emit any energy, although such an emission is to be expected from ordinary electrodynamics. These states in which the electrons are merely revolving are known as "stationary" states of the system under consideration, and in these states the relation between the frequency of rotation (ν), the average kinetic

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[*] Phil. Mag. *26*, 1, 477, 857 (1913) also *30*, 394 (1915). An excellent review of the work of Bohr and Nicholson on the structure of the atom has been given by W. D. Harkins and E. D. Wilson, Journ. Am. Chem. Soc. *37*, 1396 (1915). A summary of Bohr's theory has also been given by the writer in "Recent Views on Matter and Energy," General Electric Review *17*, 1199 (Dec. 1914.)

energy of the electron, and the radius of the orbit (r) can be calculated by the laws of ordinary dynamics.

(2) When, however, an electron passes from one stationary state to another, that is, from one orbit to another, there is an emission or absorption of energy, and the radiation emitted during such a transition is homogeneous and possesses a frequency (ν) which is determined by the relation

$$h\nu = A_1 - A_2$$

where h is Planck's constant, and A_1 and A_2 are the energies of the system in the two stationary states.

From these assumptions, Bohr deduces a number of interesting results. He is able to account qualitatively at least for the Rydberg-Ritz law for the frequency of the lines in the ordinary spectrum of an element, and in the case of the hydrogen spectrum he derives the well-known Balmer formula for the series

$$\nu = K\left(\frac{1}{\tau_2^2} - \frac{1}{\tau_1^2}\right)$$

where τ_1 and τ_2 are integers and K is the Rydberg constant. Bohr's calculated value of this constant is 3.26x10^{15}, while the observed value is 3.29x10^{15}. The agreement must be considered one of the most wonderful achievements of the theory.

Bohr also shows that on the basis of his assumption, the configuration of any system of electrons, i.e., the frequency and linear dimensions of the rings, is completely determined when the nuclear charge and the number of electrons in the different rings are given. The physical and chemical properties thus depend upon the nuclear charge. In this conclusion, Bohr therefore agrees with Moseley and indeed he shows that Moseley's relation between the frequency as derived from measurements of the X-ray spectrum, and the nuclear charge follows directly from his assumptions.

The physical picture which Bohr would assign to the hydrogen atom may be illustrated by referring to Fig. 1*. "N represents the nucleus of the atom. The rings 1, 2, and 3 correspond to the orbits of the electron in the various steady states of motion. When an electron falls from one steady state to the next one of small radius of vibration, one quantum of energy is liberated. In the fundamental spectral series, all the lines are formed by electrons falling from the second ring and beyond, all the way to the first ring. The first line in the series is due to an electron falling from the second to the first ring; the second line to an electron falling from the third to the first ring, and so on."

The different hydrogen series may be accounted for by assigning different values to τ_1 and τ_2 in the Balmer formula given above, and in the diagram Fig. 1, three such possible series are indicated. If $\tau_2 = 1$, and the values 2, 3, and 4 are assigned to τ_1, we get a series which was not known at the time Bohr wrote his first papers, but which has since been found by Lyman in the Schumann region. "If $\tau_2 = 2$, and a series of values be assigned to τ_1, the ordinary Balmer series for hydrogen results. For $\tau_2 = 3$, there results an infra-red series which was discovered by Paschen."

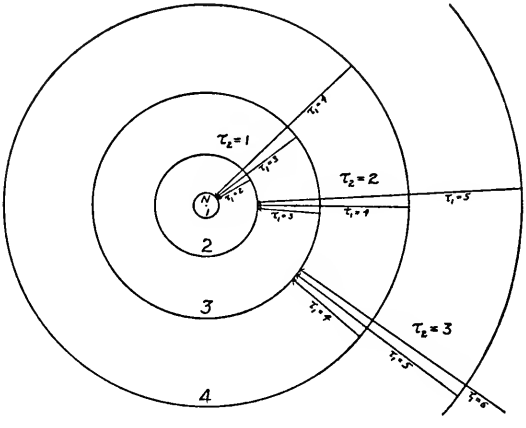

Fig. 1

Bohr's most successful results have been obtained in dealing with atoms of hydrogen and helium, although even here there are a few points on which his conclusions are not in accord with the observations. Assuming the hydrogen atom to consist of one electron rotating around a unit positive charge and that the molecule of hydrogen consists of two electrons that revolve like the governor-balls of an engine about an axis formed by the two nuclei, Bohr has attempted to calculated the heat evolved in the reaction,

$$2H = H_2$$

The result obtained, however, is not in as good accord with Langmuir's experimentally determined value as was at first thought.†

Also, serious objections have been raised by Nicholson and others against Bohr's theoretical work. "Nicholson claims to

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* W. D. Harkins and E. D. Wilson loc. cit.

† See the writer's paper "Recent Views on Matter and Energy" Part IV, General Electric Review, 1914.

have proved both by classical mechanics and by Bohr's mechanics that coplanar, concentric rings of vibrating electrons are unstable. That is, if there are to be two or more rings of electrons in an atom, they cannot lie in the same plane, which would make Bohr's theory untenable."

As a matter of fact, Bohr does not extend his calculations much beyond the lithium atom, but he suggests the following possible scheme for the arrangement of the electrons in the lighter atoms. For each element the different numbers give the number of electrons in each ring, proceeding from the center outwards.

H	1				
He	2	*Ne*	8, 2	*Ar*	8, 8, 2,
Li	2, 1	*Na*	8, 2, 1	*K*	8, 8, 2, 1
Bi	2, 2	*Mg*	8, 2, 2	*Ca*	8, 8, 2, 2
B	2, 3	*Al*	8, 2, 3	*Sc*	8, 8, 2, 3
C	2, 4	*Si*	8, 2, 4	*Ti*	8, 8, 2, 4
N	4, 3	*P*	8, 4, 3	*V*	8, 8, 4, 3
O	4, 2, 2	*S*	8, 4, 2, 2	*Cr*	8, 8, 4, 2, 2
F	4, 4, 1	*Cl*	8, 4, 4, 1	*Mn*	8, 8, 4, 4, 1

It will be observed that the elements are made to exhibit a recurring periodicity in the configuration of the electrons, which corresponds to the periodicity of chemical and physical properties. Also the number of electrons in the outermost ring corresponds in each case to the normal valency of the element.

J. J. Thomson's Recent Theory of Atomic Structure

It has been pointed out by F. A. Lindemann[†] that from the standpoint of mechanics, Bohr's atom model is only a specific application of a more general method by which a large number of models could be devised to explain the known observations on atomic structure. According to Lindemann, we may consider all the different models as belonging to either the *statical* or *dynamical* type. In each case it is necessary to introduce certain assumptions in order to assure the stability of the atom, and it therefore finally becomes a question as to which kind of assumptions are more in accord with other known phenomena. Thus, if we assume a statical model, with the electrons situated in definite positions in the atom and a central positive nucleus, it is necessary to assume replusive forces in the atom which act in opposition to the attractive forces that exist between positive and negative electric charges. On the other hand, in the case of the dynamical model, such as that of Bohr, the replusive force is replaced by a centrifugal force, but at the same time it is necessary to assume that the electrons in rotation do not radiate energy.

J. J. Thomson has, indeed, adopted the first alternative. In a paper published in 1913[‡] he suggests that the same result as is attained by applying the quantum theory (Bohr's case) would be obtained by making special assumptions as to the properties of the atom itself. "In considering the forces which may exist in the atom, we must remember that *we cannot assume that the forces due to the charges of electricity inside the atom are of exactly the* character as those given by the ordinary laws of electrostatics." In other words, Coulomb's law may actually become reversed at distances which are small compared with the dimensions of the atom.

Thomson assumes that the character of the forces acting on an electron in an atom are as follows:

(1) A radial *replusive* force, varying inversely as the cube of the distance from the center, diffused throughout the whole of the atom, combined with.

(2) A radial *attractive* force, varying inversely as the square of the distance from the center, *confined to a limited number of radial tubes in the atom.*

With these assumptions it is possible to correlate such phenomena as (1) photoelectric effect, (2) relation between "hardness" of X-rays and velocity of cathode rays, (3) the relation between characteristic X-ray emission and atomic number, (4) radiation phenomena, and (5) specific heats.

Nicholson's Work on Atomic Structure

For a complete account of Nicholson's work, the reader may be referred to the excellent summary given by Harkins and Wilson. "Nicholson also uses an atom of the Rutherford type, in which the electrons are vibrating in orbits around the positive nucleus. All of his work is, however, based on calculations made by the classical mechanics. The electrons are considered as moving in a steady state, in a ring around the nucleus. Outside forces acting on these cause them to take up a vibration perpendicular to the plane of the ring. There are several modes of vibration, depending on the number of electrons in the ring. The strongest vibration would have a frequency equal to the frequency of the electrons in the ring. In this class of vibrations, the ring vibrates as a whole, always keeping parallel to its original position. The second class of vibrations

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[*] Phil. Mag. *27*, 541 (1914) *28*, 9 (1914). The section in quotation marks is taken from the paper by Harkins and Wilson.

[†] Verhandl. d. deutsch. phys. Ges. *16*, 281 (1914)

[‡] Phil. Mag. *26*, 792 (1913)

consists in the ring vibrating in halves. That is, there are two modes and two crests in the wave which travels around the ring. It is evident that there are as many classes of vibrations as there are electrons in the atom."

An interesting feature of Nicholson's work is the fact that he deduces the possible existence of elements which have not as yet been discovered on the earth, but whose lines we are led to believe are present in stellar spectra, such as the hypothetical elements protohydrogen (atomic weight, 0.082); two other elements with atomic weights 0.327 and 0.736 respectively, whose lines are present in nebular spectra; nebulium (atomic weight, 0.31); protofluorine (atomic weight, 2.1); and arconium (atomic weight, 2.9).

Most of the success of Nicholson's work has been obtained in deriving the different spectral series of the elements. His results, if confirmed by further discoveries, will no doubt help us to obtain some knowledge of the actual evolution of the different elements. To quote once more from the paper by Harkins and Wilson:

"From the progressive changes of the spectra of the stars, and other evidence which points to their age, it seems likely that all of our common elements are more complex forms of matter than the simple ring systems and hydrogen, and are built up from them. In such spectra the elements make their appearance in the order of their atomic weights.

"According to Nicholson's idea, then, our ordinary terrestrial elements are evolution products of the simple ring systems found in the nebulae and the stars. That is, they have nuclei which are complex, containing both positive and negative electrons. This is in good accord with other facts but it does not agree with Rutherford's idea that the nucleus of the hydrogen atom may be the positive electron. If the astronomical evidence is admitted, it may be safely assumed that in the novae and nebulae, where the temperature is supposed by Nicholson to be very high, the complex atoms are unstable, breaking up into simple ones, or if the process is looked at from the other point of view, as these hot bodies cool the simple ring systems condense, becoming more complex and giving rise to the elements known on the earth."

It is interesting to observe that as far back as 1911 Nicholson suggested that all the the elements are derived from "protyles,"* which are merely single rings of electrons rotating around small nuclei of positive electricity. Only three portyle elements are used by Nicholson in the construction of all the other elements. These are: hydrogen, nebullium (*Nu*) and protofluorine (*Pf*). Thus the composition of helium would be represented by $Nu+Pf$, and similarly for the other elements.

Kossel's Explanation of the Origin of High-Frequency Spectra

The Bohr atom has, within the past three years, received additional support as a result of some interesting conclusions which have been drawn by Kossel from observations on the high-frequency spectra of different elements.†

He takes Bohr's view of the nucleus atom and assumes that the electrons are arranged in rings, one outside the other, also that the electrons radiate energy only when passing from one ring to the next. He considers the radiations which results from the removal of an electron from one of the rings, assuming that the radiation is emitted when the atom settles down into its original state. The latter process may take place in different ways. The vacant place in the ring may be taken by an electron coming directly from outside the whole system, but it may also be taken by an electron jumping from one ot the outer rings. In the latter case a vacant place will be left in that ring to be replaced in turn by another electron, etc. For the sake of brevity, we shall refer to the innermost ring as ring 1 (see Fig. 1), the next one as ring 2, and so on. Kossel now assumes that the K radiation results from the removal of an electron from ring 1, makes the interesting suggestion that the line denoted by Moseley as K corresponds to a jump from ring 3 to ring 1. On this view, we should expect that the K radiation consists of as many lines as there are rings in the atom, the lines forming a series of rapidly increasing intensities. For the L radiation, Kossel makes assumptions analagous to those for the K radiation, with the distinction that the radiation is ascribed to the removal of an electron from ring 2 instead of ring 1. A possible M radiation is ascribed to ring 3 and so on. The interest of these considerations is that they lead to the prediction of some simple relations between the frequencies, ν, of the different lines. Thus it follows as an immediate consequence of the assumption used that we must have

$$\nu_{K\beta}-\nu_{K\alpha}=\nu_{L\alpha}$$
$$\nu_{K\gamma}-\nu_{K\beta}=\nu_{L\beta}-\nu_{L\alpha}=\nu_{M\alpha}$$

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* Phil Mag. *22*, 864 (1911)

† Verhandl. d. deutsch. phys. Ges. *16*, 953 (1914).

where the subscripts refer to the α, β, and γ lines in each series. It will be seen that these relations correspond exactly to the ordinary principle of combination of spectral lines. By using Moseley's measurements for $K\alpha$ and $K\beta$ and extra-polating for the values of $L\alpha$ by the help of Moseley's empirical formula, Kossel showed that the first relation was closely satisfied for the elements from calcium to zinc.

The results recently obtained by Malmer* for the wave-lengths of the $K\alpha$ and $K\beta$ lines for a number of elements of higher atomic weights, are found to be in good accord with Kossel's prediction.

Chemical Aspects of Theories of Atomic Structure

As is evident from the above remarks, the theories so far considered have sought their principal support by referring to phenomena which are ordinarily classified as physical. The theories are thus mainly developed to satisfy conditions set by the physicist, more especially the mathematical physicist. With the latter, the most important question is whether an atom constituted according to a pre-supposed configuration of electrons and nucleus, will be stable mechanically. Consideration of chemical properties enters into these theories only as a secondary matter, and it is therefore natural that the chemist should not agree with the physicist in accepting such models without further question.

The proven facts of the existence of electrons and such phenomena as the scattering of alpha-particles and Moseley's observations have, of course, led chemists to reject the older "Daltoman" view of the atom as a little hard sphere. It is frankly recognized that electrons must play an important part in all chemical transformations, and the agreement in the respect has been obtained all the more readily because the phenomena of conduction of electricity by salts in solution and in the molten state are easily explained by means of the electron theory.

In 1908, Sir Wm. Ramsay read a paper before the London Chemical Society in which presented some interesting speculations on the mode of combination of chemical elements from this new standpoint. "If it be conceded," he states, "that a salt differs from its solution only in so far as the mobility of the solution permits of the transfer of ions, the transfer of an electron from the sodium to the chlorine must take place at the moment of combination. The reaction which occurs may be written in this form,

$$E.\,Na + Cl = Na.\,E.\,Cl,$$

where E denotes an electron. Hence the electron serves as the bond of union between the sodium and the chlorine." Similarly in all cases of combination, the reaction occurs because of the transferrence of one or more electrons from one atom to the other.

In a recent paper†, Ramsay has elaborated this conception still further. He distinguishes "constitutional" electrons from valency electrons. "The latter are removable without disturbing the groupings which determine the essential structure of the atom as a whole." The former probably rotate rapidly in rings, as shown by the Zeeman effect. As noted in the first part of this paper such a division is practically the same as that already drawn between "inner" and "outer" electrons. Referring to the experiments of K. Onnes on inducing currents in a circuit of zero resistance at extremely low temperature‡, Ramsay assumes, firstly, that the outer or valency electrons rotate in small circles on the surface of the atom. The orbits of these electrons are thus parallel to some equatorial plane fixed in the atom. Secondly, it is assumed that the circular orbits of different valency electrons need not necessarily have all the same diameters, and thirdly, "that some electrons may revolve clockwise, while others may have an anti-clockwise path, relative to the nearest pole of the sphere." Electropositive elements are supposed to differ from electronegative elements in the direction of rotation of the electrons.

On these assumptions it is possible to explain the formation of molecules by the attraction exerted between the magnetic fields due to the rotating electrons, and Ramsay shows by means of experiments with spheres and small circular wires placed around these, near the poles of the spheres, that such combinations will occur. Thus, the hydrogen or chlorine molecule would be represented according to Ramsay by the arrangement shown in Fig. 2 (*a*). The plane of the electronic orbit in each hydrogen or chlorine atom is situated perpendicular to the paper, so that the magnetic flux in the molecule would follow along the dotted circle. Similarly a molecule of HCl and one of O_2 would be represented by Figs. 2 (*b*) and 2 (*c*) respectively. In each case the atoms would arrange themselves so as to permit the maximum magnetic flux through the planes of the electronic orbits.

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* Phil. Mag. *28*, 787, 1914.

† Proc. Roy. Soc. *92*, (A) 451 (1916).

‡ See the writer's paper on "The Absolute Zero," General Electric Review.

A similar theory of the mode of formation of molecules has been suggested by Parson.* He assumes that the electron itself is a rotating ring of negative electricity and is therefore a small permanent magnet; hence the name *magneton*. The magnetons at the surfaces of the different atoms exert magnetic and electrostatic forces on each other and thus lead to chemical combination. Furthermore, the number of these valency magnetons is supposed to vary periodically, thus accounting for the periodic properties of the elements.

In general, the chemists prefer to consider the valency electrons as fixed on the surface of the atom in definite positions, in contradiction of the assumptions made by Bohr and Nicholson. In this case, the question of dynamical stability do not worry the chemists. There are, however, innumerable observations in the field of organic chemistry, such as the existence of the asymmetric carbon atom and the phenomena of stereochemical hindrance, which lead to the conclusion that the valency electrons are situated in definite positions in the atom.

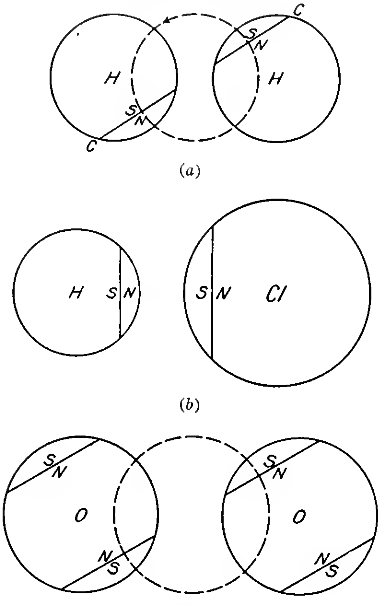
Lewis' Theory of the Cubical Atom.

This idea, that valency is due to the forces exerted between electrons situated in definite positions in each atom, has been developed by Prof. G. N. Lewis† into a comprehensive theory of the structure of the atom which is extremely suggestive. There are two fundamental sets of chemical observations which Lewis attempts to correlate by means of this theory.

The first of these is the fact that there exist two types of chemical substances, which may be designated as *polar* and *non-polar*. These coincide roughly with what have been more usually known as inorganic and organic compounds respectively, thus potassium chloride (KCl) represents the extreme polar type and methane (CH_4) the non-polar. "Nevertheless, there are many inorganic substances which, under ordinary circumstances, are predominantly non-polar, and many organic substances which, at least in a certain part of the molecule, are strongly polar."

The very striking differences in properties between the extreme polar and extreme non-polar types are summarized by Lewis in the table on this page.

"All of these properties with respect to which fundamental distinctions have been made between the two types, and which seem so unconnected, are in fact closely related, and the differences are all due to a single cause. Even before making any more special hypothesis we may very safely assume that the essential difference between the polar and the non-polar molecule is that, in the former, one or more electrons are held by sufficiently weak constraints so that they may become separated from their former positions in the atom, and in the extreme case pass altogether to another atom, thus producing in the molecule a bipole or multipole of high electrical moment. Thus in an extremely polar molecule, such as that of sodium chloride, it is probable that at least in the great majority of molecules the chlorine atom has acquired a unit negative charge



(*a*)

(*b*)

(*c*)

Fig. 2

Polar	Non-polar
Mobile	Immobile
Reactive	Inert
Condensed structure	Frame structure
Tautomerism	Isomerism
Electrophiles	Non-electrophiles
Ionized	Not ionized
Ionizing solvents	Not ionizing solvents
High dielectric constant	Low dielectric constant
Molecular complexes	No molecular complexes
Association	No association
Abnormal liquids	"Normal" liquids

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* See the writer's "Theories of Magnetism," General Electric Review, Dec., 1916, for more detailed discussion of this theory.

† J. Am. Chem. Soc. 38, 762 (1916).

and therefore the sodium atom a unit positive charge, and that the process of ionization consists only in a further separation of these charged parts.

"If then we consider the non-polar molecule as one in which the electrons belonging to the individual atom are held by such constraints that they do not move far from their normal positions, while in the polar molecule the electrons, being more mobile, so move as to separate the molecule into positive and negative parts, then all the distinguishing properties of the two types of compounds become necessary consequences of this assumption, as we may readily show."

It would take us far beyond the scope of the present paper to discuss, as Lewis does, the manner in which each of the above properties follows as a consequence of this assumption, but a few brief remarks will not be out of place with regard to the electrical properties.

From the fact that in the polar molecule "the constraints which operate against a separation of the charges are already weak, it follows that these charges may be further stretched in the electric field, and that bipoles or multipoles which already exist in the substance may, by rotation, orient themselves in the electric field, thus producing a large displacement current and therefore a high dielectric constant. Now as the difference between the dielectric constant of a substance and that of free space measures directly the number of free charges in the substance multiplied by the average distance through which these charges move under the influence of a definite electric field," it follows that the dielectric constants of polar substances must be relatively greater than those of non-polar type. Also it follows that polar substances may be readily ionized and will form ionizing solvents. That is, such substances are good conductors of electricity (electrophiles).

The second set of chemical observations which is at the basis of Lewis's theory is one which was observed by R. Abegg in connection with the valency relations of the different elements.*

According to Abegg "each element possesses both a positive and a negative maximum valency, the former being determined from its oxygen compounds (in which it gives up electrons to the oxygen atoms) and the latter from its hydrogen compounds (in which it takes up electrons from the hydrogen atoms). The maximum positive valency is the same as the number of the periodic group to which the element belongs. Whether an element shall manifest its positive or its negative electrovalency depends on the differences of polarity and the electro-affinities of the elements wherewith it combines. The manifestation of one kind of affinity appears greatly to hinder, but not completely to suspend that of the other kind."

Abegg designates the two kinds of valencies as *normal* and *contra-valencies.* The former are the stronger and are the valencies exhibited in the simplest kinds of compounds; the latter are "seldom completely employed, but increasing atomic weight facilitates their manifestation."

The following table shows the valencies of the elements arranged in the groups of the periodic system.

	GROUPS						
	I	II	III	IV	V	VI	VII
Normal valencies	+1	+2	+3		−3	−2	−1
Contra-valencies.	(−7)	(−6)	(−5)	±4	+5	+6	+7

Thus chlorine forms the compounds HCl (the normal valency of Cl being −1) and $Cl_2 0_7$ (contra-valency of +7). In the case of the first three groups, the contra-valencies are not employed except in the case of the formation of complex compounds such as $K\,AgI_2$; K_3AuCl_4, etc.

To account for these facts, Lewis has suggested "what may be called the theory of the cubical atom." Some of the assumptions used by him in postulating this theory are stated as follows:

1. "In every atom is an essential *kernel* which remains unaltered in all ordinary chemical changes and which possess an excess of positive charges corresponding in number to the ordinal number of the group in the periodic table to which the element belongs.

2. "The atom is composed of the *kernel* and an outer atom or *shell*, which, in the case of the neutral atom, contains negative electrons equal in number to the excess of positive charges of the kernel, but the number of electrons in the shell may vary during chemical change between 0 and 8.

3. "*The atom tends to hold an even number of electrons in the shell, and especially to hold eight electrons which are normally arranged symmetrically at the eight corners of a cube.*"

These are the most important of the assumptions.

The diagrams shown in Fig. 3 represent Lewis's conception of the atomic structures

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* Zeitsch. f. anorg. Chem. *39*, 330 (1904). This paper has been excellently summarized by P. Muir in his History of Chemical Theories and Laws, pp. 542–544.

of the elements lithium to fluorine. Thus lithium has one normal positive valence. It, therefore, contains one electron which may be detached with relative ease. On the other hand, fluorine has one normal negative valence and seven positive contravalencies. In other words, fluorine will take up an electron very readily in order to complete the group of eight electrons, in which condition it resembles the atom of neon, with this difference, however, that it has one negative charge. But the atom of fluorine may also give up its seven electrons (with much less ease) and then it resembles the helium atom.

Groups of two or eight electrons are apparently exceedingly stable. This accounts for the inertness of the elements of the helium group. Furthermore, the atom of every other element tends to take on or give up electrons so as to resemble either helium or one of its homologues. Thus the atom of sodium tends to give up one electron and then resembles neon, while the atom of sulphur tends to take up two electrons so that it can have the structure of the argon atom. But the atom of sulphur may also give up six electrons (as in SO_3) and then it reverts to the same structure as the atom of neon.

These facts are illustrated in the case of the first 58 elements of the periodic table by Fig. 4, which is taken from a recent paper by Kossel.* The abscissae and ordinates correspond to the atomic numbers of the different elements and the arrows indicate by their length the maximum number of electrons which each atom can give up or take on in forming compounds.

When the detachable electron is removed from the atom of *Li* we have left $(Li)^+$ which is to be considered the kernel of the atom. Lewis does not concern himself with the structure of the kernel, but a consideration of the place of this element in the periodic table shows that this kernel must consist of the nucleus (+3) and two electrons (−2) so that the net result is a unit positive charge. Similarly we have the kernels of *Be*, *Mg*, *Ca*, *Sr*, *Ba*, etc. (Group II) which possess two unit positive charges, and so on for the other groups.

Now let us consider, with Lewis, the manner in which these cubical atoms can combine to form molecules. The simplest cases are the formation of such compounds as CH_4, *HF*, *LiCl*, etc. In each case the more electropositive elements gives up one electron so as to make up the group of eight electrons in the more electronegative element. Similarly the atom of *Ca*, with two detachable electrons will give these up to the atom of oxygen which has two negative valencies and thus completes the group of eight in the latter.

According to Abegg and Lewis there is no fundamental distinction between such simple compounds as NH_3 or *HCl*, and the so-called molecular compounds, such as NH_4Cl. In NH_3, we have three hydrogen nuclei attached by means of electrons to the three unoccupied places on the nitrogen atom. Each hydrogen nucleus will be held by two adjacent electrons, as shown in Fig. 5.† In this case only the normal negative valencies of the nitrogen atom come into play, but the nitrogen atom is also able to give up electrons at the same time to another hydrogen nucleus which causes a weakening in the constraint between the latter and its electron. The result is that the NH_4 group has one easily detachable electron, and thus resembles *Li*, *Na*, and *K* in its properties, as shown in the figure.

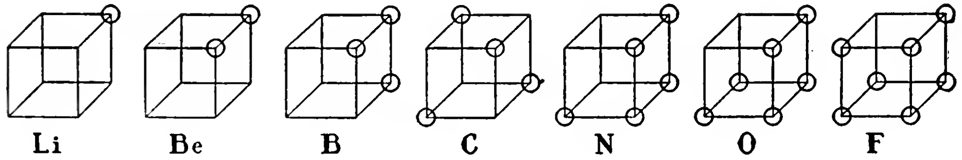

Fig. 3

Lewis also discusses the formation of the different types of carbon compounds and complex inorganic compounds, but the above remarks will, it is hoped, give some idea of the principal features of the theory.

The question of stability of such an atom is not treated by Lewis at great length. One of the assumptions which he makes at the very beginning of his paper is that "electric forces between particles which are very close together do not obey the simple law of the inverse squares which holds at greater distances," a suggestion which we have already

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* Ann. d. Phys. 49, 229 (1916).

† The electrons belonging to the *H* atoms are shown in black.

mentioned in discussing the theory of J. J. Thomson, and in discussing this in relation to Bohr's atom he writes as follows:

"It seems hardly likely that much progress can be made in the solution of the difficult problems relating to chemical combination by assigning in advance definite laws of force between the positive and negative constituents of an atom, and then on the basis of these laws building up mechanical models of the atom. We must first of all, from a study of chemical phenomena, learn the structure and arrangement of the atoms, and if we find it necessary to alter the law of force acting between charged particles at small distances, even to the extent of changing the sign of that force, it will not be the first time in the history of science that an increase in the range of observational material has required a modification of generalizations based upon a smaller field of observations. Indeed in the present case, entirely aside from any chemical reasons, a study of the mathematical theory of the electron leads, I believe, irresistably to the conclusion that Coulomb's law of inverse squares must fail at small distances."

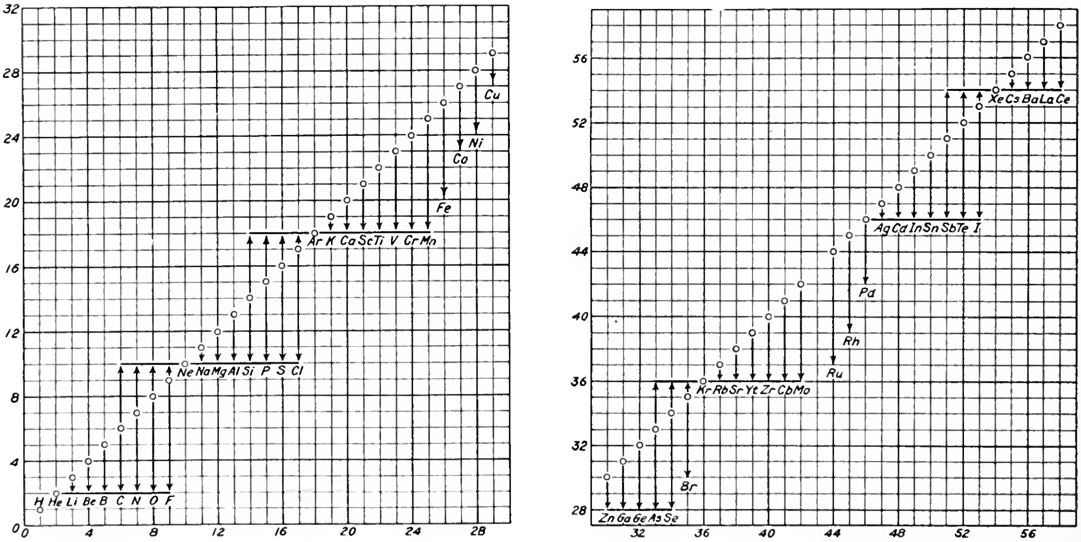

Fig. 4

At a recent symposium before the American Association for the Advancement of Science, Prof. Lewis suggested that the force between the nucleus and an electron may undergo periodic variations from repulsion to attraction as the distance from the nucleus outwards is increased, according to some such curve as that shown in Fig. 6. Here the abscissae represent distances from center of nucleus, while the ordinates represent the force exerted by the nucleus on an electron at the distance represented by the abscissa, this force being repulsive when it is below the line and attractive when it is above. Thus at the points *A*, *B*, *C* and *D*, the electron would be subjected to maximum repulsive and attractive forces, while the positions *a*, *b*, and *c* would be stable. But once disturbed from one of the latter positions, the electron would oscillate for a while and finally shift over into a new position of equilibrium. At the distance *OE* the curve representing the force exerted on the electron would become practically the same as that corresponding to Coulomb's law. Such a law of force might thus explain radiation phenomena, and perhaps the "raison d'etre" of the constant *h* in the quantum theory.

Hull's Observations on Atomic Structure

Some recent observations made by Dr. A. W. Hull, of this laboratory, on the structure of the iron atom, lend support to Lewis's theory. The method used has been described by him as follows:*

"The method consists in sending a narrow beam of monochromatic X-rays thru finely powdered crystals, and photographing the

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* Quoted from an abstract on "The Crystal Structure of Aluminum and Silicon" which will appear very shortly in the Physical Review.

diffraction images of the slit, produced by reflection in all the possible planes belonging to the crystal structure. The positions and intensities of the lines on the photograph are compared with the theoretical values for different possible arrangements of atoms, until an arrangement is found which represents completely the observed lines.

"In the preliminary calculations for determining the crystal structure, it is assumed that the scattering electrons are concentrated at the centers of the atoms. This gives wrong intensities for the lines, but causes no error in their positions. The relative intensities of the lines are complete accounted for by the position and condition of the electrons in the atoms, and since the number of lines that can be photographed is very large, this offers a powerful means of testing theories of atomic structure."

From the measurements of the intensities of the lines obtained in this manner from a crystal of iron, Hull concludes that "the electrons are displaced from the center of the iron atom along the diagonals of a cube in four groups of 2, 8, 8, 8, at distances $^1/_{32}$, $^1/_{16}$, $\frac{1}{8}$ and $\frac{1}{4}$ respectively, of the distance to the nearest atom."* That is, 24 electrons are arranged at the corners of three cubes, one fitting inside the other, with two electrons close to the centre. In the case of the carbon atom, the evidence, although not so conclusive at present, points also to the arrangement suggested by Lewis, that is, two electrons close to the center of the atom, with four other electrons arranged at the corners of a tetrahedron as shown in Fig. 3.

A. H. Compton† has recently attempted in a similar manner to calculate the possible distribution of electrons in atoms from a study of the distribution of intensities in the reflected beam of X-rays as observed by Bragg and others in their investigations on crystal structure. He concludes that "by assuming a number of electrons in each atom equal to the atomic number and making certain plausible assumptions as to the arrangement of these in rings (Bohr's theory), it is possible to account in a satisfactory manner for the observed intensities of the X-ray spectra."

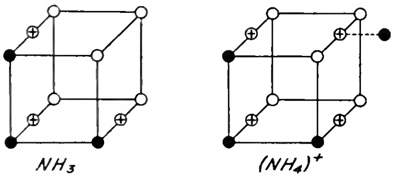

Fig. 5

Thus we find Hull, on the one hand, deducing from his observations, conclusions which are in accord with a statical theory of the atom, and Compton, on the other hand, reaching diametrically opposite conclusions. However, the observations on which Compton bases his conclusions are not nearly as complete as those made by Hull.

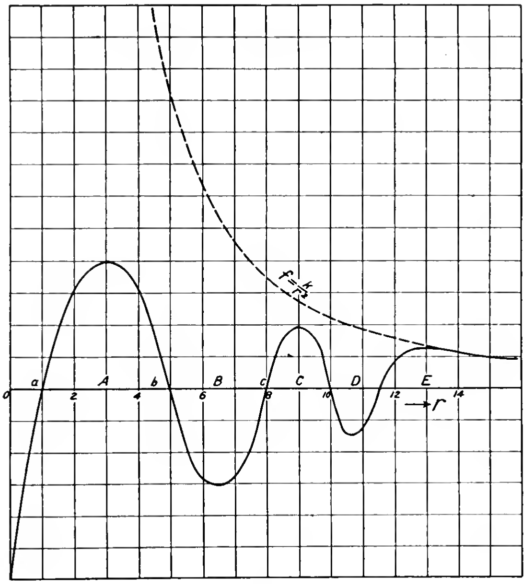

Fig. 6

Explanation of the Mode of Formation of Compounds on Bohr's Theory

An attempt has recently been made by Kossel‡ to give an explanation of the mode of formation of chemical compounds on the basis of Bohr's atomic model. Like Lewis, he bases his arguments on Abegg's work and assumes that a ring of eight electrons or two electrons is exceedingly stable. He draws a distinction between the outer or valency electrons and the inner electrons, and assumes that the number of electrons in the outer ring varies periodically from one to eight. Fig. 7 show diagrammatically the structure of the argon atom, and molecules of HCl and CaO according to Kossel's view. The only essential difference between this representation and

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* Phys. Rev., *9*, 86 (1917).
† Phys. Rev., *9*, 89 (1917).
‡ Ann Phys. *49*, 229 (1916).

that adopted by Lewis is that Kossel assumes the eight electrons to be in constant rotation around the ring.

The most interesting portion of Kossel's paper is that in which he discusses the mode of formation of complex salts, such as $KSbCl_6$, $K_2Pt\ Cl_6$, $K_3\ Al\ F_6$, $K\ Mg\ Cl_3$, etc. Thus $PtCl_4$ forms with $2KCl$, the complex salt K_2PtCl_6. In solution this salt is a good conductor of electricity and the ions are $2K^+$ and $Pt\ Cl_6^{--}$. In $Pt\ Cl_4$, platinum shows a normal positive valency of 4, but owing to the possession of contra-valencies, it is able to take up two more electrons from the potassium atoms and thereby attach two more chlorine atoms to itself. In the case of $SbCl_5$, the atom of antimony has given up five electrons to the chlorine atoms, but is able to take up one extra electron from potassium in KCl and thus forms the anion $SbCl_6^-$ in solution. Kossel attempts to answer the question as to what factors limit the number of electronegative elements which may in this manner be attached to an electropositive element.

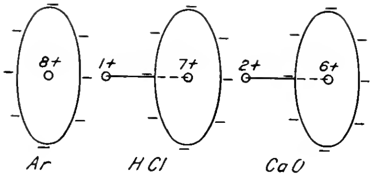

Fig. 7

"When a multiple-charged central atom, e.g. Pt^{++++} — attaches to itself atoms of opposite charge, work is gained. The amount of this energy decreases as the number already attached increases; the attraction of the central positively charged atom for the electronegative atoms becomes more and more compensated by the repulsion exerted by those which are already attached, and finally a limit is reached at which work has to be done from outside in order to force another negatively charged atom into the ring."

By making certain simple assumptions as to the relative sizes of the different atoms, Kossel is able to calculate the amount of work that would be gained when negatively charged atoms are attached one by one to form a ring around a positively charged atom. In the curves shown in Fig. 8, the work gained (W) is plotted as ordinate against N, the number of negatively charged atoms. For different values of the positive charge (M) on the central atom, it is possible to calculate in this manner a curve giving W as a function of N. The most striking fact about these results is that the maximum value of W (indicated by a mark on the curve) shifts more and more towards larger values of N as M is increased. That is, the tendency to form complex salts increases with the positive valency of the central atom. Thus, Mg has two normal positive valencies ($M = 2$). The curve indicates that the maximum number of Cl atoms which it can attach is between three and four. As a matter of fact we find that it forms a complex salt of the type $K\ Mg\ Cl_3$. On the other hand, Sb ($M = 5$) forms a complex salt $K\ Sb\ Cl_6$. The curve for M = 5 indicates a maximum near $N = 6$. Similarly, Pt^{++++} ($M = 4$) forms a complex salt $K_2\ Pt\ Cl_6$, while Pt^{++} ($M = 2$) forms a salt with fewer chlorine atoms, $K_2\ Pt\ Cl_4$.

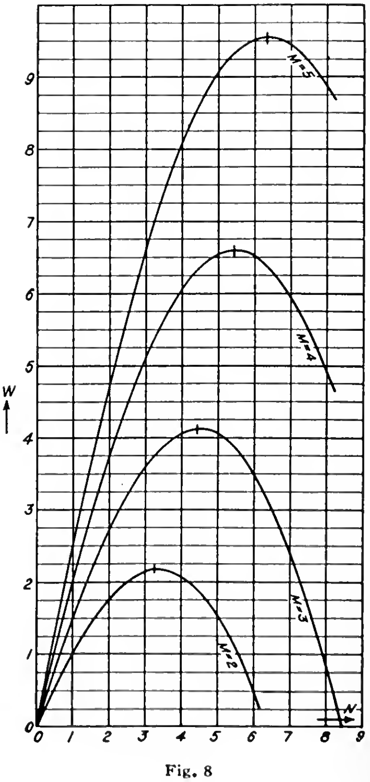

Fig. 8

The chemical observations are not always in accord with this simple scheme, but account must be taken of the fact that Kossel bases his conclusions on assumptions which are confessedly not even approximately true in a large number of cases. However the calculation for such cases is exceedingly difficult.

Bohr has shown that in analogous elements, the work required to remove an electron on the outer ring decreases with increase in the number of electrons in the inner rings. Hence the electropositivity of elements in the same group should increase with increase in atomic number. This is quite in accord with the facts. Caesium is the most electropositive element known; while in Group VII, iodine is much less electronegative than any of the other halogen elements. This is shown by the fact that when the compound ICl is electrolyzed, iodine is liberated at the *cathode*. In this respect the rare gases of Group O show an analogous variation in the ease with which they are ionized. The ionization voltage as determined by Franck and Hertz* are as follows:

He	20.5 volts
Ne	16.0 volts
Ar	12.0 volts

The weak point about Kossel's arguments is that he finds it necessary to assume that in some cases (e.g. Cl_2) as many as 14 electrons may be present in a ring. But as yet we are completely ignorant of the factors that govern the stability of such rings.

It is interesting to compare the arrangement of electrons in the different atoms, as suggested by Kossel, with that given above by Bohr:

H	1				
He	2	*Ne*	2, 8	*Ar*	2, 8, 8,
Li	2, 1	*Na*	2, 8, 1	*K*	2, 8, 8, 1
Be	2, 2	*Mg*	2, 8, 2	*Ca*	2, 8, 8, 2
B	2, 3	*Al*	2, 8, 3	*Se*	2, 8, 8, 3
C	2, 4	*Si*	2, 8, 4	*Gi*	2, 8, 8, 4
N	2, 5	*P*	2, 8, 5	*V*	2, 8, 8, 5
O	2, 6	*S*	2, 8, 6	*Cr*	2, 8, 8, 6
F	2, 7	*Cl*	2, 8, 7	*Mn*	2, 8, 8, 7

Configuration of Electrons in Heavier Elements

It will be observed that in all the theories so far discussed, no suggestions have been offered as to the mode of arrangement of the electrons in the elements of atomic weight greater than manganese ($N = 25$). If Hull's conclusions are justifiable, then we have obtained a first approximation to the configuration of the electrons in the atom of iron. As regards the other atoms, all we can do at present is to offer more or less plausible guesses. The writer believes that in the case of a large number of these elements it may be possible for the electrons to shift position from the outer ring to an inner one according to the valency in which the element exists. This would correspond to a sort of tautomerism of electrons in the atom itself. Thus, in the case of copper we may have either cuprous or cupric compounds. In the former copper is monovalent, in the latter it is divalent. This could be accounted for by assuming that in cuprous compounds the arrangement of electrons in the copper atom is 2, 8, 8, 10, 1, and that the single electron which is situated on the outer ring is given up in the formation of the salts. On the other hand, in the case of cupric compounds, the copper atom may be represented by the configuration 2, 8, 8, 9, 2. Similar considerations would apply to Ag, Hg, and Au which exhibit two different kinds of valency.

The magnetic properties of the salts of these elements lend support to this view. For instance, cuprous salts are all diamagnetic, while cupric salts are paramagnetic. The exhibition by any substance of magnetic properties may be due to the fortuitous occurrence of symmetrical arrangements of 8 electrons. As yet, we are, however, completely in the dark as to the real explanation of this phenomenon, which is no doubt intimately bound up with questions of atomic structure.†

The existence of the rare earth elements in the position which they occupy in the periodic system is also a question which looms up large in the general problem of atomic structure. The atoms of all these elements probably possess the same number of electrons in the outer ring or cubical shell, but differ in the numbers which are present in inner rings.

Structure of the Nucleus

Besides the problem of the configuration of electrons in the atom, there remains the even more difficult question of the structure of the nucleus itself. From the fact that radioactive elements emit both alpha particles and electrons, we know that the nucleus itself must be an exceedingly complex aggregation of positive and negative charges. When the atom of uranium disintegrates, it emits eight alpha particles before it reaches the end of its disintegration and becomes an atom of lead. All these particles must have come from the nucleus. It is evident that the forces which can hold at least eight positively charged helium atoms in a volume which is extremely small compared with that of the uranium atom itself—that these forces must be of an altogether different nature to any

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* Verhandl. d. deutsch. phys. Ges. *15*, 37 (1913).

† See the writer's articles in GENERAL ELECTRIC REVIEW, 1916, on "Theories of Magnetism."

with which we are familiar in ordinary mechanics. Furthermore, what law governs the time at which any atom shall spontaneously explode and emit these alpha particles? A Debierne*, who has done a great deal of work on the radioactive elements, believes that the structure of the nucleus is exceedingly complex, that the constituents of the nucleus are in a constant state of agitation, in which respect they resemble the molecules in a given volume of gas, and that following the law of probability, one of these constituents of the nucleus may at some instant acquire enough kinetic energy to carry it out beyond the confines of the nucleus and of the atom itself.

W. D. Harkins and E. D. Wilson† have put forward the rather interesting suggestion that the atoms of all the elements are made up of hydrogen and helium. They show that the deviations from whole numbers observed in the atomic weights can be ascribed to a packing effect which must occur if the other atoms are built up of hydrogen atoms. This means then, that the nucleus contains both hydrogen and helium nuclei in varying proportions.

Conclusion

The deeper we penetrate into the question of atomic structure, the greater the vista of problems that apparently opens before us. Is it an infinite series? Only the future can tell; but if past experience teaches us any lessons at all it is perhaps this: that the problems of science can never end, for that would mean an end of all human striving and existence itself.

It is a long way to have travelled from the four elements of Aristotle, through the half humorous suggestions of Lucretius and the skepticism of the nineteenth centry to an age in which we not only believe in the veritable existence of atoms but seek to penetrate even deeper into the structure of the atom itself. The pessimist may still find a grim pleasure in picking contradictions here and there, and in ridiculing the arbitrary flights of imagination in which we occasionally enjoy ourselves. But the optimist, contented with even the smallest measure of success, will ever keep well before him those words of the Sage of Chelsea which better than any other language expresses the ideals of science and progress:

"Up, up! Whatsoever thy hand findeth to do, do it with thy whole might. Work while it is called to day; for the Night cometh, wherein no man can work."

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* Annales de Physique, *4*, 323 (1915).

† Journ. Am. Chem. Soc. *37*, 1383 (1915).

REFERENCES

For those who may be interested in reading up for themselves some of the papers which have been published in recent years, on the subject of atomic structure, the following bibliography has been added. A further list of references is also given by Harkins and Wilson in their paper.

I. Reviews of Recent Work

1. A. S. Eve—Modern Views on the Constitution of the Atom. Science, July 24, 1914. Smithsonian Inst. Report, 1914, p. 183.
2. D. A Hahn and M. E. Holmes—The Valence Theory of Stark from a Chemical Standpoint. J. Am. Chem. Soc. *37*, 2611 (1915).
3. W. L. Hardin—The Nature of the Chemical Atom; Science, Nov. 10, 1916.
4. W. D. Harkins and E. D. Wilson—Recent Work on the Structure of the Atom. J. Am. Chem. Soc. *37*, 1396 (1915).
5. T. W. Richards—The Fundamental Properties of the Elements. Journal Chem. Soc. London, *99*, 1201; Science, Oct. 27, 1911. Smithsonian Inst. Report 1911, p. 199.
6. E. Rutherford—The Constitution of Matter and the Evolution of the Elements. Smithsonian Inst. Report, 1915, 0. 167.
7. S. Dushman—Recent Views on Matter and Energy. General Electric Review, 1914.
8. S. Dushman—The periodic Law. General Electric Review, *18*, 614 (1915).

II. Original Investigations

1. R. Abegg—Valency and the Periodic System. Zeitsch. f. anrorg. Chem. *39*, 330 (1904).
2. H. S. Allen—The Magnetic Field of an Atom in Relation to Theories of Spectral Series. Phil. Mag. *29*, 40 (1915).
3. W. C. Arsem—A Theory of Valency and Molecular Structure. J. Am. Chem. Soc. *36*, 1655 (1914)
4. C. G. Barkla and J. G. Dunlop—Note on the Scattering of X-rays and Atomic Structure. Phil. Mag. *31*, 222 (1916).
5. N. Bohr—Constitution of Atoms and Molecules. Phil. Mag. *26*, 1, 477, 857 (1913).
6. N. Bohr—On the Quantum Theory of Radiation and the Structure of the Atom. Phil. Mag. *30*, 394 (1915).

7. M. A. Debierne—Considerations on the Mechanism of the Radioactive Transformations and the Constitution of Atoms. Annales de Phys. *4*, 323 (1915).

8. L. Foeppl—On the Stability of the Bohr-Atom Model. Physikal. Zeitsch. *15*, 707 (1914).

9. W. D. Harkins and E. D. Wilson—The Changes of Mass and Weight Involved in the Formation of Complex Atoms. J. Am. Chem. Soc. *37*, 1367 (1915).

10. W. D. Harkins and E. D. Wilson—The Structure of Complex Atoms. The Hydrogen-Helium System. J. Am. Chem. Soc. 1383 (1915).

11. W. Kossel—Note on the Absorption of Homogeneous X-rays. II. Verhandl. d. deutsch. phys. Ges. *16*, 953 (1914).

12. W. Kossel—The Formation of Molecules in Relation to Atomic Structure. Ann. d. Phys. *49*, 229 (1916).

13. G. N. Lewis—The Atom and the Molecule. J. Am. Chem. Soc. *38*, 762 (1916).

14. F. A. Lindermann—On the Fundamentals of Atomic Models. Verhandl. d. deutsch. Phys. Ges. *16*, 281 (1914).

15. J. C. McLennan—On the Single-line Spectra of Magnesium and other Metals and their Ionizing Potentials. J. Frank. Inst. Feb., 1916, p. 191.

16. H. G. J. Moseley—The High-frequency Spectra of the Elements. Phil. Mag. *26*, 1024 (1913).

17. J. W. Nicholson—A Structural Theory of the Chemical Elements. Phil. Mag. *22*, 864 (1911).

18. J. W. Nicholson—Atomic Structure and the Spectrum of Helium. Phil. Mag. *27*, 90 (1914)

19. E. Rutherford—The Scattering of Alpha and Beta Particles by Matter and the Structure of the Atom. Phil. Mag. *21*, 669 (1911).

20. E. Rutherford and Nuttall—Scattering of Alpha Particles by Gases—Phil. Mag. *26*, 702 (1913).

21. M. Siegbahn—Report on the X-ray Spectra of the Elements. Jahrb. d. Rad. *13*, 296 (1916).

22. J. J. Thomson—On the Structure of the Atom. Phil. Mag. *26*, 792 (1913).

SALESMANSHIP FROM THE STANDPOINT OF THE BUYER

By R. G. Clapp

Brown Hoisting Machinery Company

The salesman of some years ago was taught the fallacy that real quality in salesmanship consisted in the ability to sell something that was not wanted or needed. The prosecution of this policy is certain to lead to disgruntled customers and a big loss of business. Careful thought and observation lead to the conclusion that the chief requisites of any salesman are a thorough knowledge of his product and the ability to present its merits to his customer convincingly. A permanent customer can be secured only by winning his confidence. The notion that in order to be a success a salesman must be a jolly good fellow is quickly dispelled by a glance from the viewpoint of the buyer.—Editor.

The first great trade or sale that comes to my mind is that famous deal between Jacob and Esau, described in the Bible. You will remember that Esau had just returned from a hunting expedition empty-handed and crazed from hunger. Now Jacob was a Jew and with characteristic Hebrew acumen saw his opportunity. Esau must have immediate delivery; Jacob must have a fancy premium; Esau must have his mess of pottage and Jacob demanded his last sheckel even to his birthright.

I call your attention to this famous transaction because it is typical of modern conditions, especially of the present times, for exactly the same extortion is practised by the Jew of our day, and by Gentile as well.

You will remember the rest of the story: How Esau having satisfied his hunger, began to realize he had paid a pretty price for his oatmeal, or grape-nuts, or cream of wheat, or whatever was his pet breakfast food, and went to his mother and complained to her of the hard bargain Jacob had driven. If it was a hard bargain for Esau, it boded disaster for Jacob, for there followed such a train of sorrow and trouble to Jacob that he undoubtedly wished many times that he had not squeezed Esau and left behind such an object lesson for all time.

It assuredly has a lesson for us that no business can continue to thrive that exacts or attempts to exact enormous profits. Any firm about to start in business may well consider carefully the question of profits it expects to make, for upon this decision will largely depend success. Unusual profits always invite others into such an attractive field; but the principal object of concern is the customer, for upon his good-will hinges success. Now good-will is born of confidence, and confidence involves not only quality of goods but a reasonable price for such quality.

It is true that competition governs such conditions to a very large degree, but not wholly so. To explain I will give you our experience with two firms. Smith & Jones, of Chicago, were the first people to put on the market a machine that has since come into universal use. They therefore had a monopoly of the trade. At first they sold this machine for one hundred and fifty dollars, and as no competition appeared this remained the price for several years; and the assumption is that they made a reasonable profit at that price. They then made a slight improvement in the machine. Now the improvement meant no extra cost to build, and only a slight initial increase. It probably meant nothing in loss on the old type of machines, but the convenience of this change to the purchaser was of the utmost importance. He would not hesitate to choose the improved machine. Realizing this, they demanded an extra fifty dollars for this improvement—an increase in selling price of 33⅓ per cent. We wanted the new machine but we refused to pay the extra price and bought the old. Finally they stopped making the old and forced their customers to pay two hundred dollars for the new. We rebelled, and told them it was extortion and warned them that in place of having a pleased customer we were the opposite; and that the first machine we saw that was satisfactorily we would buy in preference to theirs. The competing machine has recently arrived on the market, and in spite of former business relations with the old company we are taking up the product of the new. His high price bred a score of competitors, and his sales policy won him no friends in the trade.

Contrast this with another Chicago company. While this company was not the first in the field it was the first to put onto the market a complete line, and therefore was in a similar position to the other firm though in an altogether different field. Their policy was one of great liberality. The first tools they put on the market were rather crude, consumed excessive power, and were hard on the operator; but as improvements were made the old machines were called in and an even exchange made. This policy was carried on for some time, when it was modified by making the exchange price so attractive that no one of sense would hesitate. In addition to all this, the prices gradually cheapened, due to the use of special machinery until the device sold at fully one-half its original price. Their salesmen at the same time were of unusual quality, so that all-in-all they were not only keeping crude and imperfect machines out of the shops, thereby preventing their competitors from making headway, but most important of all, they were building up a clientile that was enthusiastic in its loyalty, and in spite of many competitors they practically control the market. I have said they used salesmen of unusual quality. I will be asked: What is quality in salesmen, and what is high standard in salesmanship?

That causes me to stop and reflect on the thousands, it seems to me, of salesmen that over the years have come in and out of our office. There is the youngster making his first call—his mouth is so full of cotton that he couldn't whistle if his life depended on it. At the other extreme is the old man who should be at his fireside. He never did know much about his line, and what he did know he has forgotten. If you give him an order you have about the same feeling as when you give to some charitable enterprise. There is the chap who whisks in and whisks out so quickly that you are led to wonder whether you are the fifth or the fiftieth person he has seen that day. Then there is the other fellow who saunters in, takes off his coat, lights a cigar, takes a seat, and is prepared, like General Grant, to stay all summer. Then there is the individual who puts his feet on your table and takes possession of your room; and there is the creature who cautiously sticks his head into the room, and apologizes as he draws in the rest of his body. There is the article whose breath is strong with whiskey; and there is that worst of all articles, the perfumed salesman. He perfumes his clothes, he perfumes his hair, he perfumes his hands, and I know that if you could get at his feet you would find them perfumed also. There is the individual that surrenders so quickly that you would like to examine him to see if he has a back-bone; and there is the bully who you feel, if you don't give him an order, will give you a black eye. There is the genius who is so full of figures and facts that he makes you fairly dizzy, and there is the other who tosses his catalog on the table, saying "Them's my sentiments."

One will offer you a cigar at arm's length as he enters the door; another in the midst of the conversation will sneak it across the table under his hand, as though he had stolen it and was trying to get it back without your seeing him. And the third leaves it on the table and runs as if he were placing a dynamite bomb. Some men when they call appear to scatter sunshine. There are others after whom you would like to scatter lime. There is one so enthusiastic over his subject that it would be sacrilege to introduce another; and there is the other who doesn't care a rap, so long as Harvard outkicks Yale.

Now all these various types of salesmen are aiming at the same mark; the same goal—successful salesmanship. Undoubtedly, the majority of them do succeed. Therefore the things that appear ridiculous to me may be the very ideal of propriety to some others. Be all things to all men; we are told, and yet I cannot see how this can be possible.

A salesman connected with a house in this city told me of his experience with an expert of his firm. This expert had an almost uncanny faculty of being able to divine each buyer's hobby, and "playing up" to it; and this seemed to my friend to be the acme of skill, and therefore success. But methods of this kind are of doubtful value; they are double-edged swords, and very keen at that. No buyer of intelligence, or having respect for his work, relishes being considered a kind of game to be hunted and tempted by various baits, as a sportsman does a trout. He knows there are only two things for him to consider: does he need the article offered for sale, and is this the one he should buy? Therefore the moment he knows the real purpose of the salesman—and he is bound to do so sooner or later, for no salesman however astute can play a part consistently and succeed—that salesman's prestige is forever lost with that buyer and no amount of pleading or cajolery will ever re-establish the salesman in his esteem, for the simple reason that his vanity has been offended. His hobby may be as tame as a game of golf or as useless as collecting postage stamps, but he is at least earnest in its pursuit. To be used by a designing salesman is a reflection on his intelligence, and therefore an offense.

A general sales manager of a large eastern firm had made repeated calls on a certain large buyer in Cleveland, but without any success. Finally, one morning he made his usual quarterly call. Much to his astonishment the buyer not only gave him a hearing but a large order as well. His surprise must have been manifest to the buyer for he explained: "You are wondering why I am going to give you this order this morning, and I will tell you why. Mr. Blank, of John Doe and Co., one of your competitors, whenever he comes to town calls me up and invites me to dinner in the evening. The usual result is that I drink too much and the next morning I am unfit for business; but when he comes around later in the day there is no way out of it but to give him the order. But this morning I am so disgusted with myself, that I am giving this order to you, so that when he comes around later it will give me pleasure to tell him I have already placed the order." And Mr. Blank salesman never sold him again.

I remember that soon after I commenced to do the buying a certain salesman used to call on me regularly, and I came to know him very well. One time he said he would like to bring his wife around to my house so that we could get better acquainted, and I was very glad to have him do so, as he was a congenial spirit and generally the type of man I could like. So we visited back and forth quite a number of times, when all at once I could see that it was merely a scheme to sell goods. The sense of dismay and humiliation so overwhelmed me that to this day I cannot think of the experience without getting mad, though it happened twenty years ago.

A salesman once told me of an experience with a buyer in Providence. The buyer had at different times given him orders and he felt he should give some tangible evidence of appreciation. He couldn't deliberately give him anything, for he was too honest for that. One day after an unusually large order he was determined to do something. By chance he found that his victim was a baseball enthusiast. He ventured an invitation to the game between Hartford and Providence, and Mr. Buyer accepted. Along about the fifth inning, with the score 8 to 3 in the home team's favor, a brilliant idea occurred to him. He would bet his friend ten dollars that Hartford would win. Mr. Buyer flushed with the fact that Hartford was behind, and while telling the salesman that he was a fool took the bet. In a few minutes the Providence team went to pieces. Hartford commenced to score and finally won the game. Well, he said a madder man he never saw, and Mr. Buyer charged him with betting on a sure thing, for he never would have offered to bet at that time if he hadn't had some tip.

Another salesman told me recently of an experience that taught him a valuable lesson. He had been courting the favor of a large oil firm and finally secured an order for several tank cars. In the course of time the cars were ready for shipment, and the oil company's inspector was called for. After a day or two he was called up by his shop superintendent, who complained that the inspector was a crank, was looking for trouble, and anyhow didn't know a tank from a bungalow. He wanted him to call on the customer and have the inspector removed, and a new one sent. So without looking into the matter as he should have done, he called on the president and in rather forceful language reminded the company that in this case a substitute might be better than the original. The president replied that Mr. Jones had been their inspector for twenty years, he had rendered excellent service, and had never had such a complaint made about him before. He said he was inclined to leave him on the job. Finally, however, after much persuasion he sent his mechanical engineer. Upon his arrival he ordered the tanks filled with water, and pressure applied. Here and there moisture appeared around a rivet head. The superintendent admitted that they leaked a little. The inspector was vindicated and left in charge. The salesman lost the confidence of the oil company, and gained along with it the ill will of the inspector for going over his head to complain about him.

Now I am telling you these actual experiences because each one of them has a point I wish to bring out. Too many salesmen regard all these things as requisite of salesmanship, when as a matter of fact they are of questionable value at best. I have said that the buyer had only two things to consider—does he need the article offered him and is this the one he should buy? If this statement is true, then these two points should be the principal ones for the salesman to bear in mind.

The old school of salesmanship taught that any fool could sell the thing a man wanted. The art of selling was to have him buy something he didn't want. This is wholly indefensible. It is as fallacious as it is wrong. A pleased and satisfied trade is the ambition of every conscientious sales organization, and to sell something to a man he doesn't want is to court disaster from the beginning, as it ought. But this doesn't mean that because he *thinks* he doesn't want it, that a salesman's efforts should cease. His conditions may be such that you know he needs it very badly, but he doesn't know; the salesmen's skill is to make him know.

Some years ago we needed a tool grinder, and we telegraphed a well-known tool manufacturer to quote us price and delivery on such a machine. We received no word from them, but the next day a man came to our office dressed in workman's clothes, wearing a blue and white polka dot shirt and collar. He explained that he was the assistant superintendent of the tool company, that two of their erectors were sick and that he had been sent out to erect a machine, and he showed us a telegram from his company requesting him to call on us in answer to our inquiry. I remember he made no apology for his dress, but proceeded to discuss the machine. I took him to the Boss, who became at once interested in what he had to say. Now the Boss was a terror to machine tool salesmen, for he seemed to be able to detect at a moment's glance at a photograph or a drawing the weakness in a machine if it had any, and woe to the salesman who attempted to prove to him that he was mistaken. Now my novice stood a searching inquiry without any sign of distress, but grew better the longer he talked. The Boss became more interested in him and took him out to the shop, where he was entirely at home. He talked about a new machine that his firm had just placed on the market, showed how much it had saved them over their old methods, and then proceeded to show how much we could save by pointing out the time the new machine could perform certain operations about our shop. The result was that the Boss couldn't get into the office quick enough to have me make out an order, not for one machine but for two. Not only an order for a two hundred dollar machine that we needed, but also an order for an eighteen hundred dollar machine that we didn't need, or rather one we did need but didn't know it; and sold too by a man who wasn't a salesman and who never pretended to be, and to an engineer who was known by machine tool manufacturers and salesmen to be a most exacting critic of machine tool practice. And why was he successful? Simply because he knew his subject thoroughly; he proved to the Boss without question that he couldn't afford to be without this machine a single day. Now this salesman's appearance was against him; his personality was not altogether assuring; he came "unheralded and unsung." He told simply what a given operation cost by our method, and what it cost by his, and a simple calculation showed the saving. That we had to have the machine was as inevitable as that the sun would rise the next morning. This salesman didn't need a bunch of letters of introduction from the superintendent to the president and back to the purchasing agent again, nor did he deem it necessary to dine and wine his victims to get him into the proper state of mind, nor did he have to criticise or ridicule the product of his competitors.

The experience of another salesman, whose business was babbitt and journal metals, a most discouraging product to sell, may be of interest. Engineers have not studied the subject of bearings with the thoroughness its importance deserves. Literature on the subject is unsatisfactory. Consumers have only a hazy conception of what they require, and as a result the business contains too many unscrupulous manufacturers. This salesman was determined to master the subject; he studied it in all its phases till he became an expert of no mean ability. He was successful as a salesman, but he could not interest the B. & W. Steel Company. He called on the superintendent in charge of machinery, but in spite of his knowledge could not interest him. They were buying from another concern, they had no trouble with their metals, the prices were right and they could see no reason to change. For seven years he continued to visit this buyer and always with the same results. After the first few trips he never mentioned his subject until he was going out the door, when he would say: "Remember, when you are having trouble with your bearings, I am ready to serve you." The interviews were always pleasant, he visited the superintendent at his home, but no business came. Finally on one of his trips the superintendent said to him: "Can you be here Saturday morning? We are having trouble with the bearings on the hot rolls on one of our mills. You will meet the master mechanic, general manager, and myself." The test of his knowledge and salesmanship had finally culminated, and after a discussion of six hours and a campaign of seven years, he won his fight.

A few years ago a man was ushered into my office; he wore a long mustache and a black slouch hat. He had every mark of the breezy west, so I was not surprised when he announced he was the editor of a well-known lumber trade publication of Chicago. He was investigating us and our product, with reference to his field. I told him as well as I could the things we manufactured, but I assured him that the lumber field did not offer us much encouragement; that we had had a man on a scouting expedition through the lumber districts of the Southwest and Northwest, and that the report had been adverse. Let me tell you how he met the situation. He quietly stated that he felt our man was mistaken; that he knew the lumbering business in every detail, both hard and soft wood; he had been in every lumbering camp of any importance in this country, and had a pretty general knowledge of the lumbering business and lumbering methods of Europe, having spent considerable time in those countries. He then clinched his argument by the astounding statement that if I would show him a piece of timber he would tell me from what part of the country it came, and the elevation above the sea at which it grew. I had a piece of pattern lumber in my room that had been sent to me with the complaint that it was too full of pitch to suit the purpose. As we had purchased a car load of it, I knew where it came from. I placed it on the table before him; he looked it over carefully, lifted it, cut it with his knife, smelled it, did everything but eat it. Finally, after about five minutes, he said it came from the lower end of a butt log of sugar pine that grew in a certain district in Central California; and that was where it came from. I surrendered; I needed no further argument to convince me that he knew his business, and that we should buy space in his publication, and as soon after as we could arrange it, did so.

And so I could go on with story after story similar to these. I could tell you about another salesman who lacked about all the attributes usually sought by salesman, and yet he was the most successful salesman his company had, because he not only thoroughly knew every detail of the manufacture of the articles he sold, but principally because he considered himself the mediator between his firm and his customer, never forgetting for a moment his duty to his employer. He was looking out for the interests of his customer all the time, giving tips as to market conditions, helping his customer to buy materials he didn't sell himself, finding a good foreman for those in need, serving wherever he could.

I will again ask what is quality in salesmanship? First and last and always, a broad and thorough knowledge of the thing you sell, a deep and abiding faith in its quality, a living enthusiasm born of such faith, and that rare ability to inspire the customer with that confidence in you and your product that he thinks of you and you only when he is about to buy.

Four elements enter into the sale of every article. First, attention; second, interest; third, desire; and fourth, possession. If you analyze these four attributes you will find that they center around the product and the argument for it. They have nothing to do with dress, though we like a well groomed man; they have nothing to do with good looks, although personality may help or mar confidence; they have nothing to do with wide acquaintance, for we know of a salesman who had all of this and couldn't win; they have nothing to do even with good fellowship, though good cheer and optimism have a bearing on sales. There was a time when all these extraneous attributes were sought in a salesman, but they have given way to the expert. A man is no longer chosen by the color of his hair or for his ability in elbow lifting; he is chosen because of his thorough knowledge of the product. The first class is being cast aside with the obsolete, like the scythe and the ox-team. It is true that the scythe is still used, but only in the fence corners, in the stony and soggy places where the modern machine will not go. In the broad fields of the harvest it is not to be found.

FLOOD LIGHTING THE NATIONAL CAPITOL

By J. A. Summers

Edison Lamp Works, Harrison, N. J.

The introduction of a simple and efficient projector has made flood lighting very popular in decorative schemes, and some of the results that are being effected by means of intensive lighting are truly beautiful. During the Inauguration the U. S. Capitol was specially lighted by these projectors, and the result was so impressive that a strong appeal has been made to have the lighting a permanent feature.—Editor.

There is no dome in Europe more graceful in its lines and proportions than the great dome on the Capitol at Washington. It has been declared more imposing than the famous old domes of St. Peter's at Rome, or St. Paul's at London, which are somewhat similar.

The Capitol stands on an eminence 90 feet above the Potomac river, and the magnificent white dome rising above it is almost the first sight to greet the visitor, no matter from which direction he approaches.

It is but fitting that this wonderful piece of architecture, pictured the world over, should be made as attractive by night as by day. During the recent inauguration celebration the illumination of the dome was first attempted, and visitors and press alike raised a clamor to have the beautiful and dignified spectacle a permanent feature of the Federal city.

Beautiful as the dome appears by day, it is when illuminated at night by a flood of light over its entire surface that all its dignity and grandeur are brought out. The surroundings, which might detract, are then clothed in darkness, and the great alabaster-like structure stands out against the dark sky—a sight to stir the highest patriotic feelings.

The dome is 135 feet in diameter at the base and 218 feet high above the roof. It is built of cast and wrought iron painted white. Around the base are 36 fluted columns, representing the 36 states in the Union at the time of the design; and under the bronze statue of Liberty surmounting it are 13 fluted columns for the 13 original colonies.

It is lighted by means of 84 G.E. flood-lighting projectors, each equipped with a 400-watt Edison Mazda flood-lighting lamp. The projectors were placed in four banks, 21 in each bank, about 200 feet from the base

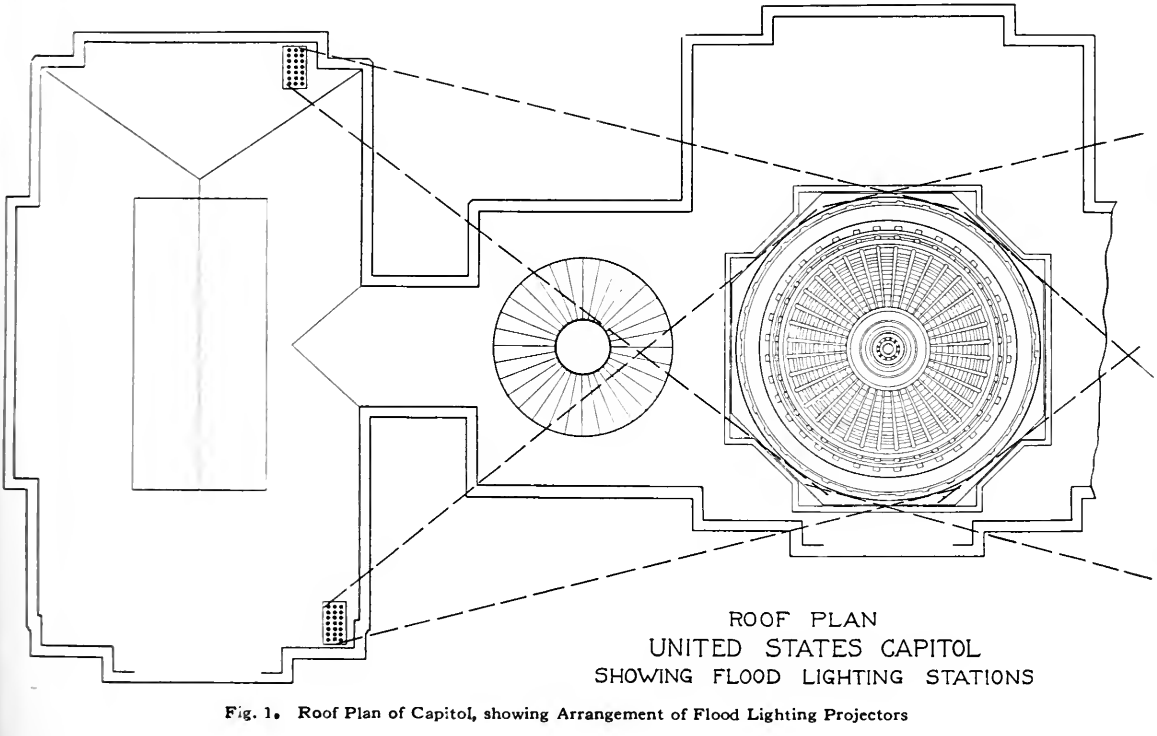
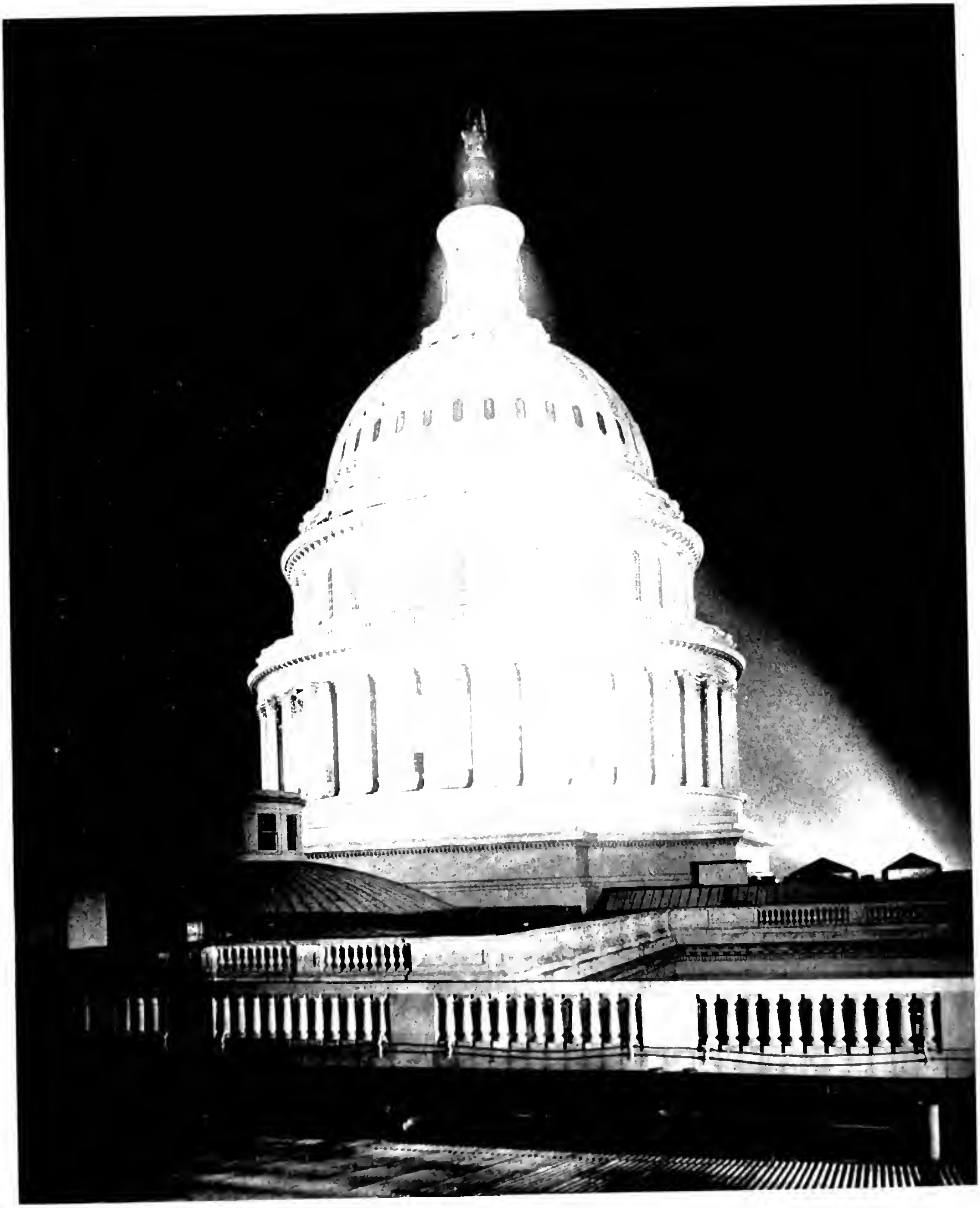
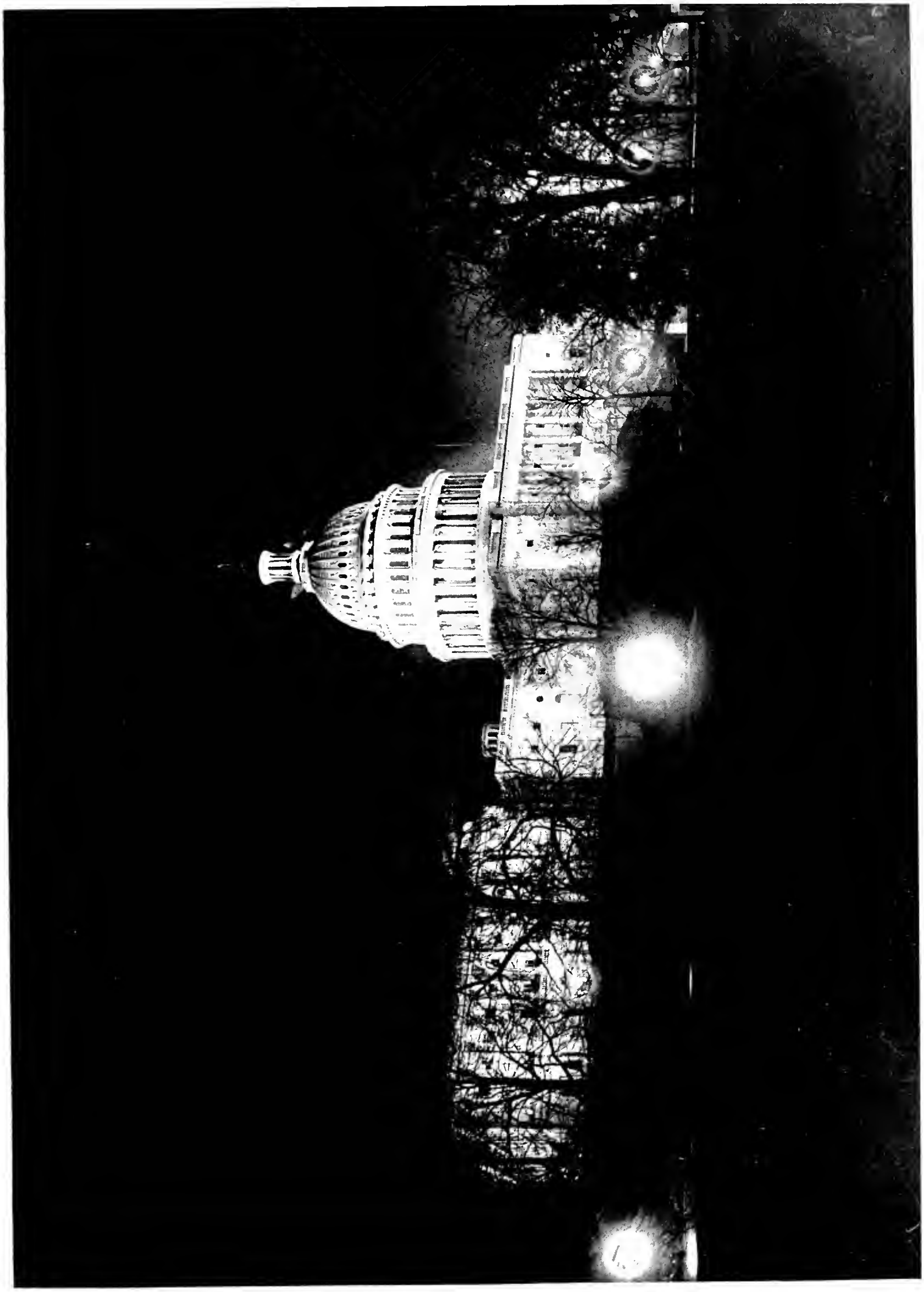


Fig. 1. Roof Plan of Capitol, showing Arrangement of Flood Lighting Projectors



Dome of U. S. Capitol Illuminated by Flood Lighting Projectors



Another View of the National Capitol under Flood Lighting

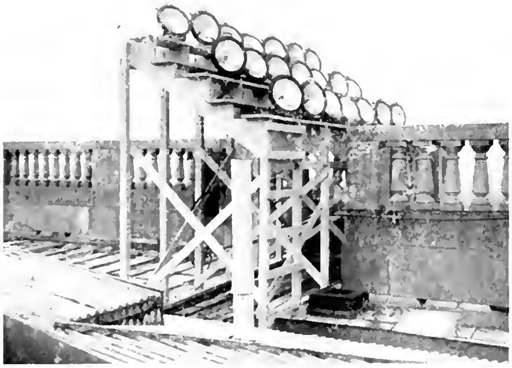


Fig. 2. One of Four Banks of Flood Lighting Projectors for Illuminating Dome

of the dome, on the corners of the House and Senate wings of the building, as shown on the roof plan, Fig. 1. This plan shows only half of the roof, but the two sides are symmetrical.

The method of mounting the projectors is shown in Fig. 2. By placing the projectors in these positions, it was possible to direct the beams of light so that the columns and other projections would receive light from different directions, thus cutting out objectional shadows but not eliminating them entirely, for their total absence would make the structure appear flat.

The building proper was lighted to a low intensity, to form a setting for the dome and relieve the contrast of a very bright dome and a dark building. The building is 750 feet long and 250 feet wide. The central portion is of sandstone painted white, and the House and Senate wings at each end are of white marble. Surrounding the building on three sides is a wide concourse bounded by a parapet. A few ornamental lamp posts with white opal globes are regularly placed on this parapet, to light the concourse. To illuminate the building, additional posts of the same style were placed on the parapet to provide for the projectors. Thirty-four G.E. flood-lighting projectors, each equipped with a 400-watt Edison Mazda flood-lighting lamp, were used on these poles.

The method of mounting the projectors was unique and not at all conspicuous. Each opal glass ball removed was replaced by a circular block of wood, to which the projector was bolted. Fig. 3 shows a view of the installation with a regular unit in the foreground and the projectors beyond.

The illumination of the Court of Honor was another installation which caused considerable favorable comment by the inauguration visitors, Fig. 4. It was built on Pennsylvania Ave., opposite the White House, and was the official reviewing stand for the President. At night it was illuminated by 40 G.E. flood-lighting projectors, each equipped with a 400-watt Edison Mazda flood-lighting lamp. The projectors were mounted in pairs on the tops of the pylons, on both sides of the street, with the beams directed toward the flags and pylons on the opposite sides of the street. The effect was magnificent.

Fig. 3. Flood Lighting Projectors for Illuminating Main Portion of Capitol

Fig. 4. Court of Honor

GENERAL ELECTRIC REVIEW

A MONTHLY MAGAZINE FOR ENGINEERS

Manager, M. P. RICE Editor, JOHN R. HEWETT Associate Editor, B. M. EOFF
Assistant Editor, E. C. SANDERS

Subscription Rates: United States and Mexico, $2.00 per year; Canada, $2.25 per year; Foreign, $2.50 per year; payable in advance. Remit by post-office or express money orders, bank checks or drafts, made payable to the *General Electric Review*, Schenectady, N. Y.

Entered as second-class matter, March 26, 1912, at the post-office at Schenectady, N. Y., under the Act of March, 1879.

VOL. XX., NO. 6 *Copyright, 1917 by General Electric Company* JUNE, 1917

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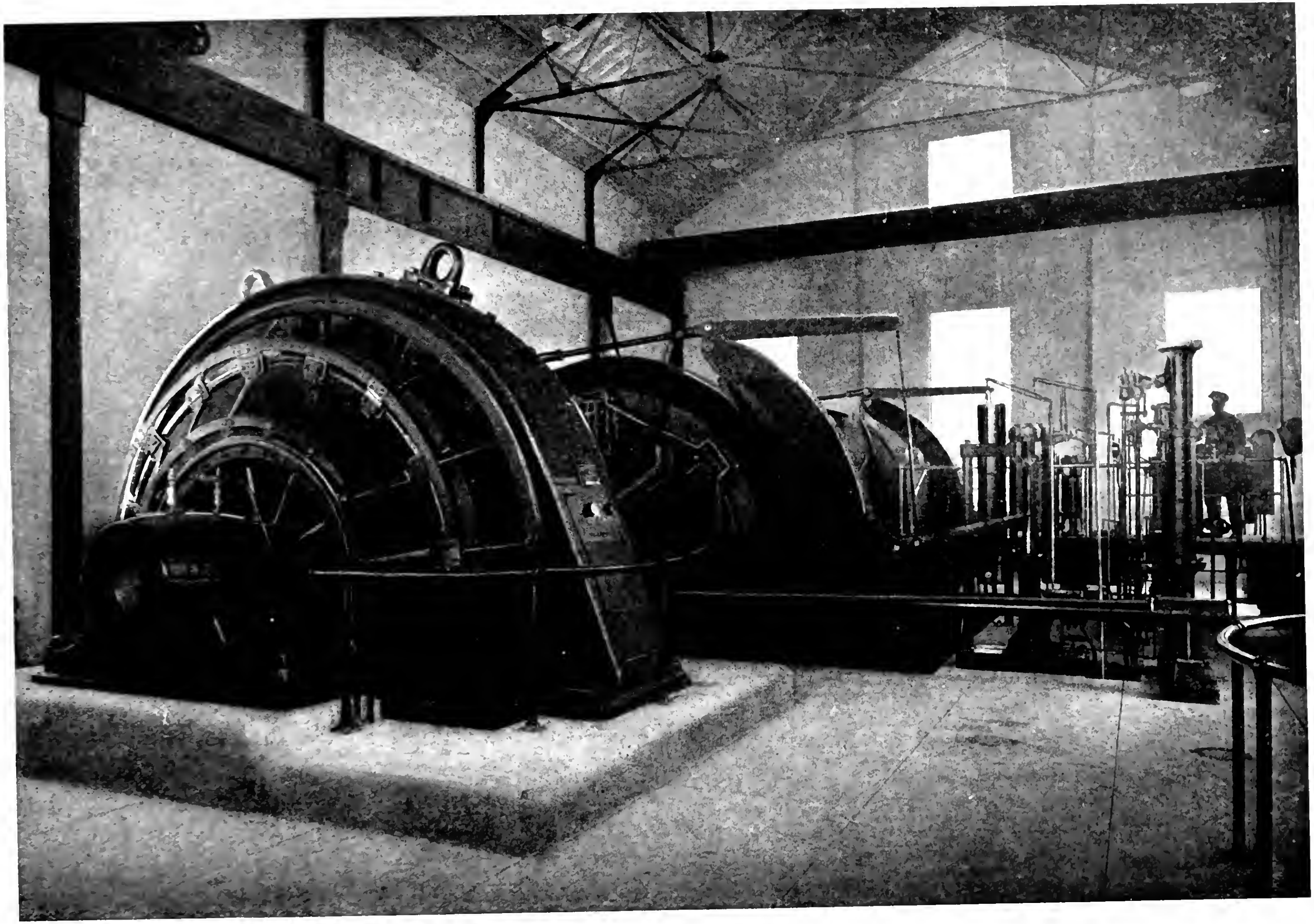

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GENERAL ELECTRIC REVIEW

LOOKING TOWARDS THE UNIVERSAL APPLICATION OF ELECTRIC POWER

Our annual June issue brings forcibly to our attention that power, or rather electrical power, is being used more widely than ever before. This has been said many times, and yet each year it becomes more apparent as new applications are made and the method of application is improved. The end is not reached and there is no probability of its being reached for many generations to come. Every new installation suggests yet another, and thus progress continues. There probably has never been a time when there has been more rapid development in the adaptation of electricity to different power purposes than in the last few years. This has been due largely to the fact that the manufacturers of the country have been called upon to increase their facilities, as the result largely of the general prosperity of the country. They have universally found that the quickest and best way to get the increased capacity was by making use of the electrical power available from the central station.

The older method of using electrical power was to replace the steam engine with a motor coupled direct to the line shaft, but the newer method is to connect the motor direct to the tool, applying the power direct instead of bringing it through miscellaneous belting, piping, etc., as previously.

The word "power," as originally used in the electrical industry, referred only to motors of different characters, whereas today the available energy of a central station or power company is spoken of in this sense, and the energy is converted to other useful purposes, such as electrical enameling ovens, core baking ovens, electrical sherardizing, the heating of glue pots, electrical steel furnaces, electrical brass furnaces, hardening furnaces, electrical welding, and many other applications too numerous to mention. All of these applications have brought about revolutions in their fields, forcing changes in the practices which had been developed under the older methods. All of these changes result usually in still greater demands for power. However, there is probably more work done today by hand power, or by other mechanical means, than is done by electrical means, and it is probable that most of them could be done more efficiently and better by electrical means; and these are the problems which we have before us.

There are several handicaps in the way before there can be a universal use of electrical power:

1. One of the essential features is that we should have universal frequency on our alternating current systems. Sixty cycles is more commonly used than any other frequency. Twenty-five cycles is probably the next most commonly used frequency, but this frequency is largely confined to systems requiring other than alternating currents; in other words, 25 cycles is seldom used for any direct application, as it is usually converted into either low-voltage direct current or high-voltage direct current. Consequently 60 cycles could be used just as well for this purpose. There are a few systems using 33 cycles and still fewer using 50 cycles. There is no reason for the existence of either one and the sooner they are eliminated the better. Unfortunately there is still another frequency which is more commonly used in mill work and in a few isolated power developments, namely 40 cycles. It would appear to us that this practice should be discontinued at the earliest possible moment and that any engineer who is recommending the installation of any new plant at this frequency is making an engineering mistake which will some day cost the user a large amount of money to rectify.

2. It would appear that the future development in this country should be to stop in some way indiscriminate building of small power houses, such as isolated plants, etc., and to start to develop a complete and continuous network of wires all over the country, not necessarily all owned and operated by one company; on the contrary a probably better arrangement would be to have individual distributing companies in each community large enough to support it, and then have large power generating companies scattered over the country in places where fuel can be most readily obtained, as well as water, labor, etc., all these power generating stations being interconnected and exchanging power as the demand for power in the adjacent neighborhoods develops. Operating in such a manner would mean that power could be produced for far less than it can be at present, both on account of the great reduction in fuel costs and also in capital investments. Also, there would be additional saving in labor.

The standardization of frequencies is not the only standardizing work which should be undertaken, but is that which could be most easily attended to first. In addition, a definite program should be laid out to standardize voltages, and more important still, the speeds of motors. There has been too little attempt made in this direction, as it has been the common method to develop a machine first and then fit a motor to it. It would be infinitely better if some cooperative work could be done to develop the machine and the motor as a complete whole and thus eliminate the very large number of special motors, which not only cost more themselves but have a tendency to increase the cost of all other motors.

C. W. Stone

MANUFACTURING CONDITIONS IN THE ELECTRICAL INDUSTRY

By D. B. Rushmore and E. W. Pilgrim

Power and Mining Engineering Department, General Electric Company

This article is a plea for the employment of standard lines of electrical apparatus wherever conditions will at all permit of its application. The great demand at this time for products of all kinds has forced manufacturers to work for maximum production, and this means concentration of effort on developed apparatus and the elimination of all special equipment. The observance by customers of this desideratum in making out specifications would work no special hardship to them, as the lines of developed apparatus of all varieties are very extensive and sufficiently broad to fulfill all ordinary requirements.—Editor.

D. B. Rushmore

The industrial conditions in the United States at present are decidedly abnormal. The rapid increase in demand has overwhelmed manufacturers and their facilities are crowded to the utmost. The difficulties of getting material and shipments extend all along the line to the producers of raw materials of every kind, and transportation as well is taxed to its limit.

The imperative necessity of reaching and continuing maximum production and of doing everything possible to meet the demands of the situation, and especially those Government demands which are now coming rapidly upon us, emphasizes the importance of a proper understanding on the part of the customer of certain factors with regard to electrical manufacturing, which in normal times are not always brought forcibly to his notice.

The electrical apparatus used mostly in industry consists largely of generators, exciters, transformers, switchboards, motors and controllers. These lines of apparatus have, in general, been developed after years of careful study, after the expenditure of many hundreds of thousands of dollars, and after engaging the attention of a large force of highly trained men. Every effort has naturally been made in their development to have them meet the greatest range of requirements of service.

Under normal conditions a certain amount of what is called special apparatus is necessary and permissible. It is however possible in many cases, without a very great sacrifice, to use standard apparatus, or to adjust the method of drive or the machine to be driven to the electric motor, with much less modification than otherwise.

E. W. Pilgrim

With the idea of explaining a little more fully the situation regarding standard and special apparatus, and of impressing all customers with the urgent necessity of utilizing standard apparatus wherever possible, the following facts are presented:

The General Electric Company, like all other manufacturing industries, is overcrowded with work in all its departments. Many orders have been received for apparatus from the Government due to the present war situation and many men have enlisted in the Government service from the Engineering and Drafting Departments. It is necessary therefore to immediately work along lines for maximum production. This means, among other things, that every effort be turned to the utilizing of standard apparatus and that special apparatus and modifications of any kind be eliminated. Customers should be asked to co-operate with manufacturers by confining their requirements to developed apparatus.

The General Electric Company's facilities are probably as great as those of any other company. It has a large trained force of engineers and draftsmen, and its factories are immense, well organized and well manned. An idea of their size can be obtained from the accompanying photographs.

The apparatus manufactured by the General Electric Company covers practically the entire field of electrical applications, ranging from Mazda miniature flashlights to 45,000 kw. Curtis steam turbines, and embracing 119 different classes, each class subdivided into hundreds of varieties. As an illustration: There are listed 25 h.p. induction motors at five different speeds, four voltages, three frequencies, three forms, two

Main Office Building, General Electric Company, Schenectady, N. Y.
This building accommodates approximately 2300 employees.

Laboratory and Office Building at Schenectady Works.

phases, or a total or 360 different motors. There are six sizes between 15 and 50 horse power inclusive, making 2,160 standard listed motors. Any one of these motors can be furnished with pulley and base for belt drive, with short shaft for coupling or gearings with windings treated to resist moisture for operation in mines and other damp places, with back geared attachments, or with vertical parts; which means that the company stands ready to supply 10,800 different induction motors from 15 to 50 horse power of only one type, and there are listed 15 different types.

There have been issued to date 202,000 catalogue numbers, and new numbers are being issued at the rate of 18,000 per year. The switchboard handbook contains a list of 22 lines of panels consisting of 767 types having from 2 to 150 sub-divisions and aggregating approximately 9,000 catalogue number panels.

All lines of transformers, direct current motors, controllers, compensators, railway motors, etc., are as complete as the items mentioned above, and this shows the enormous number of individual requirements which can be met from apparatus now listed as standard.

The views of the Small Motor Department, Lynn Works, pages 429 and 431, illustrate the wonderful system which enables the company to turn out over 75,000 small motors and generators per year. In this department the work is so arranged that the parts progress from one section to another until they are assembled, tested, painted and shipped.

Each item listed by catalogue number or rating is not necessarily regarded as standard, but any listed part can be fabricated without requiring engineering instructions. Standard apparatus is usually listed in heavy faced type and represents those items mostly used, which are either carried in stock as a unit or its parts are stocked. Apparatus is regarded as special when a number of new patterns, dies and windings are required, and semi-standard or partly special when changes such as length of shaft, diameter of pulley fit or new field or armature windings using existing forms only are required; but in either case production is greatly interfered with. Take for example an engine or water-wheel-driven generator where the speed is not standard and a change in frame may be required to meet special conditions, and the guarantees as to efficiency, heating, overloads, etc., differ from those of the standard line. In order to build this machine there would be required—

1. Attention from the designing engineers.
2. Layouts and special drawings to be made in the drafting room. After the engineering and drafting have been completed a new drawing list is required and the factory must obtain from the blue print department a complete set of new drawings.
3. Undoubtedly a special size of copper would be required for the armature and fields. This means that the factory cannot draw from its stock, but is required to place an order on the wire drawing manufacturers, who, no doubt, would have to set up their machines in order to finish copper for this small order, thus upsetting their schedule on standard sizes.
4. Changes in the armature spider, flanges, frame or commutator shell necessitates either new patterns in the pattern shop, or perhaps if the change is slight an existing pattern of the standard machine can be used; but this takes the pattern away from standard production while the changes are being made and while the single casting is being cast.
5. The schedule of the foundry is interfered with, as they must wait for this special pattern or changed pattern before they can start work, instead of being able to take the standard pattern from the shelf when the time is opportune for making the casting.
6. If any new dies are required, the time and expense of making these dies are just as great for this one machine as they would be for getting out the dies for standard machines from which a great many duplicates would be made.
7. Machine work may require new tools, or if carried along and built without tools, will require layouts which necessitate the time of an expert mechanic and is not as accurate as when jigs can be used.
8. The assembly becomes special, and considerable time is necessarily consumed in going over the new drawings by the assemblers to determine just how the various parts go together. Many of these operations, when they reach the factory, require a breaking down and setting up of the machines for these special pieces. This operation often requires more time than would ordinarily be spent in performing the same operation on a large number of pieces. After the machine has been assembled, the testing requires additional time, as it is necessary to make a complete set of tests in order to

Schenectady Works

Lynn Works

Pittsfield Works

Erie Works

VIEWS OF SOME GENERAL ELECTRIC COMPANY PLANTS determine, before a machine leaves the factory, that it is perfect, both electrically and mechanically, and meets the guarantees required by the contract. The shops are not the only sections of the organization which have been interfered with in the fabricating of these special machines, as the cost accounting, bookkeeping, production and shipping departments are also more or less affected.

As another example, suppose a request were received for a two pole, 700 h.p., 1500 r.p.m., 25 cycle, form M induction motor. This motor would be special throughout, and in order to build it, new dies for stator and rotor would be required, and new patterns throughout. In normal times it would be a good motor to quote on, but with the present factory conditions it would be undesirable to build it because of the many special features, the pattern department and die-making department being overcrowded with work on the renewal of patterns and dies for standard machines. Another example is a request for a 700 h.p. synchronous motor at 514 r.p.m., with an alternative for direct connection at 120 r.p.m. The customer desires these motors totally enclosed, self-ventilated, which would require a number of new patterns and special work. As the machines are of the pedestal type construction, enclosing them is quite difficult. This requires quoting on the machines open, and pointing out to the customer that he can keep the motors cleaner by having them open and giving them attention than they would be if enclosed so that the attendants could not readily inspect them.

The Company manufactures some 3,500 different wiring devices, probably one-half of which could be omitted; these devices having been designed because of trade requirements in different territories. For example, on page 39 of the 1916 supply catalogue there are listed 11 receptacles used in the building of electric signs. If the manufacturers of electric signs would agree to a standard device only one of these would be required. As another illustration, wiring devices are all approved by the Underwriters' Laboratories, but this does not necessarily mean that they will meet the requirements of the New York City Departments of Fire, Water, Gas and Electricity, or if they are acceptable to the New York City Departments that they will be satisfactory to Chicago or San Francisco. Recently a request was received for a 30-ampere double-pole lever switch, where the customer wanted the switch blades and clips heavier; the contention being that a 30-ampere switch is not mechanically strong enough. The demand was very limited (about fifty per year). The normal production of these switches is 2,700 per year and to build this switch would have required a special slate base and a special connecting strip punching. This change appears small, but it would have required special attention from the engineering, drafting and production departments before it reached the factory. The factory would have been required to order special slate bases to be specially drilled and specially assembled. In fact, the order would have to be carried through the factory as a special item, receiving the attention of every department. This would have interfered with the production of possibly four to five times as many standard switches.

It might be well to point out here the routine, showing the difference in time required between entering an order for special and for standard apparatus. Take the case of a standard 50 h.p. induction motor. The local office makes out the requisition and sends the factory copies direct to the factory production department. From here they are distributed to the interested sections, and the order is filled from stock or from a stock manufacturing order. The same motor with special features requires that the local office make out a requisition for the construction department. The construction department distributes the original to the factory and makes copies for the engineers. The factory copy goes to the shipping department, where copies are made and sent to the interested factory sections. Work cannot be started in the factory until the engineering instructions in the form of a new drawing list has been received. Very often before the engineers can issue their instructions it is necessary to receive from the customer through the local office additional information on a special piece of apparatus, and it is not unusual for three or four weeks' time to be consumed in getting all these details settled.

It might be well to briefly mention here what has been done and is being done by the American Institute of Electrical Engineers towards the standardization of electrical apparatus. The first step taken by the Institute in this direction was a topical discussion on standardization of generators, motors and transformers, which took place simultaneously in New York and Chicago on the evening of Jan. 26th, 1898. As a result of this discussion, a Committee on Standardization was appointed, which consisted of seven members. This Committee has worked faithfully from time to time and the members have been increased as the scope of the work has been enlarged, until the 1915-16 Committee contained twenty-five members. The results of the work of this Committee have been the publication of Standardization Rules of the American Institute of Electrical Engineers, edition of December, 1916, which consists of 115 pages, covering the standardization of ratings of all classes of electrical machinery, standardization of type of insulation to be used under various conditions of installation, and standardization of methods of testing of electrical machinery, setting forth just what losses, etc., are to be included in determining efficiencies, etc.

In order that the character of apparatus may be more carefully considered before it is offered for sale in large quantities, standardizing committees having charge of the important articles manufactured have been appointed. The action of these committees is subject to a review by the proper executive officers of the Company and by the sales and manufacturing committees. In view of the magnitude of the company's business and the variety of articles, any such review will of necessity be limited to cases of unusual importance affecting all departments or the general policy. Therefore, the decisions of the standardizing committees are practically final and conclusive. The committees are made up as follows:

Induction Motor Testing

Ex-Officials . . . . { Department Managers
Works Managers
Department Engineers }
Designing Engineers
Factory Representatives
Consulting Engineers (when matters involving theoretical or general considerations of sufficient importance are under discussion).

One member is a member of all committees and has general supervision of their work.

The duties of the committees are:

1. To pass upon the suitability of proposed or existing designs from the standpoint of:

Design
Manufacture
Salability

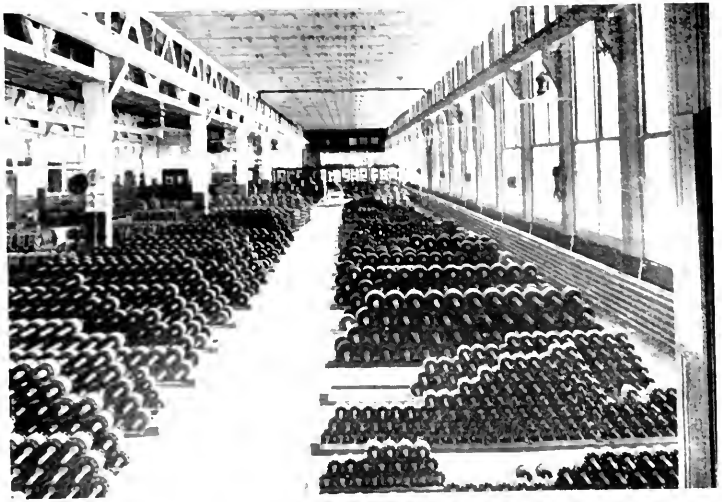
2. To suggest articles which it is desirable to have designed.

3. To recommend appropriations for development and the quantity of apparatus to be produced on first order.

4. To investigate and compare the General Electric Company's apparatus with similar apparatus made by competitors.

As an example of the duties of the various standardizing committees we might cite the program followed in authorizing a new standard line of motors.

The commercial department, for various reasons having decided that it is advisable to market a new line of motors, consults with the commercial engineering department who after a careful study of inquiries which have been received determine upon the ratings, speeds, and general characteristics of the line of motors. The designing engineers are then called upon to make a preliminary design, usually of a representative size. This preliminary design is then discussed in detail by the standardizing committee for this class of apparatus, and the design may be turned down several times before receiving final approval. After the design has been approved the standardizing committee asks for an appropriation sufficient to build and test this motor. After the motor has been built and tested, if it meets all requirements, other motors in the line will be taken up in the same way and de-



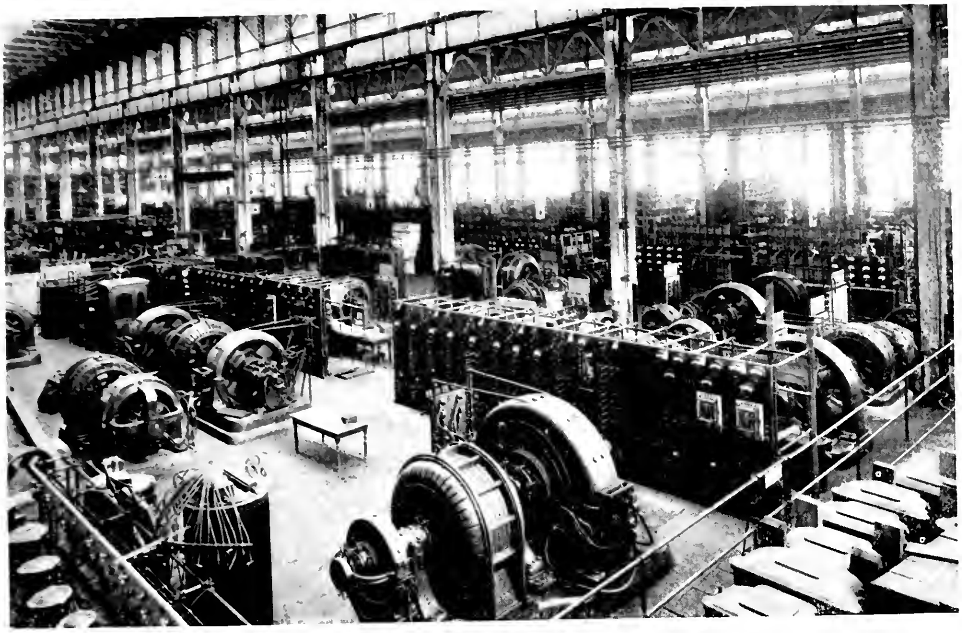
Stock of Riveted Frame Induction Motor Parts

Stock of Direct Current Motor Parts

Testing

Motor Winding

VIEWS IN SMALL MOTOR DEPARTMENT, LYNN WORKS



Transformer Test, Pittsfield Works

Iron Foundry, Schenectady Works

In addition to the usual cupola equipment this foundry has a 25-ton electric furnace signed, built, and tested. Appropriations for tools and the stocking of parts of each size of motor are also authorized, and the entire line is not advertised or offered for sale until sufficient stock has accumulated to make prompt deliveries. The bringing out of a new line of apparatus will probably consume the time of the standardizing committee, designing engineers and other departments for from one to two years, and will involve an expense of several hundred thousand dollars before the first machine is ready for the market. At present there are 43 standardizing committees, as follows:

Air brakes and air brake compressors
Air compressors (centrifugal)
A-c. generators
Arc lamps and appurtenances
D-c. generators and motor generators
D-c. motors
Demand indicators
Fabroil gears
Fan motors
Flow meters
Fractional horse power motors
General voltage regulators
Heating devices—domestic
Heating devices—industrial (inc. resistance furnaces)
Hoist, mill and similar motors
Induction motors
Induction and feeder regulators
Industrial control (inc. rheostats)
Instruments (inc. current and potential transformers)
Line material (transmission)
Line material (trolley) (inc. rail bonds)
Lightning arresters
Marine appliances
Marine generator sets
Mining locomotives
Miners' electric lamps
Ozonators
Railway Control and car equipments
Railway locomotives and equipments
Railway motors
Rectifiers—multiple (inc. panels)
Repulsion induction motors
Searchlights
Sheet steel
Sockets and wiring supplies (inc. punched clip switches and cabinet panels)
Steam turbines
Synchronous converters (inc. double current generators)
Switchboard panels (except cabinet panels and rectifier panels)
Switch s, circuit breakers, etc.
Transformers (except current and potential)
Watthour meters
Wireless telegraph and telephone work.

This list shows thoroughly the standardization of all the various lines of apparatus and how this routine is interfered with in the factory when a special or modified piece of standard apparatus is ordered. These special requirements not only handicap the factory but increase the cost. When a cost estimate is put through the cost departments on special apparatus, a higher figure is used for all the labor items. Extra charges are made for any new winding forms, dies, patterns, pattern changes, engineering and drafting that may be required, and all these items are included in the price which the customer must pay for the special machine.

There are a great many ways in which the customer can be assisted in adapting his requirements to standard machines. It is only within the past few months that the General Electric Company have started to rate various lines of machines in accordance with the A.I.E.E. rules, and not all of the lines of machines are yet on this basis. The engineers have also begun to rewrite standard specifications which accompany propositions to cover guarantees in accordance with the A.I.E.E. rules. This will go a long way toward getting customers familiar with the new standards.

Co-operation is sought with consulting engineers, architects, general managers and superintendents, who in making up their specifications covering any particular items very often quite naturally write into them ideas of their own which, requiring perhaps only a slight variation from what is regarded as standard, make the piece of apparatus entirely special. This will encourage them in specifying A.I.E.E. standards, and also tends to put all on the same basis when bidding on competitive propositions.

Salesmen can do a great deal if, when receiving an inquiry from a customer or visiting a customer, they will take more time to go over carefully any drawings which the customer may have of the machinery which he wishes to drive; or if the machinery is installed in his factory to carefully look it over and make a thorough inspection with a view to determining if it is possible to adapt a standard machine. When new developments are being contemplated, salesmen should at once see that the interested parties are furnished with bulletins and white prints showing dimensions and ratings, and other literature, so they will be perfectly familiar with the standard lines which the Company has to offer.

No doubt a very great saving can be brought about by a more thorough co-operation with customers before specifications are written or inquiries for propositions sent to the factory. At the present time, on account of the shortage of both labor and material this will be of the utmost importance, and the only way by which shipments can be bettered will be to keep production along standard lines.

ELECTRIC MINE HOISTING

By R. S. Sage

Power and Mining Engineering Department, General Electric Company

In the introduction of this comprehensive article are reviewed the factors responsible for the adoption of electricity as the motive power for mine hoisting. Typical duty cycles are next considered; and then the body of the article is devoted to a detailed description of the equipment, operation, and advantages of the induction motor, the Ward Leonard, and the Ilgner Ward Leonard systems of electric hoisting.—Editor.

R. S. Sage

General

Although electric motors were used to drive some of the mine hoists in this country as early as twenty-five years ago, it has been only within comparatively recent years that installations of considerable size or importance have been made. Also, the progress was extremely slow for a number of years.

The only available electric power for many years was direct current; and this could be obtained only in limited quantities which meant that the then practical and economical limit of size for electric hoists was soon reached. Even after favorable power conditions were attained, it was necessary to overcome much prejudice against the new drive. The steam engine, the common form of drive, while not all that could be desired, was still considered by superintendents and operators to be a cheap and generally satisfactory driver.

With the advent of expert mining reports and accurate cost accounting methods came disillusionment, but it was years before mine operators could no longer afford to ignore the advantages offered by electric drive for their hoists.

Today, there are hundreds of electrically-driven mine hoists installed in this country; and not only has steam drive become the exception instead of the rule for new installations, but large numbers of old steam hoists have been advantageously changed over to electric drive. This change is made with little difficulty or inconvenience and without interrupting production.

The improved methods of control and the extension of central-station service were two great factors which gave impetus to the adoption of the electric hoist. In the earlier days, the intermittent and fluctuating mine hoist load could not be carried by the central station with its comparatively small generating capacity, poor regulating ability, and low-voltage distribution. These conditions have been changed, however, and central stations with modern equipment are now usually willing and glad to get mining load. In the last few years, especially, there have been many large and important mine hoist electrifications.

It is estimated that nearly 1,000,000 horse power in electric motors are used today in the coal and metal mining industry of the country.

While much power is purchased, even a greater amount is generated by the mining companies. The consolidation of properties in numerous instances, especially in the coal and iron mining fields, has made the generation of power economically possible; and in many cases these central stations are of considerable size. Often the mining company in this way becomes a power supply company and markets a portion of its power to adjoining properties or to other neighboring industries. All of the economies of centralization are secured, and by raising the load-factor the use of the simplest type of hoisting equipment is permitted.

While each particular case should be considered on its own merits, the electric drive has many undisputed advantages over its competitors. These features will be touched upon briefly.

Safety and reliability probably should stand first in these advantages. The electric hoist lends itself readily to the application of simple devices which make for safety and protection against interruption of service, and which make safe operation less dependent upon the skill of the operator. It is less liable to get beyond control, and should the mechanical brakes fail the ability to brake by means of electric current may mean the saving of human life or property.

The cost of operation is of course of great importance, and in many cases it is the determining factor when the choice of drive is to be made. In general, it can be shown that the cost of operating the electric hoist is less than that of any other. Only where the cost of electric power is very high and that of fuel very low can the steam hoist be more economically operated. In any case, the cost of labor, maintenance, repairs, and supplies is higher in the case of the steam hoist. It is particularly true in mining districts that steam is generated very uneconomically. Often one or more hoists are served by long lines of steam pipes laid exposed to the air, resulting in heavy losses due to condensation and leaky joints. It has been estimated that the average steam hoist consumes at least 100 pounds of steam per shaft horsepower-hour. This means that the average efficiency (coal burned to useful work) is about 2 per cent.

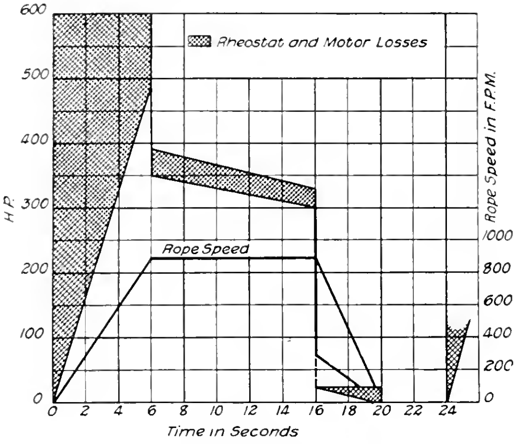


Fig. 1. Typical Load Diagram for Induction Motor Driven Hoist Having a Cylindrical Drum

The first cost of the electric as compared with the steam or air hoist is usually approximately the same for new installations. The control in the best system of electric hoisting is extremely accurate and sensitive, and with the most simple type is as good as that of the steam hoist.

The uniform turning effort exerted by the electric motor gives the hoist a steady motion which increases the life of the hoisting cable, the shaft guides, bearings, and foundations.

The space required for the installation of the electric hoist is much less than for the steam hoist. In general, the advantages claimed for the electric hoist over the steam also apply as compared with the air-driven hoist.

The three more common systems of electric hoisting as practiced in this country are the induction motor with rheostatic control, the direct-current motor with Ward Leonard control, and the direct-current motor with Ward Leonard control and flywheel equalization.

Ordinarily, the induction motor is used for small and medium capacity hoists, and where first cost is of prime consideration, and in large capacities where exact control is not imperative as with some slope hoists. By far the greater number of electric hoists are of this type and they have been built in capacities up to 1800 h.p.

For medium and large capacity hoists and where exact control is of great importance, the Ward Leonard control is used; and where the conditions of the power supply require the elimination of peaks, the flywheel equalizing system is combined with the Ward Leonard control.

A large number of hoists operated by Ward Leonard control are in operation in this country, but their application is much more extensive in European countries, particularly in Germany. It is the commoner practice in this country to install induction motors on account of the lower first cost and simplicity of application.

Duty Cycles

Before describing the various hoisting systems it seems advisable to consider briefly the nature of the hoist duty cycles, though a discussion of the methods of calculating them will not be entered into.

Fig. 1 shows a typical load diagram for a hoist with a cylindrical drum. In general, the cycle consists of a period during which all the moving parts are accelerated from rest to full running speed, followed by a period of running at full speed, and then by a slowing down to rest. Usually the hoist remains at rest for a period while loading and unloading, then if a balanced hoist it is reversed and the cycle repeated. If unbalanced, that is, if there is no empty skip or cage and car being lowered in counter-balance with that being hoisted, it is necessary to lower the empty skip either with the motor connected to the line and braking electrically or by means of the mechanical brakes. It is obviously more efficient to operate a hoist having a counterbalanced skip.

It is assumed that acceleration and retardation are accomplished uniformly under the action of a uniform torque from the motor. If, therefore, the motor is controlled rheostatically, the area shown in the shaded portion is wasted in the rheostat and in the motor.

Hoist motors are usually given a continuous rating determined by the "root mean square" or heating value of the cycle. In the case of balanced hoists, the motor must often be capable of hoisting loads out of balance. Out-of-balance operation may consist of merely hoisting an empty cage with a light load, as a man, or it may mean that full load must be hoisted for considerable periods of time. Occasionally this condition determines the size of the motor.

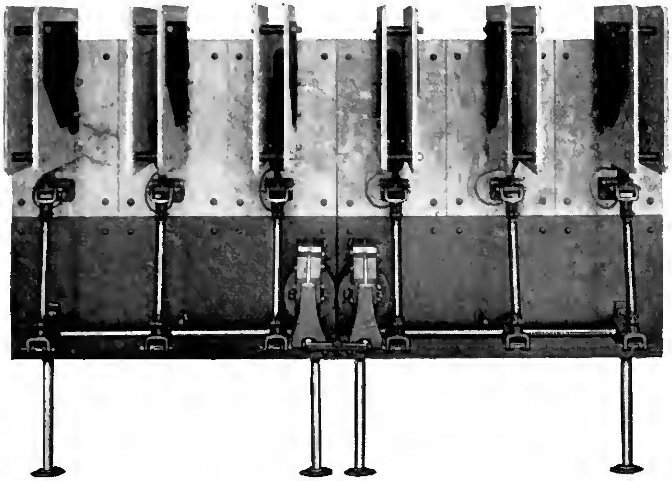


Fig. 3. Magnetic Operating Reversing Switches

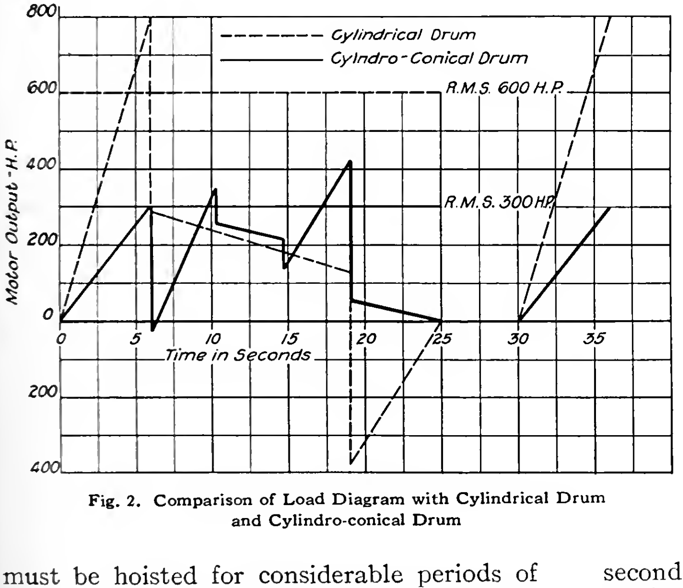


Fig. 2. Comparison of Load Diagram with Cylindrical Drum and Cylindro-conical Drum

On the normal cycle, the motor is subjected to the heaviest loads during starting and stopping, and its capacity may often be determined by these parts of the cycle, especially in the case of short frequent cycles. The length of the rest period also greatly influences the capacity of the motor for such cycles. In the case of long cycles, however, neither of these factors ordinarily has such a controlling influence on the rating of the motor.

Very great advantages may often be obtained by the use of especially designed hoist drums as is well shown in Fig. 2. The broken line represents a load diagram based on using a simple cylindrical drum, and the full line a diagram representing the same work done based on a cylindro-conical type of drum.

This hoist was for a coal mine with a depth of 650 feet, hoisting at an average rope speed of 2600 feet per minute. The special drums had a minimum diameter of 5 feet and a maximum of 9 feet. There were 4.15 turns wound on the smaller cylindrical portion, 6.5 turns on the cone, and 15.62 turns on the larger cylinder.

The peak at starting has been reduced from 800 h.p. to 310 h.p., the size of the motor from 600 h.p. to 300 h.p., and the power consumed per trip from 12,000 h.p-seconds to 6000 h.p-seconds. The overall efficiency in the first case is about 25 per cent; in the second about 50 per cent.

The saving effected in this particular case is somewhat greater than is usually gained by the use of special drums. Some advantage may usually be expected in the case of single short lifts and high rope speeds, as with coal mine hoists. Ordinarily, little advantage could be expected from the use of special drums for deep mine hoists, such as in metal mines where hoisting from various levels and unbalanced hoisting is necessary. In some instances, however, they have been used for metal mine hoisting from one level, in which case some reduction has been effected in the starting peak and a little in the power consumed but probably little or nothing has been saved in the size of the motor.

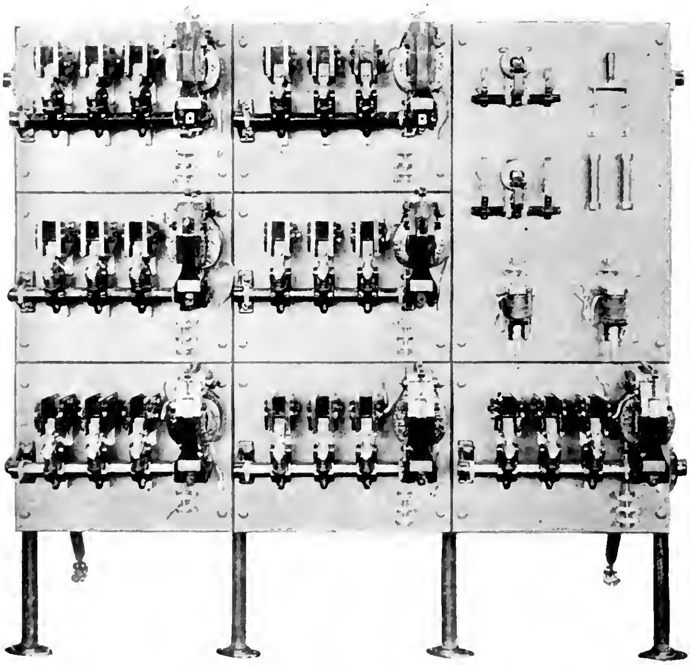


Fig. 4. Magnetically Operated Contactor Panel for Cutting In and Out Sections of Resistance

Induction Motor Hoists

The simplest and most common type of electric mine hoist is that driven by the variable-speed wound-rotor induction motor, connected to the winding drum shaft through gears. When this type of hoist is of appreciable size its control is of the magnetic type, i.e., the primary reversing switches are magnetically-operated, and the speed is controlled by cutting iron-grid resistance *in* or *out* of the secondary circuit by means of magnetically-operated switches, or the resistance is of the liquid type being varied by changing the height of a column of liquid surrounding the electrodes connected in the secondary circuit. These equipments are designed for the usual frequencies and voltages, 2200 and 440 volts being those most often used.

It has been found impracticable to use reversing switches operating under oil for hoist service where several operations per minute are often necessary, on account of the rapid carbonization of the oil and wear of the tips.

The magnetically-operated reversing switches illustrated in Fig. 3 were therefore developed; these interrupt the circuits in air. A large number of these switches have been put into operation and handle currents as high as 1000 amperes at 2200 volts with no difficulty. The operating magnets are mounted on slate bases at the lower part of the panel and transmit motion to the switches through stout impregnated wooden rods. The tips are fitted with scientifically designed arcing horns which prevent excessive burning of the tips and assist in interrupting the arc. Blow-out coils and large arc-chutes are also provided.

The forward and reverse switches are interlocked mechanically so that both cannot be *in* at the same time. In addition electric interlocks are provided which prevent the excitation of one magnet until the other is open. For the handling of low-voltage (550 volts) primary circuits, the contactors used do not require many of the refinements necessary for higher voltage circuits.

Where iron-grid resistance is used, magnetically-operated switches are used to cut *in* and *out* the various sections. Fig. 4 illustrates a panel mounting such switches. Ordinarily it is recommended that a total of eight steps be provided. Both the primary and the secondary switches are controlled through a master controller which handles only the current required to operate the magnets. Automatic acceleration is provided by means of current-limit relays which function to permit the succeeding sections of resistance to be cut *out*, only when the current has fallen to a certain predetermined minimum. In this way even though the operator should throw the master controller suddenly to the full-speed position, the hoist will automatically come up to speed in the proper number of steps thereby protecting both the apparatus and the power system. The operator is free to start as slowly as he desires as he has individual control over practically all of the accelerating switches.

The common form of master controller used for this type of hoist equipment is provided with a vertical handle, and has a segment in the *off* position for resetting a small contactor through whose contacts all of the control circuits, including the excitation for the low-voltage release of the line circuit-breaker, are wired. In case of a shut down due to the opening of the circuit-breaker, power cannot be applied to the motor again until the controller is brought to the *off* position; this allows the small contactor previously mentioned to close, thereby establishing a source of excitation for the contactors and low-voltage release.

In Fig. 5 is shown a set of speed-torque curves for an eight-point magnetic control equipment. The relays have been so set as to cut *out* the succeeding sections of resistance when the current falls to approximately full-load current. On the basis of the number of steps shown, the current would rise to approximately 150 per cent as the various sections are cut *out*. The lower figure shows the action of automatic acceleration for a typical hoist load diagram. The dead load and friction amount to about 85 per cent of what is assumed as full-load torque; and as the motor does not exert a torque higher than this until on the third step, the first three contactors close in rapid succession before the motor starts. The heavy dotted line represents the average torque required to get the hoist up to speed in the specified time. For the cycle shown, this amounts to 125 per cent which is very close to the average which the motor will develop under the control of the automatic starting equipment.

The purpose of the first three steps is to provide regulating points when it is desired to run at low speeds, as when inspecting shaft and rope, taking up slack rope, etc.

Under certain conditions it may be necessary to lift a load requiring a higher torque from the motor than that for which the relays are normally set. To take care of this a normally open push-button is used to by-pass the relays and allow those sections of the resistance to be cut out directly, which will allow the motor to develop its maximum torque.

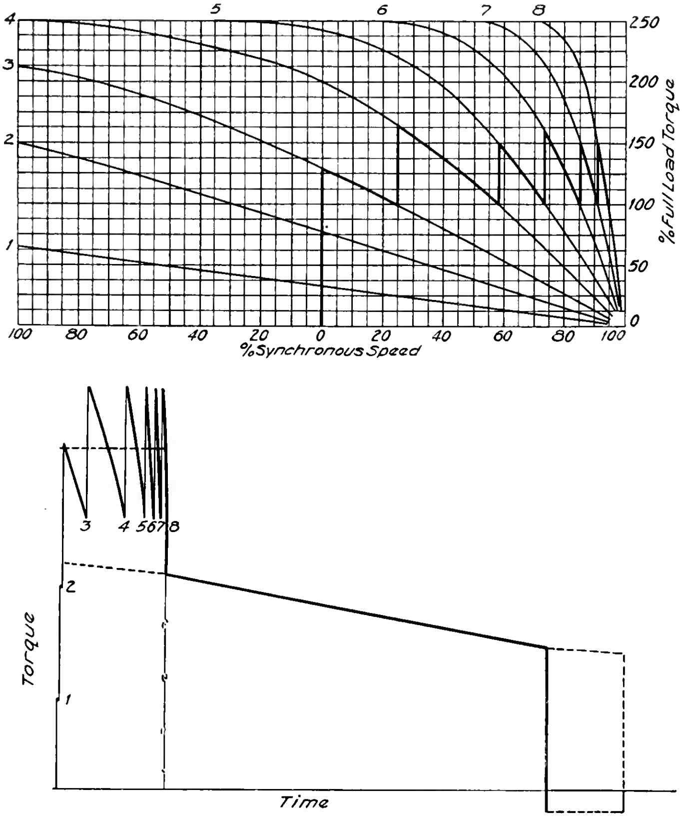


Fig. 5. Speed Torque Curves for 8-point Magnetic Control Equipment and the Action of Automatic Acceleration

In many cases it is desirable to use liquid rheostats, especially for large hoists. A very successful type is shown in Fig. 6. This rheostat embodies the time-limit element during acceleration which affords protection similar to that given by the current limit element for the type of control just described.

While the principle underlying the use of a liquid as the resistance element of a rheostat is a simple one, it has required ingenious designing to produce a rheostat that will operate successfully under the conditions met in mine hoist service. Besides providing a high resistance at the start and for low-speed running, the rheostat must have a low minimum resistance so that the hoist can be operated at full speed without excessive loss in the rotor circuit. To obtain a low value of minimum resistance, a multiplicity of plates must be used, spaced closely together. In the earlier designs, and in some still on the market, trouble results from arcing between the plates during reversal at high speed for under these conditions double standstill potential is developed between the collector rings. A design was perfected, from which a large number of rheostats have been built and put into successful operation, which has overcome all practical difficulties and which embodies all the characteristics essential to successful service. In this design two separate sections of electrodes are used, one consisting of widely spaced pipes of graduated lengths (forming the high-resistance section) and the other of a nest of closely spaced plates (forming the low-resistance section). At start only the high resistance is connected in the rotor circuit, but as the level of the liquid rises in the electrode chamber and the motor has reached a considerable speed and the secondary voltage has fallen to a low value, the low-resistance section of plates is cut into the circuit in multiple with the pipes and the acceleration of the motor is completed, so that at the maximum level of the liquid the resistance in circuit is very low. A small motor-driven centrifugal pump forces the liquid into the electrode chamber from a storage tank which is formed by the lower portion of the rheostat. The speed of the motor is controlled by means of a lever operating a weir, whose position determines the level of the liquid. To this same lever is connected a master controller which operates the primary switches that control the direction of rotation of the motor. As the weir constitutes practically one entire wall of the electrode chamber, it can be emptied practically as quickly as the lever can be brought to the *off* position.

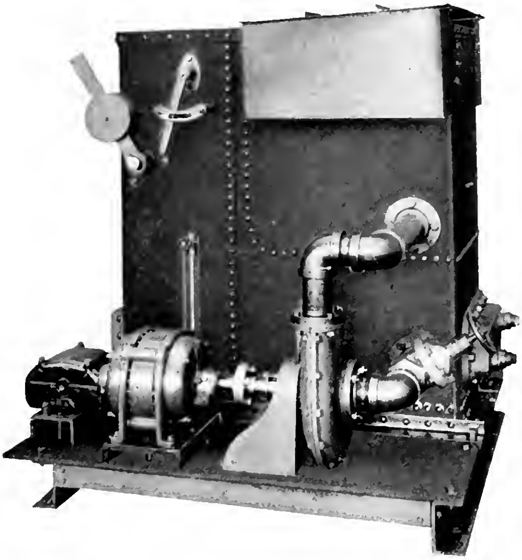


Fig. 6. Motor Operated Liquid Rheostat

An adjustable sill is provided when required to increase the height of the liquid at the start, thereby decreasing the time required to attain full speed. For normal operation, where high resistance is not required, the sill is adjusted so as to obtain the fastest acceleration; and when high resistance is wanted for low speed running, the sill is lowered. A lever located on the operator's stand controls this sill, so that adjustments are quickly and conveniently made. The liquid in the storage tank is cooled by means of a nest of coils through which cooling water is circulated.

The liquid rheostat is especially recommended for induction-motor-driven hoists of large capacity and for those where a considerable amount of partial speed operation is required, as with some slope hoists. It affords a somewhat finer degree of control than the grid resistance type since it provides an infinite number of steps.

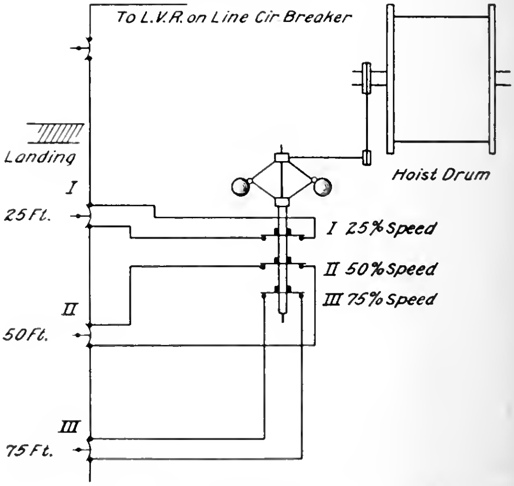


Fig. 7. Diagram of Apparatus for Protection against Overwinding

It is customary to employ an individual main line oil circuit-breaker for induction motor mine hoists. Attachments are provided which open the breaker on heavy sustained overloads, or on failure of voltage, or on the opening of the hand emergency switch.

In order to automatically set the hoist brakes in emergency cases, a solenoid is provided for each brake. The solenoid when de-energized will close the admission and open the exhaust ports of the brake engine, or if the brakes are hand-operated the solenoids will simply trip a latch which releases a weight that causes the brakes to be set. The solenoids are wired across one phase inside the main circuit-breaker so that any condition which causes the breaker to open will set the brakes.

With high-voltage equipments means are provided which prevent any chance of one primary contactor closing before the arc due to the opening of the reverse has been completely interrupted, thereby preventing any possibility of a short-circuit through the contactors.

It is obvious from upper curves of Fig. 5, a diagram showing the speed-torque characteristics of the induction motor on various resistance points, that it is not possible, irrespective of the value of the load, to automatically slow down to a certain desired speed as the landing is approached. For this reason protection against over-winding is best obtained by a system which constrains the operator to slow down properly under the penalty of a complete shut-down before the end of travel is reached. Fig. 7 illustrates in a general way the principle of such a system adapted to a single-shaft hoist. A flyball governor is geared to the hoist drum and carries several sets of contacts which are in multiple with an equal number of contacts on a geared limit switch or on switches installed in the hoist shaft guides. All of these contacts are wired in the exciting circuit of the low-voltage trip of the line oil switch. The limit switches are open circuited consecutively as the skip nears the landing and, unless each is short circuited by the corresponding contacts on the governor, the hoist is shut down. But, if the speed has been reduced to the proper value when each of the switches is reached, the contacts on the governor will short circuit the switches and no shut-down will occur. An additional limit switch is usually placed just above the landing which will also open the line circuit-breaker if the skip goes by the landing. If the hoist is shut down by this limit switch, it is necessary to provide means which will prevent starting again in the same direction. This is furnished by an arrangement of lever switches which must be manipulated in order to reëstablish the power supply and which permit the exciting of only the proper primary contactor. The usual protective devices operate on this or some similar principle.

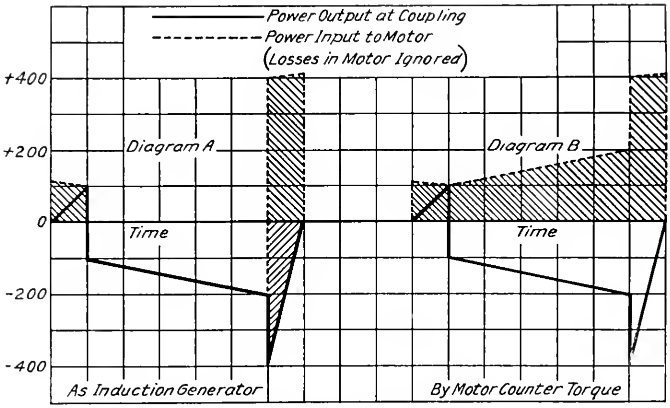


Fig. 8. Diagrams of Load Curves During Lowering by an Induction Motor Acting as a Generator and by "Plugging"

There are three ways in which loads may be lowered out of balance: viz., first, by means of the mechanical brakes; second, by means of the induction motor running as a generator at a speed slightly above synchronism; and third, by means of counter-torque from the motor.

Lowering by the mechanical brakes is objectionable on account of the great wear on the brake shoes, the necessity of providing sufficient area to prevent overheating, and the danger of failure in operation.

In the second method mentioned the motor is connected to the power supply in the direction tending to drive the hoist down or the hoist is allowed to accelerate to speed by the action of gravity alone before connecting the motor to the line, the mechanical brakes being used to prevent speeding beyond control until the motor connection is made. The hoist will then run at a speed such that the motor is driven slightly above synchronism, the energy being returned to the power system. To stop the hoist it is necessary to use the mechanical brakes or throw the motor into the first or second point of the reverse. In any event it is desirable to partially apply the mechanical brakes, for while bringing the controller from its running position to the *off* position the electrical braking effort is being gradually reduced to nothing and the hoist will speed up unless checked. This method of braking is economical but is practicable only for fairly long cycles in which sufficient time is allowed for the manipulation of the control. It is practiced with the greatest safety in the case of long slope hoists.

The third method involves reversing the motor so that it exerts a torque in opposition to that of the hoist. Although it is easier of control than the second method, it is very wasteful of energy and requires a heavy duty rheostat.

Diagram *A* of Fig. 8 illustrates the second method of lowering, i.e., with induction motor running as a generator. The energy represented by the area not shaded, i.e., while the motor is running at full speed, is returned to the line. The shaded area above time axis is taken from the power supply if the braking is done by reversing the motor, or is dissipated as heat at the brake tread if the hoist is brought to rest with the mechanical brakes.

Diagram *B* of Fig. 8 represents braking by means of the motor counter-torque or, as it is often referred to, by "plugging." The shaded area is supplied by the power supply and practically the entire energy represented by the total area of the diagram is absorbed by the rheostat in the rotor circuit.

Ward Leonard and Ilgner Ward Leonard Systems

In the Ward Leonard system of control the voltage applied to the motor, and therefore its speed, is varied by varying the field strength of a separate generator which is usually driven by an alternating-current motor. By reversing the field connections, the polarity of the generator voltage is reversed and consequently the rotation of the hoist motor, which operates always at constant field strength. The excitation for the motor and generator fields is supplied by an exciter usually direct connected to the motor-generator set.

In general, this system is used for hoists the control of which requires a high degree of accuracy and whose importance justifies the greater investment. Or, its adoption may be necessary on account of the conditions of the power supply. Since the torque required for acceleration is produced at varying voltage from practically zero to normal, the power builds up gradually during the period of acceleration instead of being thrown on the system suddenly and maintained at the maximum throughout the entire time for acceleration as is the case with the induction-motor-driven hoist. This is of considerable practical advantage in cases where the hoist load is a large percentage of the station capacity, for the generating apparatus would probably be able to maintain normal voltage on the system through its regulating devices.

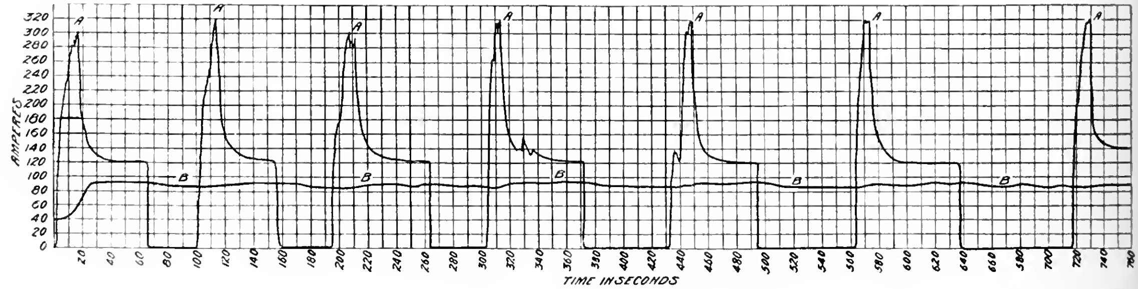


Fig. 9. Load Curves showing Effect of Flywheel Motor-generator Set on Load Curve

In cases where power is generated under such conditions as to preclude the possibility of carrying the heavy peak loads without disturbance to other apparatus operating on the system, and where power is purchased under heavy penality in the power rates for peak loads, an equalizing equipment is necessary.

The most common system used consists of a flywheel directly connected to the Ward Leonard motor-generator set and a device for automatically varying the speed through the secondary rheostatic control of the slip-ring induction motor that drives the set.

This is the so-called Ilgner Ward Leonard system. This arrangement limits the power taken from the supply circuit to a certain predetermined amount, whatever power required by the hoist in excess of this value being supplied by the energy given up by the flywheel as the wheel reduces in speed. During the periods of light power demand, the speed of the wheel is increased and energy is stored in anticipation of the next peak load.

The smoothing out action of a flywheel motor-generator set used in connection with a direct-current hoist motor is illustrated in Fig. 9. The extreme fluctuations of load to which the generator is subjected is supplied by the line as an almost uniform demand. If the cycles are fully equalized, the input to the set will be at a uniform value; and if only partially equalized, as would result from using a smaller flywheel, the power input will vary, the maximum value being somewhat greater than the uniform value for full equalization.

The curves shown in Fig. 10 illustrate the speed-torque characteristic of a shunt-wound motor operated on the Ward Leonard control system for various values of generator voltage, i.e., for various steps of the controller. There is a striking difference between this and the induction motor characteristic in that there is but a slight change in the speed over the entire load range, on any one step. It is this characteristic which makes the Ward Leonard system the superior of the induction motor system for the control of the electric hoist. Complete control of the speed from standstill to maximum is provided for all values of load from maximum positive to maximum negative, it being seldom necessary to resort to the use of the mechanical brakes. As the character of the load changes from positive to negative, the functions of the machines automatically invert, the hoist motor speeding up slightly and becoming a generator driving the generator of the set as a motor. Energy is absorbed by the set until slightly above synchronism, when energy is returned to the power supply.

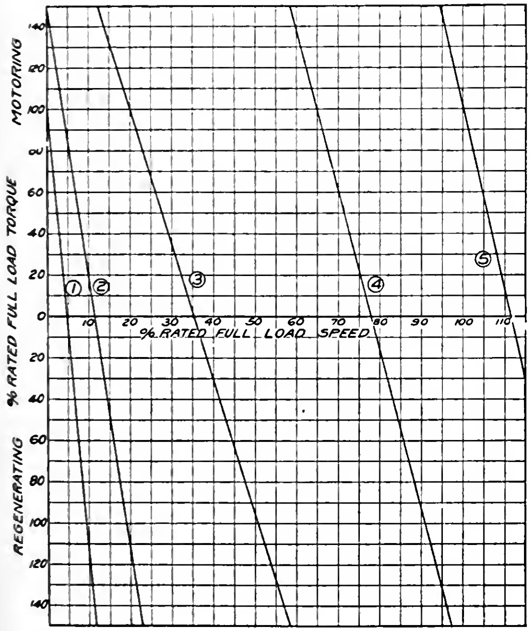


Fig. 10. Speed-torque Characteristic of Shunt-wound Motor with Ward Leonard Control

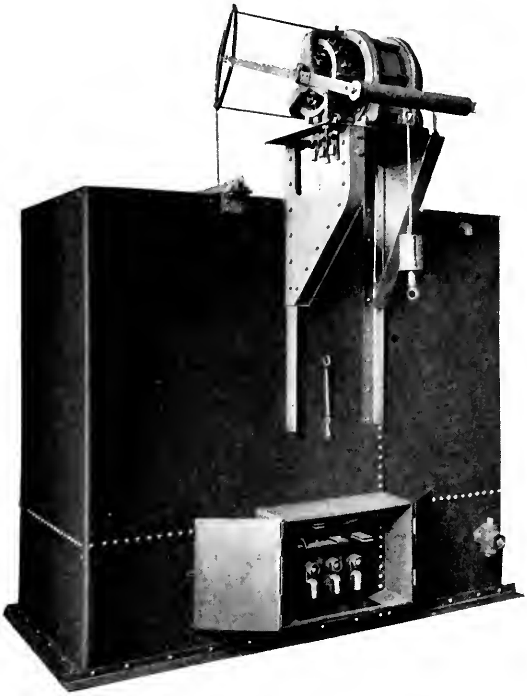


Fig. 11. Liquid Slip Regulator as Used with Ilgner Ward Leonard System

The lowering of unbalanced loads is as readily accomplished as the hoisting, and in this operation a large proportion of the energy available at the hoist motor coupling is returned to the power system. Since only the generator field circuit is manipulated in controlling the speed, the currents involved are relatively small and no difficulty is experienced in providing a large number of steps.

This type of control is ideal for the application of safety devices and it is possible to protect against almost every emergency.

The accuracy afforded by the Ward Leonard control is exemplified in the installation at the Inspiration Copper Co., Miami, Arizona, of a double automatic hoisting equipment. This consists of two double-compartment ore hoists each driven by a 580-h.p. direct-current motor, each receiving power through an individual generator driven by an induction motor having a flywheel. The ore is hoisted in 12-ton skips at a maximum speed of 750 ft. per min. from a depth of 630 ft.

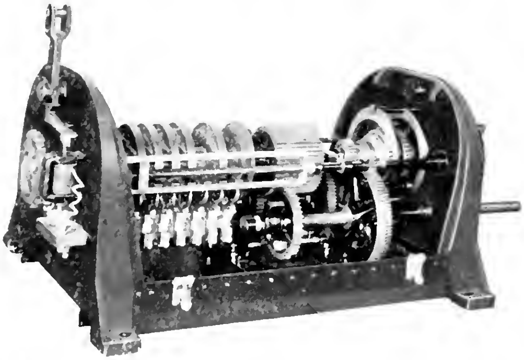


Fig. 12. Controller Used with the Ilgner Ward Leonard System

These hoists operate entirely automatically, i.e., no operator is required at the control levers. The skips are automatically loaded and started, hoisted and automatically stopped and dumped entirely without any manipulation by an operator. These hoists have been operating for the past year and a half and have been successful in every way, and have a daily output considerably in excess of that for which they were designed.

The Ward Leonard motor-generator sets which are not provided with flywheel equalization are driven either by constant-speed induction motors or synchronous motors. The choice of which to use is influenced by a number of considerations such as the relative first cost, which depends on the capacity, and the desirability of power-factor correction. In some cases the high pull-out torque required would require a synchronous motor of larger capacity than that required to meet the average duty; while an induction motor, which has inherently a high overload capacity, would not be thus handicapped. The synchronous driven set can be designed to operate at a high average power-factor and for this reason it is quite frequently used where the station capacity is already operating under a low power-factor load. In the majority of cases, however, the squirrel-cage induction motor is used on account of its high torque characteristics, simplicity, and reliability.

The Ilgner Ward Leonard system requires the use of a phase-wound rotor induction motor as the set must operate at varying speeds.

A type of liquid slip regulator used with the Ilgner Ward Leonard system is shown in Fig. 11. It is operated by a regulating motor having its primary windings either connected in series with the windings of the main induction motor or excited from a series transformer. The regulating motor operates the slip regulator by means of a lever arm having a counterweight for the purpose of adjustment. The torque of the motor varies with the line current; and when this current tends to exceed a certain predetermined value, the torque of the motor will overcome the weight of the moving parts of the slip regulator, introducing resistance into the rotor circuits of the main induction motor, thereby causing the motor to slow down and thus allow the flywheel to give up its energy. When the current tends to fall below the predetermined value, the weight of the moving parts of the slip regulator will overcome the torque of the motor and the resistance will be automatically cut *out*, the wheel absorbing energy as the set speeds up. The regulator is also used to start the set.

While differing in several details, the general scheme of control is quite similar for both the Ilgner Ward Leonard system and the Ward Leonard system without a flywheel, except of course that a slip regulator is necessary with the former.

A single-pole circuit-breaker is placed in the direct-current circuit and is adjusted to open at very high overloads and under various emergency conditions. Any condition which opens the breaker serves to set the hoist brakes.

The circuit-breaker is opened by:

(1) Heavy direct-current overloads.
(2) Loss of exciter voltage.
(3) Dangerously low motor field.
(4) Opening of speed-limit switch on set.
(5) Opening of hand emergency switch.
(6) Opening of hatchway limit switches.

The opening of the line oil switch for the system without flywheel also opens the circuit-breaker, but with the Ilgner Ward Leonard system the set is not disconnected from the hoist motor as quite often the energy in the wheel is sufficient to operate the hoist until the trip which has begun is completed, or until an intermediate landing can be made. All of the control circuits are wired through a small contactor which is reset in the *off* position of the controller, thereby protecting against starting with the controller in the running position.

A type of controller commonly used is shown in Fig. 12. It is intended to be connected to an operating lever of the engine type. To it is also connected the field rheostat. The controller cylinder carries segments for connecting the generator field reversed and reduced across the armature in the *off* position to prevent the possibility of the hoist creeping. In the *off* position a block of resistance is inserted in series with the motor field to reduce the heating and incidentally to save a portion of the standby losses.

It is also customary to incorporate in the controller mechanical devices which will limit the rate of acceleration and retardation, and which also will turn the controller gradually to the *off* position near the end of the travel.

In contrast with the induction motor hoist, the direct current hoist can thus be retarded at approximately the same rate irrespective of the value of the load. This feature is not intended to provide automatic stopping as a regular operating condition, but only in case the operator for some reason fails to stop the hoist in the regular manner.

In addition to these devices, the controller contains limit switches which deënergize the brake solenoids if the hoist over-travels the landing by any predetermined amount. It is considered unnecessary for the switches to open the direct-current circuit-breaker, for they can operate only after the controller has been turned to the *off* position and the speed is very low.

As the speed of the set varies for the Ilgner Ward Leonard system, it is necessary to supply a voltage regulator to maintain constant exciter voltage throughout the speed range of the set.

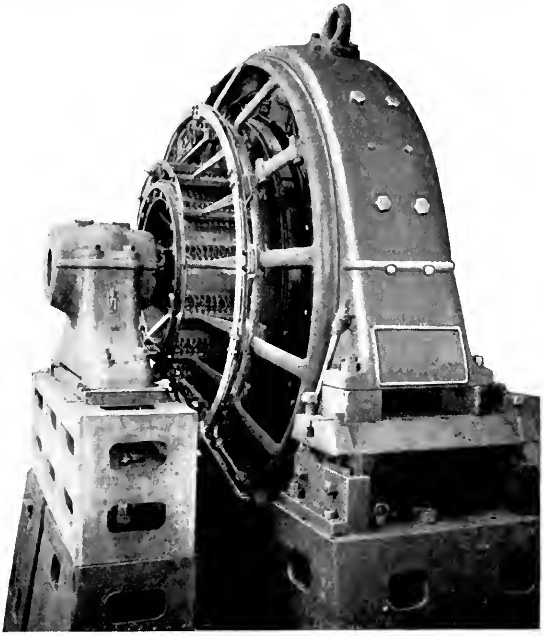


Fig. 13. 900-h.p. 71-r.p.m. Direct-current Hoist Motor for Ilgner Ward Leonard System of Hoist

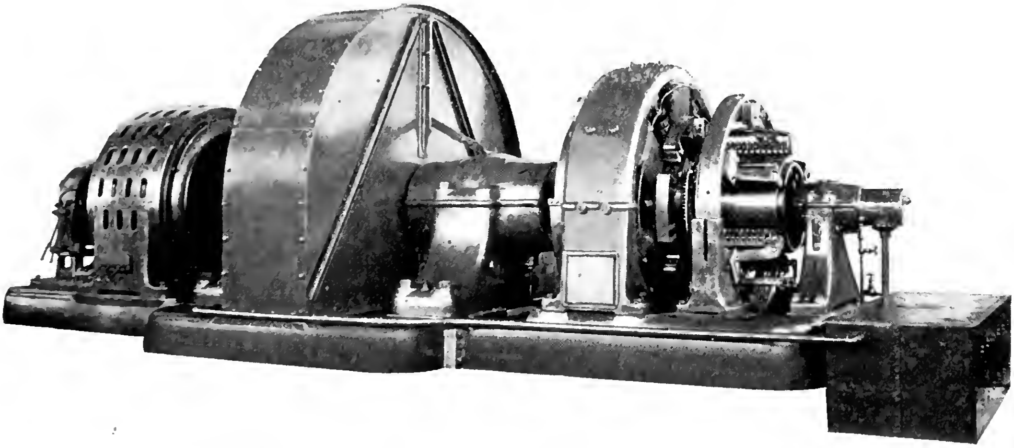


Fig. 14. Motor-generator Set of Ilgner Ward Leonard System

Fig. 13 shows a 900-h.p., 71-r.p.m., 300-volt direct-current hoist motor for direct connection to the hoist drum, and Fig. 14 the motor-generator set used for its operation.

The generator is rated 675 kw. and the induction motor 825 h.p. The set has a synchronous speed of 720 r.p.m. and operates on a 2200-volt three-phase 60-cycle system. The wheel weighs approximately 30,000 pounds, and in dropping its speed 11 per cent from full-load speed will give up approximately 19,000 h.p-seconds, which is the amount of energy required by the hoist during that part of the cycle in which the demand exceeds the limit that can be supplied directly by the supply system.

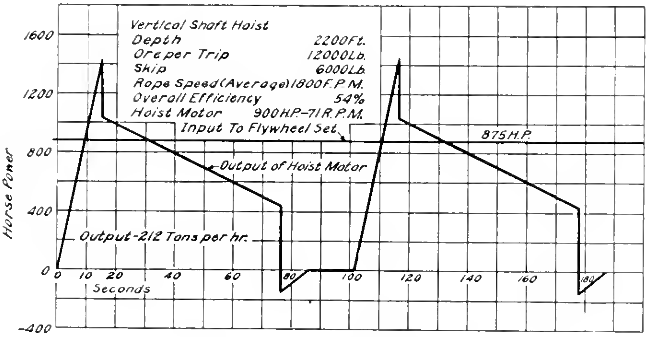


Fig. 15. Normal Duty Cycle of Motor and Motor-generator Set shown in Figs. 13 and 14

The normal duty cycle on which this equipment was required to operate is shown in Fig. 15. This is the case of a deep metal mine and a fairly long cycle.

The peak load on the hoist motor is about 1435 h.p. while the demand from the power supply is limited to about 875 h.p. If an induction motor had been used, gears would have been necessary and the peak load drawn from the line would have been approximately 1900 h.p. In this particular case the mining company generated its own power and the equalization of the load cycles was necessary. The actual power consumed per trip in accordance with this duty cycle is about 10 or 12 per cent more than by an induction motor driving the hoist, but this is a small matter compared with the great advantages gained by this type of control. If the company had been purchasing power, the increased power consumption would have been more than offset by the reduction in reservation charges.

The advantage gained by the use of the Ilgner Ward Leonard system is even more strikingly shown in Fig. 16 which is the case of a coal mine hoist. The hoist motor is rated 1400 h.p. at 90 r.p.m. The et consists of a 1000-kw. generator,s a 600-h.p., 720-r.p.m. induction motor and a direct coupled 30,000-lb. steel plate flywheel. The peak load on the hoist motor has a momentary value of 1800 h.p., while the demand from the supply system is limited to a uniform value of about 600 h.p. In this case the demand from the wheel is only about 7000 h.p.-seconds which is given up by a 10 per cent reduction in the speed of the set. If an induction motor had been used to drive the hoist, gears would have been necessary, the peak demand from the line would have been approximately 2600 h.p., and the power consumed per trip would have been from 80 to 100 per cent greater. In general the greatest advantage can be expected in cases where the lift is short, the load heavy, and the rope speed very high as in this case.

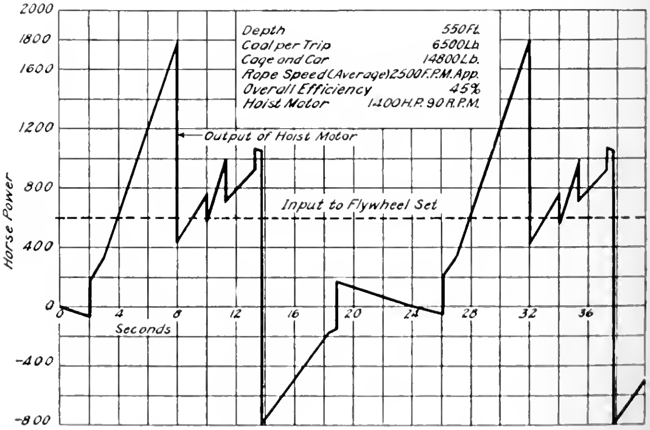


Fig. 16. Duty Cycle of 1400-h.p. 90-r.p.m. Motor Operating on Ilgner Ward Leonard System with Motor-generator Set Consisting of 1000-kw. Generator and 600-h.p. Induction Motor Coupled to 30,000-lb. Flywheel

TENDENCIES OF MOTOR APPLICATION

By W. L. Merrill

Power and Mining Engineering Department, General Electric Company

This article first reviews the development of the methods of applying electric motors to industrial drive. The progress that has been made is traced from the time when the motor was installed to replace the factory steam engine to the present time when motors are used for semi-group, group, and individual drives. The body of the article is confined to a discussion of the last type; and a strong plea is made for the extended adoption of designs in which the motor is incorporated as an *integral* part of the machine it drives.—Editor.

W. L. Merrill

THE first commercial use of electricity was in the field of lighting, next came railroading, while its use for industrial power purposes has been a more recent development. The engineering talent in the early stages of the art was devoted almost exclusively to the first two methods of utilization. Gradually, however, some of the advantages of motor drive were realized, but usually these were under very special conditions.

Some of the first installations made were replacements of steam engines by electric motors; and, in some cases, the engine was left intact so that if trouble developed with the new system of drive the original method could be resorted to. With the first installations of electric drive there became available a method of more conveniently measuring power than had been possible heretofore. The power measurements of these original motor installations were made in order to arrive at the amount of the monthly bill. Naturally, when the bill had to be paid in cash each month, the operators sought ways and means to reduce this charge. With the old methods of steam drive the charge was not segregated, the power being so interwoven with the general factory charges that very little was known of the actual cost of power as delivered at the active part of the operations. It was soon realized, however, that a large percentage of power was wasted in its transmission from the motor to the point of ultimate operation in belts and counter-shafting.

The next step in the application of motors was to divide mills or shops into several groups, which might be termed semi-group drive. This eliminated some of the heavy

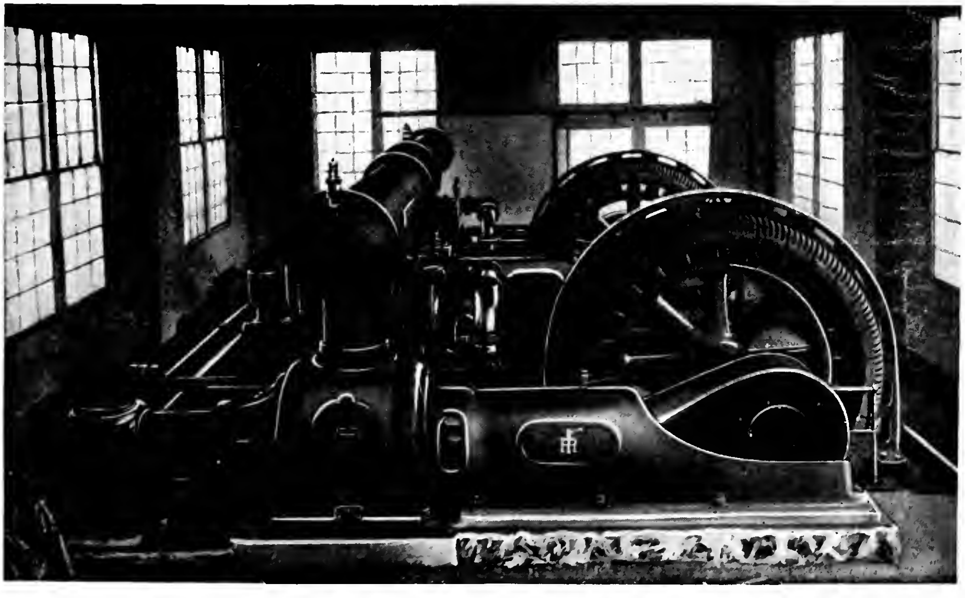


Fig. 1. Motor Built-in Applied to Air Compressor

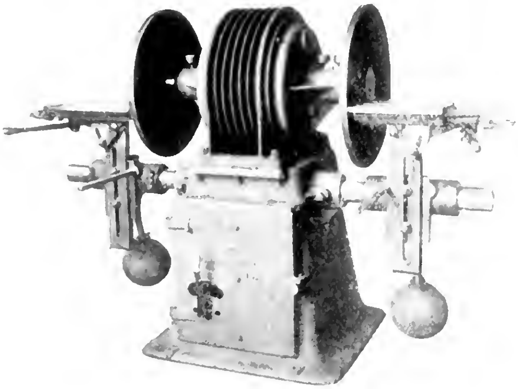


Fig. 2. Motor Built-in. Double Disk Grinder

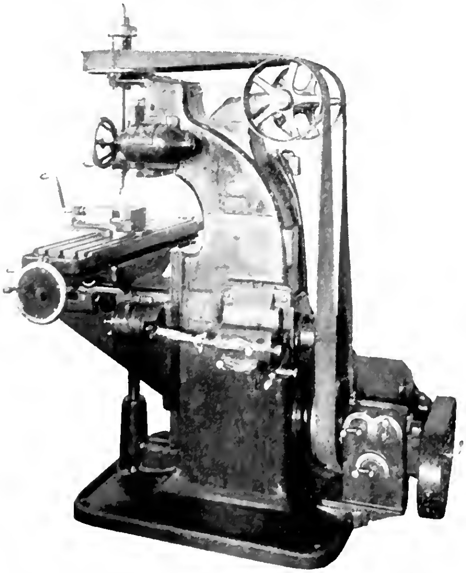


Fig. 3. Individual Drive. Vertical Miller. Why not a vertical motor built-in?

belting and shafting maintenance; and from a review of the conditions at that time, it seemed that the ultimate economies had been reached.

Later, however, tests and data indicated that in a great many industries it was advantageous to still further divide the units of drive, and there resulted what is known as group drive. This consisted of driving with one motor a group of machines that work the same hours on the same product. It was felt under these conditions that no further economies could be obtained.

We are all familiar with the old installation of a motor belted to a centrifugal pump; in many cases the speeds of both were approximately the same. It was only a step to direct connect the motor to the pump on the same base. This is now the almost universal practice.

We are also familiar with the motor application to coffee grinders and meat choppers. First, we had the motor under the grocer's counter belted to the grinder or chopper, as the case might be. Later, provisions were made on the machines to take various makes of standard motors geared directly to the machine. Now, the familiar combination is that of the motor and grinder or chopper built as an integral whole. This arrangement eliminates the bearings which heretofore had

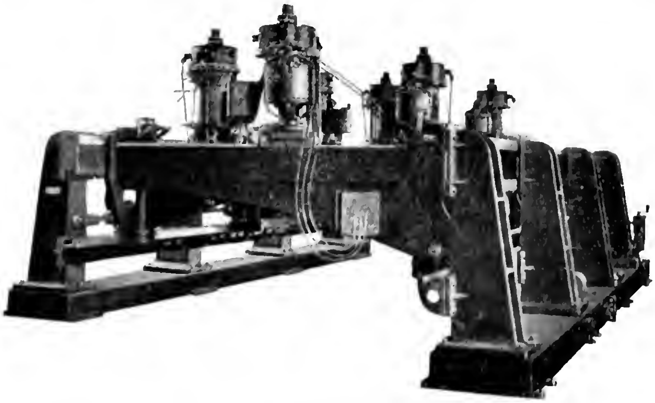


Fig. 4. Boiler Plate Drilling Machine. Note motors direct geared to drills

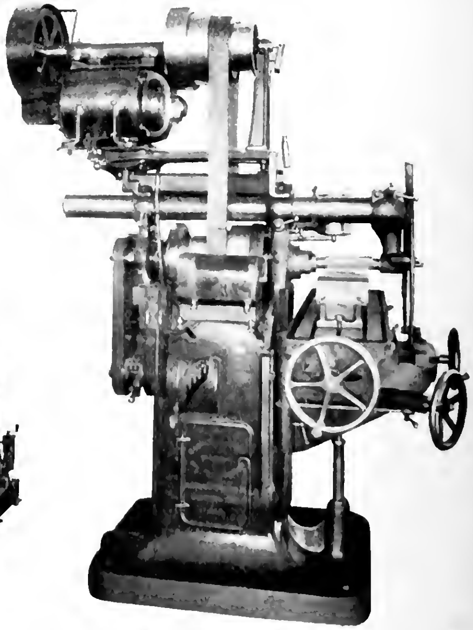


Fig. 5. Individual drive. Note extra framework, countershafting and bearings. Why not a motor built-in?

been furnished by each manufacturer, as well as the practice of using the motor as a mount for the remainder of the machinery, thereby producing an efficient unit with the least amount of mechanical complications and, hence, the least cost to the ultimate consumer.

In a number of industries this last method is quite in evidence; although there is such a demand for belt-driven apparatus that the manufacturers of machinery are somewhat at a loss to know just to what extent to produce machinery having the motor built as an integral part, making it necessary to duplicate some of their lines. Consequently, one of the common practices is to supply machinery with the necessary trains of gears with provision made at the power receiving end to take either motor or pulley drive. Under these conditions, when the machine is sold as a motor-driven machine the customer has to purchase the extra gearing and mechanical equipments and also pay the price of a standard motor with its own bearings; sometimes a base in addition. It would appear at first thought that this is a most economical way of supplying the trade. It allows the machinery manufacturer to concentrate on a particular model. It allows the electrical manufacturer to build standard types of motors any of which can be applied to the machine, thereby usually giving the customer a choice.

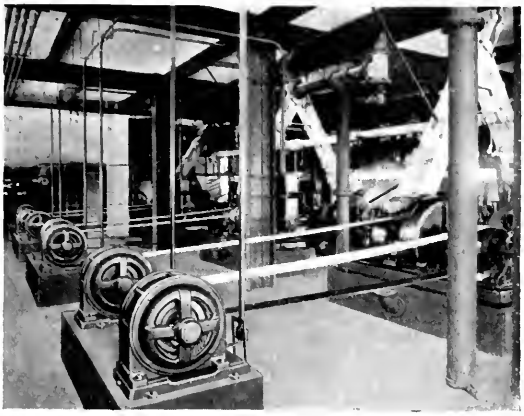


Fig. 6. Individual Drive Attrition Mills. Note floor space necessary

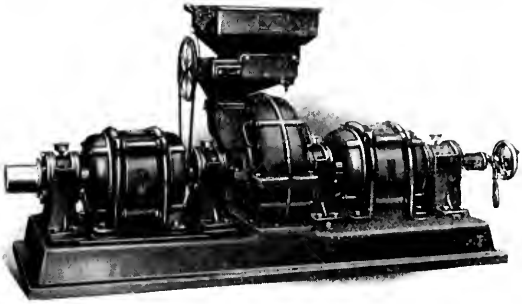


Fig. 7. Attrition Mill with Motors Built-in

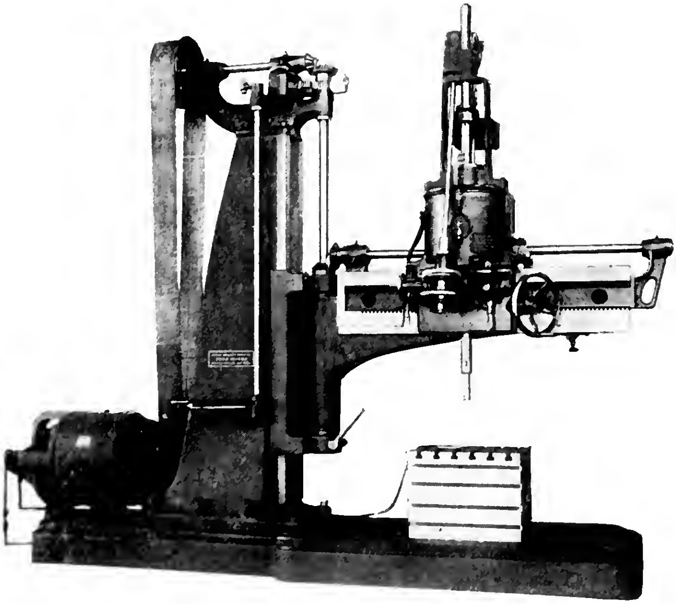


Fig. 8. Individual Drive, Radial Drill. Note amount of gearing and belting necessary to drive drill

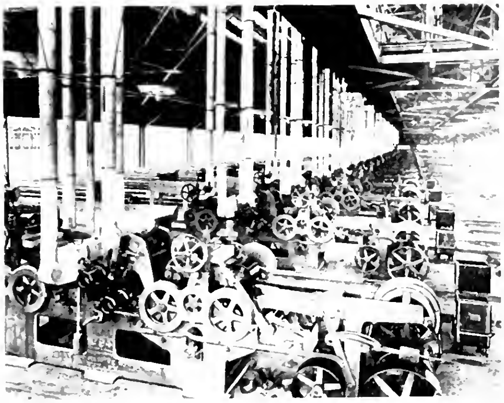


Fig. 9. Individual Drive. Planing Machines

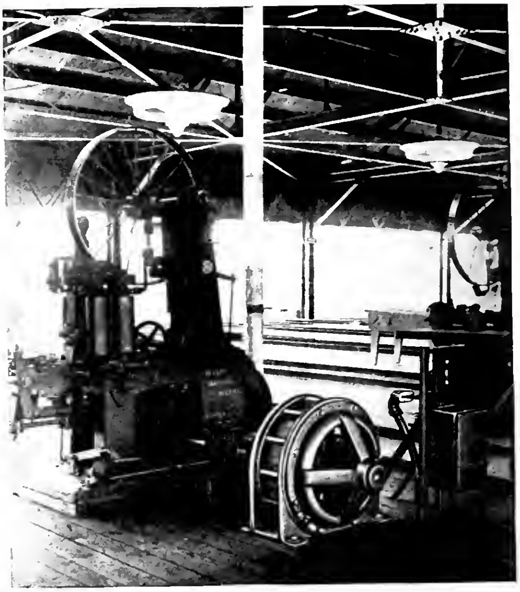


Fig. 11. Individual Drive for Band Saw. Note extra bearings and floor space necessary for this type of drive

We are gradually coming, however, in the tremendous use of tools and machinery in this country, to realize that there are many types of machines which are built in such quantities that both the electrical and the machinery manufacturers can afford to combine their designs and offer a self-contained unit, eliminating all unnecessary parts which have heretofore been common to both. Examples of these are: the attrition mill, emery wheel, sugar centrifugal, and various types of metal and woodworking machinery.

The electrical manufacturers have in many cases in the past been reluctant to take up the

Fig. 10. Motor Built in Sugar Centrifugals. Individual Drive for sugar centrifugals is usually accomplished by horizontal motor and quarter turn belt for each centrifugal

Fig. 12. Individual Drive. Note floor space and extra mechanical parts

manufacture of special types of motors or to manufacture incomplete motors to be built into machinery. It appeared that it would eventually become necessary to build such a varied line of motors that production could not be as concentrated as by building standard complete motors of various ratings and stocking them for anyone's needs. Experience has shown, however, that the opposite is true, for when a so-called special motor is successfully built as an integral part of a machine, assuming that there is a substantial demand for this combination, this type becomes the standard and a very desirable line of manufacture.

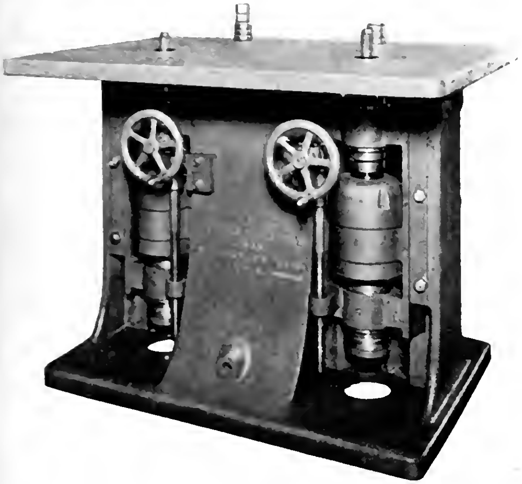


Fig. 13. Double Spindle Shaper with Motor Built-in

Fig. 14. Motor Suitable for Band Saw Drive, Mounting Lower Wheel Directly on the Shaft

The purpose of this article is to focus the attention of manufacturers and machinery purchasers on the many advantages gained in the use and manufacture of this type of machinery. It seems needless to call attention to the fact that—in our modern plants where we are striving for the maximum output for a given floor space, the maximum overall efficiency of tools and machinery, and the minimum number of parts and minimum maintenance—this "motor built-in" combination offers very distinct advantages over the so-called "individual drive," which usually consists of belting, gearing, or direct connecting a standard motor to a standard machine. The present tendency is shown by the number of new types of combination of machines with "motors built-in" that are put on the market each year. It seems that the time is not far distant when manufacturers of many types of machines will have to abandon the practice of offering to the trade practically the same machine for a belt, gear, or motor drive, and adopt the "motor built-in" design as the ultimate electric drive.

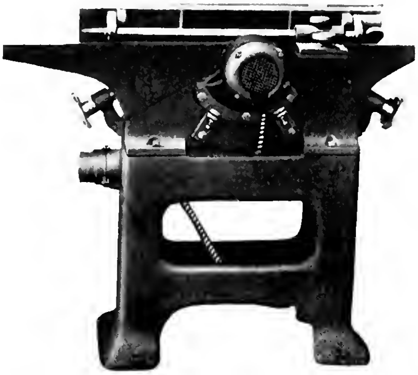


Fig. 15. Motor Built-in. Wood Surfacer

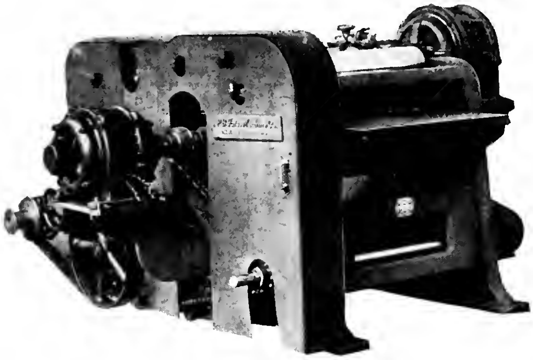


Fig. 16. Motors Built-in. Planer Machines

ELECTRIC SHOVELS

By H. W. Rogers

Power and Mining Engineering Department, General Electric Company

It is not the purpose of this article to justify the use of the electric shovel or to draw any comparison between it and the steam shovel, as those phases of the situation have been analyzed in a previous article*, but rather to treat the electrical situation fairly and to bring out such characteristics as have a marked bearing on the selection of the type of motor to accomplish the desired results.—Editor.

H. W. Rogers

BOTH direct-current motors and alternating-current motors are suitable for driving electric shovels. The former class may be subdivided into the shunt motor, the compound motor, and the series motor; but for reasons which will become evident, this discussion will be confined to the series motor only. In the latter class there is only one type of motor which may be considered at the present time, the slip-ring polyphase induction motor.

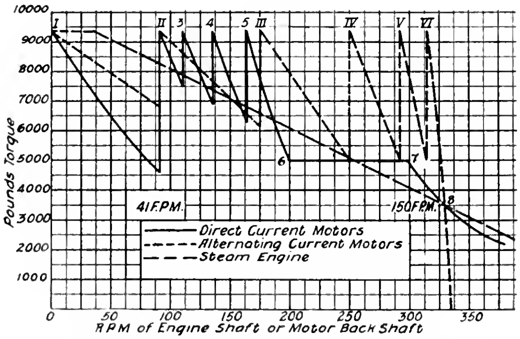


Fig. 1. Speed-torque Curves for Direct-current and Alternating-current Motors and Steam Engine without Governor

	D-C. Motor	A-C. Motor
Horse power (continuous)	70	120
Horse power (intermittent)	87 (60 min. 75 deg.)	150 (30 min. 55 deg.)
Speed in r.p.m.	535	514
Volts	550	550
Gear ratio	2.61	1.53
WR²	222	735

There is therefore a question as to which of the two motors should be used; and since they do not possess the same characteristics, they cannot be equally adaptable, although both types may be used to obtain satisfactory operation comparable with steam equipment.

For the discussion it will first be necessary to revert to the steam shovel and to analyze the characteristics of the steam engine ordinarily used for this class of service, which is usually operated at three-quarter or full cut-off and has no means of governing other than by hand throttling. In other words, it has no automatic governor and under such conditions will speed up or slow down when the load is increased or decreased.

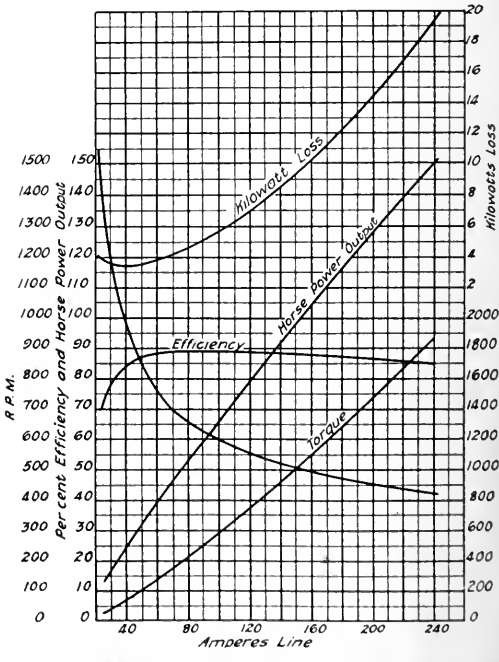


Fig. 2. Characteristic Curves of one of two like Direct-current Motors upon which the full-line curve of Fig. 1 is based

The curve shown in Fig. 1 by the broken line is representative of the speed-torque characteristic on such an engine with wide open throttle. The decrease in torque as the speed increases is a natural tendency that is probably accentuated by a throttling effect in the valves and piping and a reduction in

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* See "The Application of Electric Motors to Shovels," H. W. Rogers, G.E. Review, June, 1914, page 680.

steam pressure due to the increased demand, thus producing a straight-line curve.

The full-line curve and the dotted-line curve, Fig. 1, show the speed-torque characteristics of the direct-current series motor and the alternating-current slip-ring motor respectively, both types being selected to give the same speed under maximum digging conditions and also under light load conditions. In each case the control points have been laid out to follow the engine curve as closely as possible, but even under the best conditions the alternating-current motor does not approach this curve very closely for the motor is inherently capable of delivering considerably more power than is desirable at the high speeds.

	D-C. Motor	A-C. Motor
Horse power (continuous)	70	120
Horse power (intermittent)	87 (60 min. 75°)	150 (30 min. 55°)
Speed in r.p.m.	535	514
Volts	550	550
Gear ratio	2.61	1.53
WR²	222	735

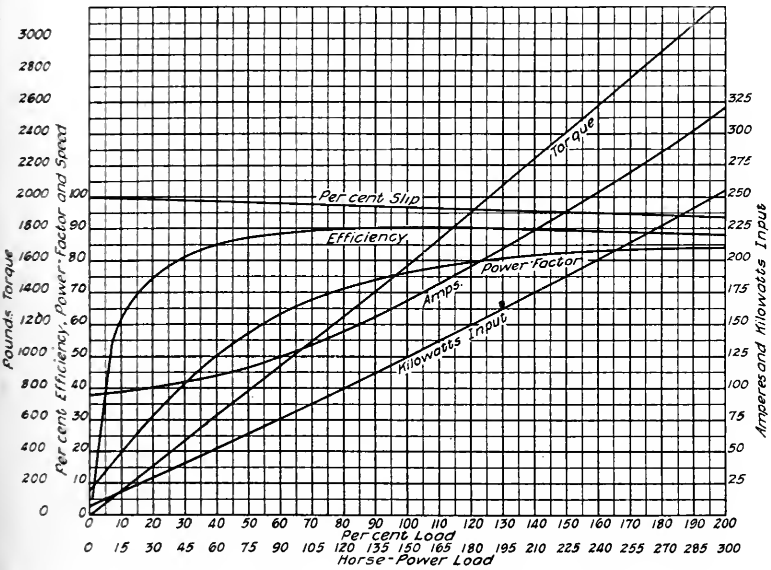

Fig. 3. Characteristic Curves of one of two like Alternating-current Motors upon which the dotted-line curve of Fig. 1 is based

In each case two motors have been used to meet the steam engine conditions, these motors being geared to the same drum and operating in parallel. The characteristics of the direct-current motors are given in Fig. 2 and those of the alternating-current motors in Fig. 3. The first control point on either the direct-current or the alternating-current motors will give maximum bail pull at zero speed while the second point will give 90 r.p.m. at maximum bail pull by either type of motor. The full dipper speed of either motor is 330 r.p.m. which corresponds to approximately 150 feet per minute.

The speed at which either type of motor operates depends upon the setting of the current-limit relays; but assuming that these are not used, the maximum speed at which the direct-current motors can operate when delivering maximum torque is 163 r.p.m., while the alternating-current motors can operate at 315 r.p.m. While this is a condition which does not exist, since the current-limit relays prevent operation at the higher speeds under heavy loads, it serves to indicate the excess of motor capacity one is forced to accept in selecting an alternating-current motor.

As indicated in Fig. 1, the direct-current motors will produce the curve *I*, *II*, *3*, *4*, *5*, *6*, *7*, *8*, the resistance being entirely cut out of the circuit at the point *5* and the speed being increased from *6* to *7* by field weakening. The alternating-current motors will produce the curve *I*, *II*, *III*, *IV*, *V*, *VI*, *8*, with rheostatic losses at all speeds except the synchronous speed.

It must be granted that the engine characteristics shown in Fig. 1 are not only satisfactory but desirable, on account of the severe digging conditions, in order to relieve excessive strains when striking obstructions suddenly. This characteristic which is inherent in the direct-current series motor permits the use of a smaller capacity than is possible when using slip-ring induction motors. It is, of course, possible to approach the engine curve very closely with an induction motor by using a permanent secondary resistance, but the maximum torque would have to be available at stand-still and the synchronous speed would necessarily be considerably in excess of that shown on the curve which would result in a much larger motor than is used in the comparison.

The gear ratios used on both the direct-current and alternating-current motors are such that 177 per cent of the normal current will give the maximum required torque at the back shaft.

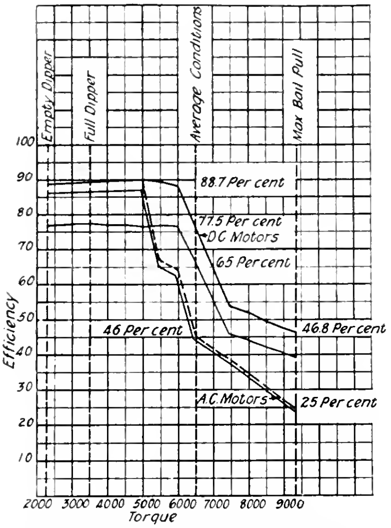

Fig. 4. Overall Efficiency Curves of Direct-current and Alternating-current Motors operating under the Torque Conditions shown in Fig. 1

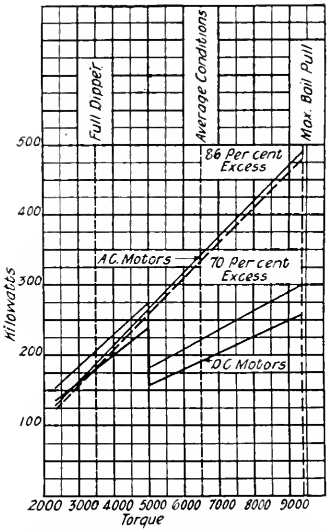

Fig. 5. Kw. Input Curves of Direct-current and Alternating-current Motors Operating under Conditions similar to those in Fig. 4

Fig. 4 represents the overall efficiency of the direct-current and alternating-current motors operating under the various torque conditions shown in Fig. 1 and illustrates the values given in Table I. Under maximum torque conditions the efficiency of the alternating-current motors is only 25 per cent as against 46.8 per cent for the direct-current motors. Under average conditions the efficiencies are 46 per cent and 77.5 per cent respectively; while under full-dipper maximum-speed conditions the efficiencies are practically the same. It should be noted, however, that at 6000 pounds torque the direct-current motors are operating at 88.7 per cent efficiency without rheostatic loss, while the alternating-current motors are operating at only 65 per cent efficiency with a rheostatic loss. The maximum light-load speed of the alternating-current motor is 332 r.p.m. as against 372 r.p.m. for the direct-current motors.

Fig. 5 shows curves, plotted from Table I, of the comparative kilowatt input to the direct-current and alternating-current motors under conditions similar to those in Fig. 4. Attention is called to the fact that the only time during the whole cycle when the power consumption is the same on both the direct-current and alternating-current motors is at the maximum speed which occurs only after the actual digging is completed.

With maximum bail pull the kilowatt input is 86 per cent more on the alternating-current motors than on the direct-current motors; while under average conditions, i.e., 6500 pounds torque, the kilowatt input is 70 per cent more on the alternating-current motors than on the direct-current motors.

As a further comparison between the two types of motors consideration will be given to a duty cycle for the hoisting motors of 7 feet actual digging and 7 feet hoisting at full speed with a full dipper after the digging is completed. The hoisting at full speed will be the same under all conditions but the actual digging will vary in time, torque, and speed according to the conditions, consequently it has been necessary to consider various torques during the actual digging in order to cover all possible variations in the cycle of operation. Fig. 6 represents the kilowatt-hour consumption of the direct-current and alternating-current motors when operating on the above cycle, the kilowatt-hours given being the summation of the digging and running light consumption as indicated in Table II. With both types of motor, the useful energy is represented by the shaded portion to the left of *ABCD*. The rheostatic loss with the direct-current motors is represented by the shaded portion *ABE* while the rheostatic loss with the alternating-current motors is represented by the shaded portion *ACF*.

The actual torque required during the assumed cycle may vary between 9400 pounds and 3500 pounds depending on the conditions but the motors will operate from 67 to 78 per cent of the operating time on rheostatic control between 6500 pounds and 9400 pounds. Consequently, the power consumption will be from 47 to 72 per cent more for the alternating-current motors than for the direct-current motors and this excess of power consumption is all rheostatic loss.

TABLE I

BACK-SHAFT	MOTOR		OUTPUT		INPUT	EFFICIENCY
Torque	Torque	Speed	H.P.	Kw.	Kw.	Per Cent
DIRECT-CURRENT MOTORS						
Two Motors in Multiple						
9400	3600	235	161.2	120.4	257.4	46.8
9000	3450	245	161.0	120.2	250	48
8500	3260	258	160.2	119.6	238.6	50.1
8000	3060	274	159.8	119.2	227.4	52.5
7500	2870	285	156.0	116.4	215.4	54.1
7000	2680	350	178.6	133.4	204.4	65.2
6500	2490	423	200.6	149.6	193.0	77.5
6000	2300	493	216.0	161.2	181.6	88.7
5500	2100	507	203.0	151.6	169.4	89.5
		522	191	142.6	158.4	
5000	1920	783	286	214	238	90
4500	1724	803	264	196.6	219.2	89.7
4000	1520	828	242	180	201.0	89.6
3500	1340	856	218	163	181.4	89.6
ALTERNATING-CURRENT MOTORS						
Two Motors in Multiple						
9400	6140	138	161.4	120.6	480.0	25
9000	5880	153	171.4	128.0	460 0	27.8
8500	5560	173	183.2	136.8	434.0	31.5
8000	5240	194	192.6	144.4	406.0	35.5
7500	4900	214	200.0	148.0	380.0	39.2
7000	4580	233	203.0	151.8	356.0	42.5
6500	4240	252	203.4	152.0	330.0	46
6000	3920	356	266.0	198.6	306.0	65
5500	3600	370	254.0	189.4	282.0	67.2
5000	3260	500	310.0	231.4	256.0	90.2
4500	2940	502	280.0	209.6	232.0	90.2
4000	2620	503	250.0	186.4	208.0	89.7
3500	2290	503	220.0	164.0	184.0	89

TABLE II

Torque	SPEED*		TIME				KILOWATT-SECONDS CONSUMPTION					
			Digging		Light Load		Digging		Light Load		Total	
	D-C.	A-C.	D-C.	A-C.	D-C.	A-C.	D-C.	A-C.	D-C.	A-C.	D-C.	A-C.
9400	41	41	10.25	10.25	2.8	2.8	2640	4920	512	515	3152	5435
9000	42.6	45.4	9.9	9.25	2.8	2.8	2475	4250	512	515	2987	4765
8500	45	51.3	9.3	8.19	2.8	2.8	2220	3555	512	515	2732	4070
8000	47.7	57.5	8.8	7.3	2.8	2.8	2000	2970	512	515	2512	3485
7500	49.5	63.5	8.5	6.62	2.8	2.8	1830	2520	512	515	2342	3035
7000	61	69	6.9	6.1	2.8	2.8	1410	2175	512	515	1922	2690
6500	73.5	74.7	5.7	5.62	2.8	2.8	1100	1855	512	515	1612	2370
6000	85.7	106	4.9	3.96	2.8	2.8	890	1215	512	515	1402	1730
5500	88.2	110	4.75	3.82	2.8	2.8	805	1078	512	515	1317	1593
5000	136	148	3.1	2.84	2.8	2.8	738	727	512	515	1250	1242
4500	140	149	3.0	2.82	2.8	2.8	657	655	512	515	1169	1170
4000	144	150	2.92	2 8	2.8	2.8	587	582	512	515	1099	1097
3500	150	150	2.8	2.8	2.8	2.8	512	515	512	515	1024	1030

* Speed is given in feet per minute at the dipper.

The foregoing comparisons are based on a direct-current 550-volt equipment without a motor generator set and on an alternating-current 550-volt equipment without transformers. Although such an arrangement is possible in a large number of cases where either direct-current or low-voltage alternating-current is available, the greater demand will undoubtedly be for shovels that must operate from a high-voltage alternating-current supply which necessitates the use of an induction motor-generator set with the direct-current equipment or transformers with the alternating-current equipment.

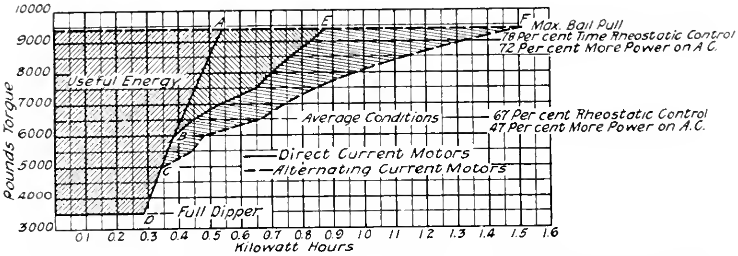

Fig. 6. Comparative Power Consumption of Direct-current and Alternating-current Motors Operating on a Cycle based on 7-ft. digging under various loads and 7-ft. hoisting with full dipper at high speed

Fig. 7 represents the comparative overall efficiency and power-factor of the direct-current and alternating-current equipments, the former including an induction motor-generator set of 150 kw. 575 volts direct-current and the latter transformers of 375 kv-a. Here the power-factor of the direct-current equipment is considerably better than that of the alternating-current equipment under all load conditions, and the overall efficiency is higher under all loads above 5200 pounds torque and lower under loads varying between 3500 pounds torque (full-dipper) and 5200 pounds torque. It must be remembered, however, that the average torque conditions are 6500 pounds and at this load the efficiencies are 68 per cent for the direct-current and 45 per cent for the alternating-current equipment, also that the hoist motors are operating from 67 per cent to 78 per cent of their operating time at loads between 6500 pounds torque and 9400 pounds torque and only a small percentage of their time on the lighter loads. The kilowatt input under such conditions is shown by the light full lines in Fig. 5, the power consumption on loads below 5000 pounds torque being slightly more on the direct-current equipment than on the alternating-current equipment; while for loads above this value the power consumption on the alternating-current equipment is very much in excess of that on the direct-current equipment.

Where a single isolated shovel is concerned, it would be necessary to use either the direct-current equipment with a motor-generator set or the alternating-current equipment with the transformers where only high-voltage alternating-current is available; but where a number of shovels are operating within a short radius, a considerable saving in both power and initial cost can be effected by using direct-current shovels and operating them from a single motor-generator set because direct-current power may be readily transmitted on a three-wire system at 600/1200 volts with the neutral grounded; while it would not be practical to transmit low-voltage alternating current on account of the heavy current resulting from the larger capacity in induction motors.

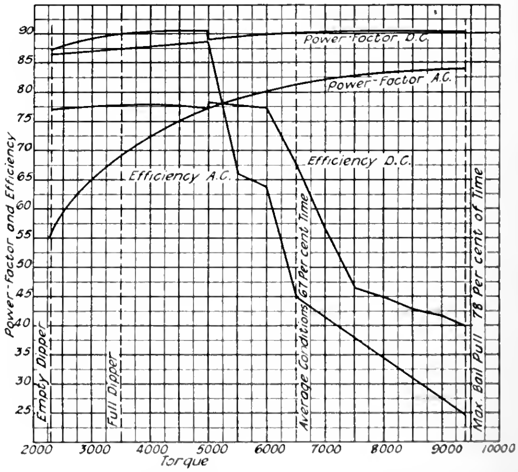

Fig. 7. Overall Efficiency and Power-factor Curves of the Direct-current Equipment with Motor-generator set and of Alternating-current Equipment with Transformers

Electric Stripping Shovel, Piney Fork Coal Company, Smithfield, Ohio

MINE PUMPS

By Fred J. Schwarz

Power and Mining Engineering Department, General Electric Company

An indication of the quantity of water that must be removed from mines is afforded by the estimate that from fifteen to twenty tons of water is lifted to the surface for every ton of coal delivered. Several different methods are employed for getting rid of this water, namely, tunnel and drainage, syphons, air lifts, water hoists, and pumps. The author reviews the mine conditions that can best be served by each of these methods. Pumps find the greatest number of applications and a more extended discussion of their characteristics is given. Some of the more interesting installations are discussed.—Editor.

Fred J. Schwarz

MINE pumping in its broadest sense, involving all methods for the removal of water from a mine, affodrs one of the most important problems in mine development and mine economies.

The quantity of water found in mines varies over wide limits depending on their location and the climatic, geologic and surface conditions of the surrounding country. The quantity of water that may be encountered and its great variation between various mines plays a very important part in the cost of production of the coal or ore. It has been estimated that in the coal mines of the United States an average of 15 to 20 tons of water are lifted to the surface per ton of coal, and in some instances may even exceed 35 tons. A better appreciation of this volume of water may be obtained when it is considered that a ton of water is equivalent to 240 gallons; hence an average of 3600 to 4800 gallons of water are lifted per ton of coal. It has been estimated that, in the anthracite field, 1,000,000 gallons of water are pumped to the surface per minute.

The sources of water in a mine can be determined only after a careful study of the topography and structural geology of the surrounding district, as well as the prevailing climatic conditions, and the natural drainage, both surface and underground. The quantity depends on the nature and structure of the rock between the surface and workings, the extent to which the workings tap water-bearing strata, and the amount of water in the overlying strata. The amount of water in the overlying strata is dependent on the extent of the rainfall and relative amounts which are carried off by natural drainage and streams, and the amount which seeps into the surface. In some mining districts great underground rivers have been tapped during the mining operations, which have caused serious flooding of the mine workings.

The characteristics and contents of mine water depend on the composition of the strata through which it has passed before entering the workings. There are a large number of mines where the water contains large quantities of acid which cause rapid corrosion of the ordinary machinery used for the removal of the water. In such cases apparatus especially constructed to resist acid or special means for lifting the water are required. Where considerable blasting is done in the vicinity of the water, it will often contain particles of grit held in suspension. This grit must be removed by settling or special provision made in the pumping machines to minimize the wear which is caused by it.

The temperature of the water ordinarily found in mines is rather low, generally about 60 deg. F. However, there are some mines where the temperature of the water is quite high, notably the C & C shaft at Virginia City, Nevada, where the temperature of the water reaches 165 to 175 deg. F.

The methods employed for removing water from a mine can be divided into the following five classes:

1. Tunnels and drainage.
2. Siphons.
3. Air lifts.
4. Water hoists.
5. Pumps.

The first of these methods is so simple and well understood that no further mention need be made in regard to it. One of the more notable of these tunnels is the four-mile drainage and transportation tunnel of the Yak Mining, Milling and Tunnel Co. which drains a large territory in the Leadville, Colorado, district and has a flow of approximately 1200 gallons per minute. At several places along this tunnel, where the workings extend below it, the water is pumped into the main channel.

Siphons are but little used except where the water has to be carried some distance at a small incline, and can often be used to advantage where, on account of faults, it is necessary to make a dip in the workings.

Air lifts are used to advantage where water is encountered at a long distance from the main shaft or pump, and where it is possible to sink a bore hole to the water. In such a case the air lift would be much more efficient than pumping the water through long pipe lines with their high friction losses.

The advantages of the air lift is its simplicity, there being no moving parts; the ease and cheapness of installation; its ability to handle acid, gritty and foul water; and its high rate of discharge. The principal disadvantage of the air lift is the necessity of having a sump or bore hole of sufficient depth to give the proper submergence, which varies from 30 to 70 per cent of the lift and is inversely proportional to the lift.

Water hoists have a limited application and are used principally where the water is acid and it is not feasible to use other methods of raising the water. This method of lifting mine water was developed in the early days of coal mining in the Pennsylvania coal fields. It is simple in construction and gives a comparatively high efficiency. The water hoist consists of two balanced buckets, each capable of raising several thousand gallons from any depth, and operates in the same manner as a mine hoist, requiring a hoist tower (Fig. 1) and drum type hoist driven by either steam engine or electric motor. The installation of a water hoist, however, involves a very heavy initial outlay both for the hoist itself and its accessories, as well as for the two-compartment shaft which must be sunk for the buckets.

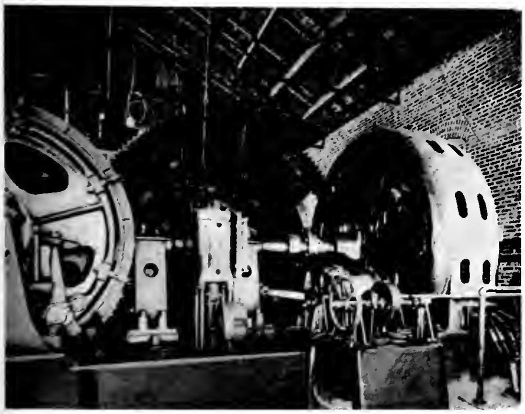

Fig. 1. Head Frame and Hoist House, D., L. & W. R. R., Hampton, Pa.

One of the largest of the motor-driven water hoists now in operation is that installed at Hampton, Pa., by the Delaware, Lackawanna and Western Railroad (Fig. 2). This hoist, together with two motor-driven centrifugal pumps, takes care of the water from eight mines within a radius of one and one-half miles which is collected into a central sump. This hoist has a capacity of 250,000 gallons per hour, hoisting 3100 gallons per lift from a depth of 500 feet. The equipment consists of an 800-h.p., 2200-volt, 225-r.p.m., General Electric Company squirrel cage induction motor geared to a cylindro-conical drum hoist, the drum having a maximum diameter of 16 ft. and a minimum diameter of 10 ft. The equipment is entirely automatic, the motor running continuously and is controlled by a reversing gear device. The change in the direction of rotation of the drum is accomplished automatically by means of a solenoid operated pneumatic clutch.

Fig. 2. Water Hoist at Hampton Shaft, D., L. & W. R. R., Hampton, Pa.

A more recent and larger installation is that at No. 14 Shaft of the Lehigh Coal and Navigation Co., at Lansford, Pa. This hoist has a capacity of 3600 gallons per lift from a depth of 865 ft., which is equivalent to 175,000 gallons per hour. The motor is geared to a 12-ft. diameter double cylindrical drum hoist. This equipment is non-automatic in that it requires an operator to start, stop and control it by means of a liquid rheostat.

The fifth means of handling water that finds application in mines, viz., pumps, is the most widely used. Mine pumps for the raising of water to higher levels or to the surface fall into three general divisions, depending on the service they are to perform.

1. Station pumps.
2. Sinking pumps.
3. Unwatering pumps.

Station or ejecting pumps are usually of large capacity (700 to 2000 gallons per minute), as they are usually required to lift the total amount of water made by the mine to the surface. These pumps are stationary and are usually located at the foot of the shaft and pump the water from a main sump into which the water is relayed by the smaller sinking pumps. The station pumps, therefore, can be designed for a definite service as to head and volume.

Sinking pumps are mostly of small size (100 to 500 gallons per minute) and are scattered throughout the mine, pumping the water from the various workings into the main sump from which it is raised to the surface by the station pumps. These pumps must naturally pump at varying heads and are arranged so that they can be lowered or raised in order to keep the pump at the surface of the water. Sinking pumps in vertical shafts are either supported by cables or chains or are mounted on floats; on inclines they are mounted on trucks.

Unwatering pumps, commonly called sinking pumps, combine both the features of the station pump and the small sinker. Their application is limited to the unwatering of flooded mines, which may include disused mines which have been flooded for considerable periods and which it is desired to reclaim, or mines which are temporarily flooded due to the tapping of large bodies of water with which the station pumps are unable to cope and the flow of which varies during the year due to the climatic or other conditions.

All pumps may be divided into two general classes:

1. Reciprocating or plunger pumps.
2. Centrifugal pumps.

The principles and characteristics of both plunger and centrifugal pumps are so well known that they need no explanation. Each of these classes has its own special advantages and disadvantages, and the application and use of one or the other usually requires considerable study of the conditions under which they are to operate.

The selection of the type of pump to be used for any given mine cannot be decided on their general characteristics, but all the conditions surrounding each individual installation must be fully known, and it is only through careful study that it is possible to determine whether a reciprocating or a centrifugal pump would prove the more advantageous and economical.

The plunger pump is inherently more efficient than the centrifugal pump, and it is this factor that has in the past given it a preference for station pump service. The centrifugal pump, however, has been developed in the past few years to such an extent that the efficiency has been decidedly increased. By the use of high speed motors direct connected to the pump, thereby doing away with all gear losses, the over-all efficiency of the pump and motor has overcome the preference which plunger pumps previously had in this respect. At the present time there is a wide difference of opinion among many large operators as to which type of pump should be considered the best practice for station service, but from the large number of installations of centrifugal pumps within the past few years this type seems to be gaining the preference.

Among the disadvantages of the plunger or reciprocating pump are its high first cost, this being approximately five times that of the centrifugal pump; the large floor space and head room required for installation; the relatively high cost of maintenance due to the large number of wearing parts, such as valve seats, valves, plungers or pistions; and packing troubles which are eliminated in the centrifugal pump.

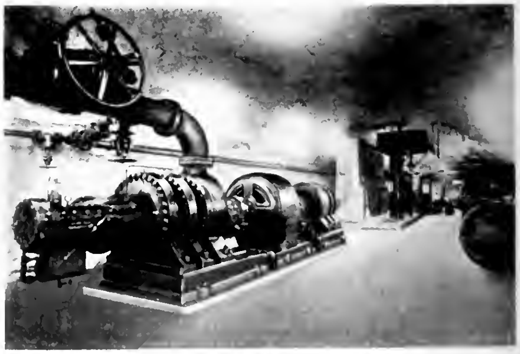

Fig. 3. Pumping Station, 12th Level, Chapin Mine, Oliver Iron Mining Co., Iron Mt., Mich. 1050-h.p., 2200-volt, 60-cycle Wound Rotor Motors

The centrifugal pump on the other hand has the advantages of simplicity, durability, and reliability, together with low first cost, low maintenance charges, and small floor space and head room. It has certain limitations, however, to which the reciprocating pump can be more easily adapted.

Difficulty is frequently experienced with centrifugal pumps when the water is highly acidulous. Bronze alloys have been used to resist acid water, but such alloys usually contain a large percentage of lead which makes the alloy soft and incapable of successfully resisting the abrasive action to which the moving parts of a centrifugal pump are subjected, due to its high rotative speed. Reciprocating pumps with wood or cement lined water ends and bronze valves and valve seats have been designed to handle highly acidulous waters. But even when so designed, considerable trouble is often experienced with the valves and valve seats, which require frequent replacement.

The centrifugal pump is designed for a definite duty, that is, to deliver a specified volume of water against a uniform head. It is not possible to vary the conditions of output and head except in one of two ways, both of which materially reduce the efficiency, first, by reducing the speed, and second, by throttling the discharge. The centrifugal pump therefore, except for its efficiency, is equally well adapted for station service on account of the fixed conditions of output, but is not so well suited to sinking or gathering where there is usually a large variation in the operating conditions.

However, since for sinking purposes efficiency is not an important item, centrifugal pumps may be used for this service, and when so used have the advantage over the reciprocating pump in that they are of lighter weight, occupy less space, have no valves to get out of order, and are consequently more reliable.

For the most successful operation centrifugal pumps require short suction lines and practically no suction lift. This is due to the necessity of keeping the pump primed, which is a difficult matter with a long suction line in a mine or a suction line having a considerable lift. Inasmuch as gathering pumps as a rule require long suction lines, the reciprocating pump finds favor for this service.

Not many years ago all mine pumps were operated by steam or air, while today in opening new mines electric pumps are used almost exclusively, and in many cases the old steam pumps have been changed over for electric drive. The application of motors for driving mine pumps effects increased economies and efficiencies which cannot be obtained with steam or air driven pumps; and in addition other benefits are derived, such as doing away with objectionable steam pipes and the saving in space occupied by the steam and exhaust lines, as well as the saving in space occupied by the motor as compared with the space required for the steam end of the pump.

As an indication of the extent to which mine pumps have been electrified, Table I is given, which is a partial list of equipments requiring motors of 150 h.p. and larger which have been built by the General Electric Company.

A comparison of the steam consumption of a steam driven pump with a motor driven pump shows up greatly to the advantage of the electric pump. The steam consumption for the most economical type of condensing mine pump runs from 60 to 70 lbs. per water horse power hour, these figures being an average of a large number of duplex compound and triple expansion condensing pumps of from 600 to 1200 gallons per minute capacity. To arrive at the steam consumption for the motor-driven pumps let us assume that the steam consumption of the engine driving the generator is 25 lbs. per indicated horse power hour; that the generator efficiency is 90 per cent; that the transmission line efficiency is 95 per cent; that the motor efficiency is 90 per cent; and that the pumping efficiency for the reciprocating pump is 88 per cent. The steam consumption per horse power-hour duty on the water would be approximately 37 lbs. Comparing this with the 60 to 80 pounds consumption by the steam-driven pump shows clearly why the electric pump has been so universally adopted where electric power is available.

There are a number of pump installations in this country which are worthy of mention on account of their size or special engineering features.

Chapin Mine, Oliver Iron and Mining Company

At the Chapin Mine of the Oliver Iron and Mining Company at Iron Mountain, Michigan, there were installed in 1914 centrifugal pumps to take care of a flow of approximately 3000 gallons per minute. Previous to this time the flow was taken care of by various air or steam operated pumps of the Riedler triplex tandem compound condensing crank-and-flywheel and duplex triple expansion direct acting types. There is also installed at this mine a large Cornish pump having a capacity of approximately 2000 gallons per minute against a head of 1500 ft.

The original centrifugal pumping installation at the Chapin Mine consisted of two 3-stage Worthington centrifugal pumps at the 16th level, each having a capacity of

3000 gallons per minute against a head of 412 ft. Each of these pumps is driven by a 450-h.p., 2200-volt, 1200-r.p.m., General Electric wound rotor induction motor. These pumps handle the entire flow from the 16th level to a sump on the 12th level, where the water is relayed to the surface by two 6-stage Worthington centrifugal pumps each having a capacity of 3000 gallons per minute against a head of 1000 ft. Each of these pumps is driven by a direct connected 1050-h.p., 2200-volt, 1200-r.p.m., General Electric wound rotor induction motor (Fig. 3). One pump on each level is capable of handling he total flow from the 16th level to the surface, so that the maximum capacity of the four pumps is 6000 gallons per minute from the 16th level to the surface. Each of the 12th level pumps consists of a single 3-stage unit, and each of the 12th level pumps of two 3-stage units connected to either end of the motor. All of these units are of the same design and dimensions and, except for the impellers, are interchangeable.

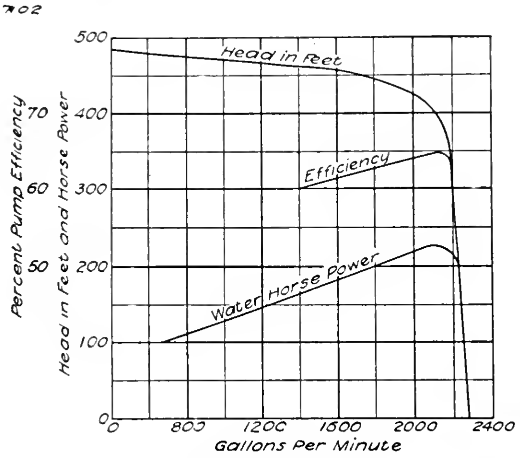

Fig. 4. Test Curves of Unwatering Pumps, Downtown Mines Co., Leadville, Colo.

The guaranteed wire-to-water efficiencies on these pumps were 71.8 per cent for the 16th level pumps, and 83.3 per cent for the 12th level pumps. Factory tests made at the plant of the General Electric Company at Schenectady showed efficiencies considerably in excess of this. During the first nine months operation the 12th level pumps showed an average overall efficiency of 69.5 per cent when pumping against a dynamic head of 991 ft. This efficiency included the cable losses from the power station to the pumps and also the lighting for the shaft and pump stations. The water was measured by a Venturi meter, the power was measured by a watthour-meter on the switchboard, and the head by a pressure gauge in the discharge of the pump.

Schooley Shaft, Pennsylvania Coal Company

One of the first of the large dewatering projects in this country was that undertaken at the Schooley Shaft of the Pennsylvania Coal Company, at Wyoming, Pa. In 1900, the opening of a crevice between the Susquehanna River and the Schooley Shaft caused this mine to be flooded and it remained full of water until about four years ago when dewatering was attempted. This shaft is approximately 590 ft. deep and the water was up to within approximately 50 ft. from the surface. Vertical sinking pumps were selected for this work, each consisting of a two-stage Alberger pump of 2000 gallons per minute capacity against a head of 350 ft. driven by a 300-h.p., 440-volt, 1800-r.p.m., squirrel cage induction motor. Each of these pumps is mounted in a float, the pump being located in the bottom and surmounted by the motor. These pumps have a range of head of 75 to 350 ft., and were used in parallel until about half way down the shaft, where one of the pumps became stationary, and the two pumps were operated in series until the bottom was reached.

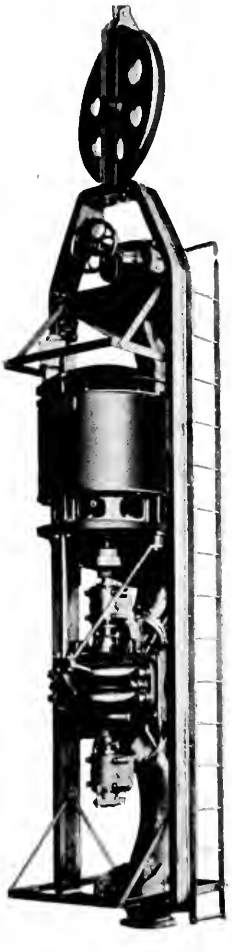

Fig. 5. Vertical Centrifugal Unwatering Pump Driven by 300-h.p., 550-volt, 1845-r.p.m. Motor, Downtown Mines Co., Leadville, Colo.

Penrose Shaft, Downtown Mines Company

One of the largest undertakings attempted in this country for the unwatering of a flooded mine by means of electrically driven pumps is that of the Penrose Shaft of the Downtown Mines Company at Leadville, Colorado.

In 1907-8, due to the low price of metals, the mines in this district were permitted to flood. During 1914-15, the Downtown Mines Company was formed and in May, 1915, the unwatering of the Penrose Shaft was begun. The equipment consisted of four duplicate pumps, each consisting of a two-stage centrifugal pump having a capacity of 2000 gallons per minute at a head of 425 ft. and designed especially for adaptation to the varying head encountered in the sinking process (Fig. 4). Each pump is driven by a direct connected 300 h.p., 550-volt, 1845-r.p.m., General Electric squirrel cage induction motor. The motors were of the vertical box frame type, open at top and bottom and furnished with a drip cover to prevent water dripping into the motors (Fig. 5).

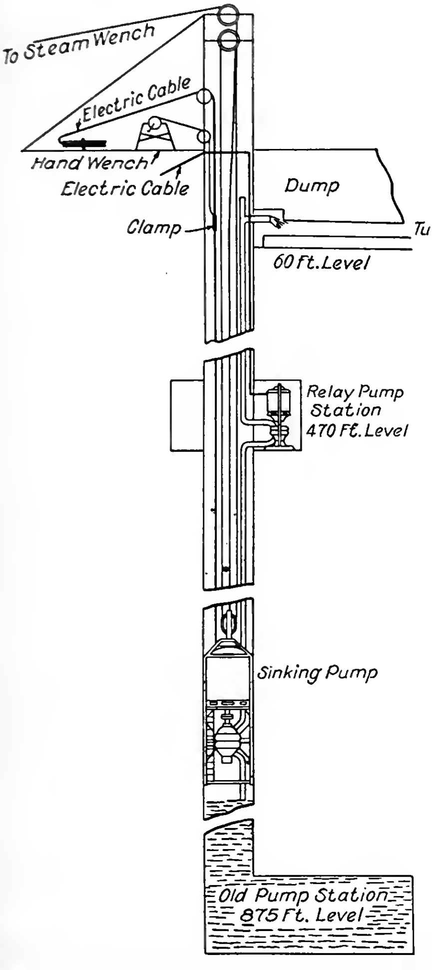

Fig. 6. Method of Suspending Unwatering Pumps and Connections Between Unwatering Pump, Relay Pumps and surface. Downtown Mines Co., Leadville, Colo.

Two of these pumps were arranged for suspension in the shaft and were used for the sinking process, and the other two were arranged for station mounting at the 470 ft. level and were used as relays for the sinkers after they had passed this level (Fig. 6). The sinking pumps and motors were mounted on a channel iron framework and were suspended in the shafts by steel cable. They were hoisted and lowered in the shaft by steam winches having a worm gear reduction which held the drums in any position without the use of brakes. Steam was used for these winches in preference to electric power because of the necessity of hoisting the pumps in case of failure of the power supply. The wire armored power cable was hoisted and lowered by hand winches. The cable was coiled on the landing floor at the surface in figure-eight coils having approximate overall dimensions of 10 by 27 ft.

Fig. 7. 150-h.p., 1845-r.p.m., 440-volt Squirrel Cage Totally Enclosed Water-cooled Motor for Driving Unwatering Pump. Iron & Silver Mining Co., Leadville, Colo.

The dewatering period lasted about 9 months. This length of time was required on account of the method employed. The water would be lowered with two pumps and then held at that level with one pump until the ground was sure to be drained. This was a safety precaution to prevent lowering the water too rapidly, which might cause some obstruction to break loose in the old workings and flood the pumps. This trouble was actually experienced in the early stages of the dewatering of the Schooley shaft mentioned above. Another delay in the pumping was caused by the necessity of holding the water at approximately the 540 ft. level until a station could be cut and the two relay pumps installed.

When the water had been lowered to the 875 ft. or lowest level, there was installed a 4-stage vertical centrifugal pump having a capacity of 2000 gallons per minute against a head of 900 ft. This pump was built by the Harris Engineering Works, Providence, R. I., and is driven by a 650-h.p., 550-volt, 1800-r.p.m., General Electric squirrel cage induction motor. This pump has a guaranteed overall efficiency of 70 per cent. The two sinkers are also permanently installed in the station at the 875 ft. level and, together with the relay pumps at the 540 ft. level, are held as emergency pumps in case of the failure of the large station pump.

Iron and Silver Mining Company

The Iron and Silver Mining Company is preparing to install dewatering pumps in the Mikado shaft. The equipment will consist of two 4-stage vertical centrifugal pumps designed to deliver 1000 gallons per minute against a maximum head of 315 ft. These pumps will be direct-connected to 150-h.p., 440-volt, 1845-r.p.m., General Electric vertical induction motors. The motors will be totally enclosed and water cooled (Fig. 7). This construction is more desirable for sinking pump service, as they are absolutely protected from drip, splashing, or the saturated condition of the atmosphere, and will probably give less trouble than the open motor for this service.

DYNAMIC BRAKING SPEED-TORQUE CURVES OF SERIES MOTORS

By James A. Jackson

Power and Mining Engineering Department, General Electric Company

Because of the many ways in which the field current and armature current of the series motor can be varied, either independently or together, an infinite number of relations between speed and torque may be obtained in dynamic braking. The author shows some of the more commonly used connections of armature, field and regulating resistance and the speed-torque curves that result therefrom. By selecting one or the other of these arrangements speed-torque characteristics to fill the braking requirements of practically any service may be obtained. The flexibility of this method of braking is largely responsible for its increasing popularity, although the elimination of frequent adjustment and renewal of parts that are necessary on the mechanical friction types of brake is a considerable factor in its favor.—Editor.


James A. Jackson

Dynamic braking in all its applications on electric motors is increasing in popularity from year to year on account of its flexibility and the ease with which the energy is dissipated. Not uncommon, however, are men still found who are skeptical regarding the use of this type of braking, the only apparent reason being that they have not familiarized themselves with its characteristics. Dynamic braking should not be assumed to be a "cure all," for there are certain classes of service where the dissipation of energy necessitated by lowering a load or stopping a car can be satisfactorily taken care of by some form of mechanical friction device. However, where the service is severe, requiring frequent adjustment and renewal of parts of a mechanical friction brake, dynamic braking is undoubtedly far superior.

This article will deal entirely with the series motor, as this type is used in the greatest number of cases in which dynamic braking finds its largest field. It has some applications on shunt motors, principally where armatures must be stopped rapidly to secure quick reversals such as on certain machine tools. It is a simple matter in such cases to calculate the speed-torque characteristics provided the field strength is maintained constant, as the variables are then in the armature circuit only. With a series motor connected for dynamic braking, the current in both the field and armature can vary either at the same time or independently. For instance, the current in the two circuits can rise together or fall together; it can rise in one circuit and fall in the other simultaneously, or it can rise or fall in the field circuit and then rise or fall in the armature circuit in sequence, depending upon the scheme of connections and the manner in which the resistance is cut in or out. Now bearing in mind that any change in field strength changes the magnetic density, and hence the "pounds torque per ampere armature" and the "volts generated per revolution per minute," it can be readily seen that an infinite number of relations between speed and torque are obtainable.

The object of this article is to show and explain the most commonly used of these relations of speed to torque, together with the schematic diagrams of the connections by which they are obtained. No attempt will be made to show how the curves are calculated and it must be understood that the curves shown in any one diagram bear no relation to the curves in any other diagram. In other words, the resistance values used in calculating one set of curves were not used in calculating any other set, except in Figs. 1 and 2 where the same values were used on account of the similarity of these two schemes of connections.

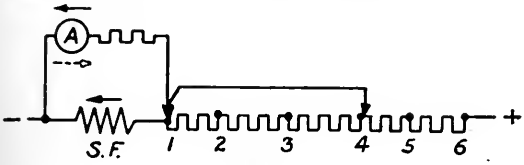

Fig. 1

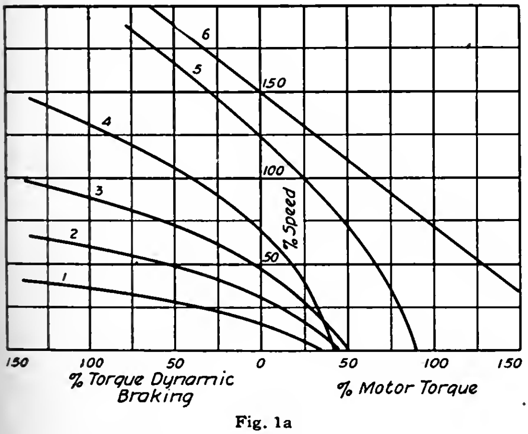

Fig. 1a

In all the diagrams, the connection bearing the arrowhead moves consecutively over the various points beginning at *1* and the speed-torque curves are numbered accordingly. In Fig. 1, however, the resistance is cut into circuit somewhat differently in that the arrow at *4* remains stationary until the arrow at *1* moves consecutively over *2* and *3* onto *4* after which the two arrows move as one over *5* and *6*.

In all the diagrams it will be noted that one block of resistance is connected permanently in the closed dynamic braking circuit. This must be left in the circuit to prevent a short circuit on the motor. Also, in all the connections shown, the direction of the current in the series field never changes and is shown by a solid arrow. The current in the armature does change, however, at the point where the torque changes from motor torque to dynamic braking torque. Solid arrows show the direction of flow of current for motor torque while dotted arrows show the flow for dynamic braking torque.

The speed-torque curves corresponding to each set of connections are given the same Fig. number with a letter added.

Fig. 1 shows the connections commonly used on manually operated controllers for crane hoist work where it is necessary to have, on all points, strong dynamic braking torque with fairly close speed regulation for lowering loads and also a reasonably strong motor torque for overcoming friction when driving down an unloaded hook. Fig. 1a shows that with the particular values of resistance used the motor torque at standstill is never less than 35 per cent which is ample to break the static friction and start down an average crane hook without load. Furthermore, assuming that it takes 20 per cent torque to drive down an unloaded hook after static friction is broken, Curve *6* shows that a speed of 134 per cent will be reached. This high speed is a great advantage as a time saver on a crane with a high lift. On the dynamic braking side, the curves droop or flatten out, which is characteristic of any set of connections where the series field is connected inside the dynamic braking circuit. This tends toward a small speed change for a large torque change; viz., good speed regulation. At the point where the curves cross the zero torque line the pull tending to overhaul the motor just balances friction, thus requiring neither motor torque nor braking torque from the motor. "No torque" means that there must be no current in either the field or in the armature, or in both. An inspection of the connection diagram shows that there must always be current in the field as it is directly across the line with a resistance in series; hence for zero torque there must be no armature current. A voltage is being generated, however, as the armature is revolving (driven by the overhauling load) in a magnetic field; but if this voltage is of such a value as to exactly balance the ohmic drop across the field and its series resistance inside the parallel circuit, no current will be allowed to flow through the armature and zero torque will result. This explanation of the zero torque point applies to all of the curves shown.

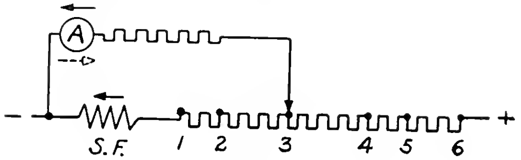

Fig. 2

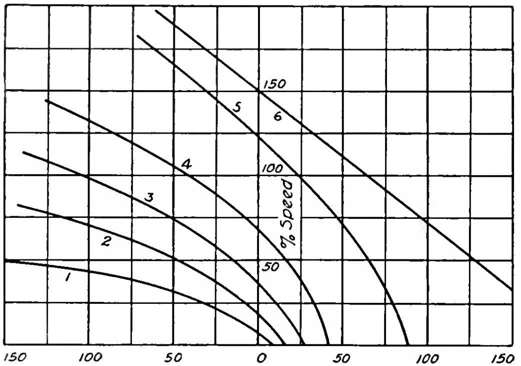

Fig. 2a

The connections in Fig. 2 are quite similar to those in Fig. 1, yet an inspection of Fig. 2a shows that quite different speed-torque curves are obtained on points *1*, *2* and *3*. Of course, points *4*, *5*, and *6* give identical results for the two sets of connections. The starting torque on points *1*, *2*, and *3* of Fig. 2a is 10, 18, and 27 per cent respectively; while in Fig. 1a it is 35, 45, and 50 per cent, which higher values are very advantageous for breaking static friction and securing a quick acceleration. The high torque obtained in Fig. 1 is due to the low series resistance, i.e., only that between *4* and *6* being in circuit; while in Fig. 2 a much higher series resistance is in circuit. The speed regulation is not so good for Fig. 2 as for Fig. 1, the curves being considerably steeper. The reason for this is that the field excitation from the line is smaller, due to the high series resistance. For average crane hoist work, it can readily be seen that Fig. 1 gives better characteristics than Fig. 2.

Fig. 3 will be considered with three different arrangements of resistance to show the effect of each on the characteristic curves: first, with resistance *D* and *C* in circuit and *B* left out; second, with *C*, *B*, and *D* all in circuit; third, with *C* and *B* in circuit and *D* left out.

Taking the first case, the sum of the resistances of *C* and the armature *A* is assumed to be so large relative to the resistance of the series field *SF* that only a negligible current from the line flows through the armature at starting. This means practically no motor torque and the overhauling load must always be sufficient to overcome friction and start the motor. Fig. 3a gives curves obtained with this connection. They show no motor torque but show strong braking torque with low speeds and a good speed regulation again due to the series field being strengthened by all the dynamic braking current. In the second case, the resistance *B* has been introduced to make the resistance of *B* plus *SF* more nearly equal to

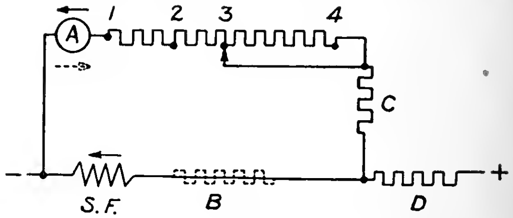

Fig. 3

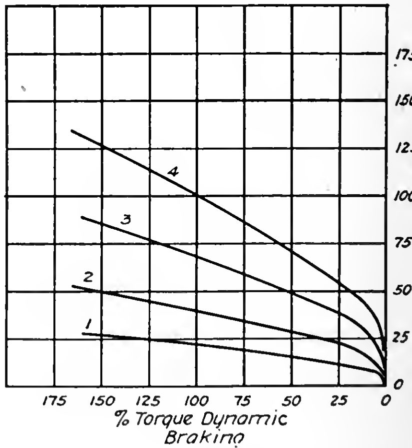

Fig. 3a

C plus *A*, thus causing a good proportion of the line current at starting to flow through the armature. This causes motor torque and the solid curves in Fig. 3b show the characteristics. Now, if resistance is cut into the armature circuit, as by moving the arrow from *1* to *4*, the motor torque at starting decreases, for if this resistance were increased to infinity no current would flow through the armature and zero torque would result. When the speed reaches a value sufficient to reverse the armature current and cause dynamic braking, it can readily be seen that the higher the resistance in the armature circuit the higher must be the generated voltage, and hence speed, to produce a given current and torque, Therefore, the higher the resistance the steeper the speed-torque curve and the poorer the speed regulation. In the third case, the motor becomes essentially a shunt motor with constant field strength and running with permanent resistance in series with the armature. The characteristic curves become straight lines (neglecting armature reactance) as shown by the dotted curves of Fig. 3b. Strong motor torque is produced as there is no series resistance outside the parallel circuit to limit the current, and the braking becomes regenerative (supplying power to the line) rather than dynamic.

One characteristic point regarding this particular connection is the fact that all the curves for any one of the three cases given cross the zero torque line at exactly the same per cent speed. This will be readily understood when it is remembered that for zero torque there is no current in the armature circuit, and that the voltage generated at zero torque is equal to the ohmic drop across the series field plus the resistance in the field circuit. This ohmic drop always being the same at the zero torque point, the speed must be the same for any value of resistance in the armature circuit.

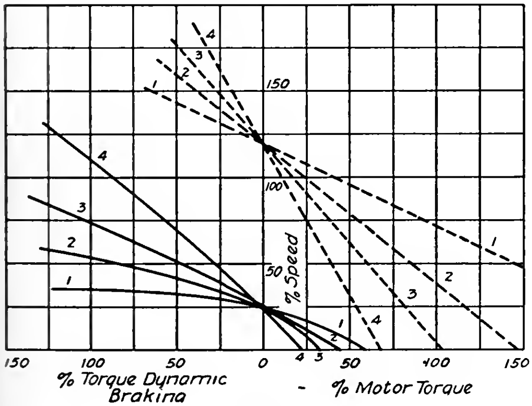

Fig. 3b

Fig. 4 shows a connection which differs from Figs. 1, 2, and 3, in that the series field *SF* is not included in the dynamic braking circuit. Hence, instead of the dynamic braking current strengthening the field it weakens the field, causing the speed-torque curves to turn upward (poor speed regulation) soon after dynamic braking starts (see Fig. 4a). This curving upward depends on the amount of resistance in series with the motor and it disappears entirely when all series resistance is cut out. For instance, assume the resistance in series to be infinity. This would permit no excitation, hence no torque, and the speed-torque curve would become a vertical line coinciding with the zero torque line. Next, assume all series resistance to be short-circuited; the motor becomes a shunt motor whose excitation depends on the resistance in parallel with the armature and whose armature voltage is line voltage minus the drop across the series field. This gives essentially a shunt motor characteristic curve which, within workable limits, is nearly a straight line.

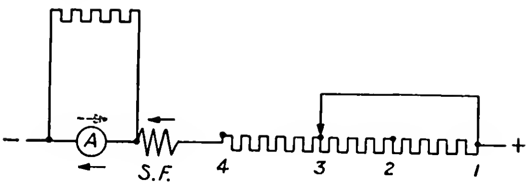

Fig. 4

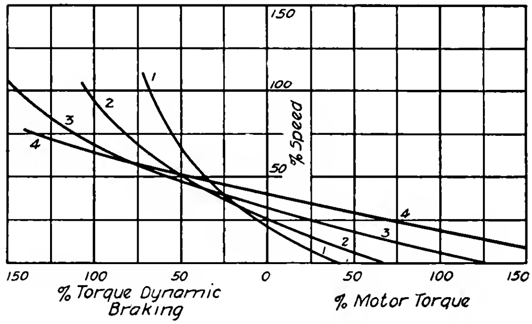

Fig. 4a

The per cent torque at standstill and the per cent speed at zero torque, or in other words the steepness of the curves, depends on the amount of resistance in parallel with the armature. For example, if this resistance were infinity the curves would cross the zero torque line at infinity and maximum starting torque would result as the connections would be those of a plain series motor. On the other hand, if the parallel resistance were zero there would be no starting torque as the armature would be short-circuited, but as soon as driven by an overhauling load a powerful dynamic braking current would flow due to the low resistance of the closed circuit and the strong separately excited field.

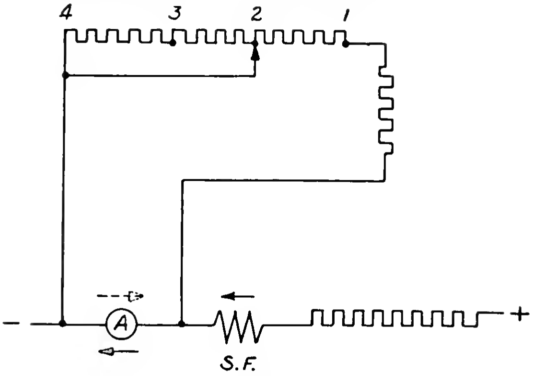

Fig. 5

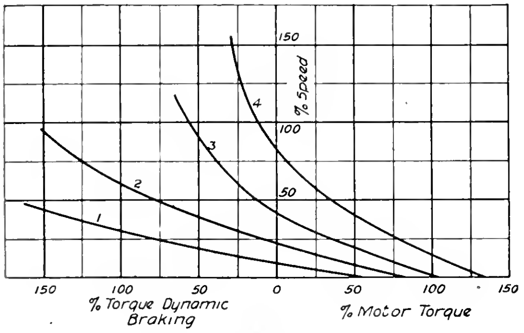

Fig. 5a

The connections in Fig. 5 are similar to those in Fig. 4, only variations in speed and torque are obtained by varying the resistance in parallel with the armature instead of that in series with the motor. Here again, speed regulation, when dynamic braking, becomes very poor as soon as the resistance around the armature is increased to any great extent. Fig. 5a shows very clearly the tendency of the motor to run with shunt characteristics when the resistance around the armature is low and to approach series characteristics when the resistance is high, becoming a true series motor when the resistance reaches infinity.

Fig. 6 shows connections which are seldom used as no motor torque is produced, hence the load must always be sufficient to start the motor against all friction. Neglecting armature reaction, the speed-torque curves, Fig. 6a, are straight lines as would result from any shunt generator. This connection is wasteful of current as there is a constant fixed loss to excite the field.

A connection which is largely used as an emergency dynamic braking circuit in case of failure of power is shown in Fig. 7. The connection is that of a series generator short-circuited through a suitable resistance. If driven by an overhauling load in the proper direction to build up the series field, a braking torque will be exerted and the speed-torque curves will be almost the same as those shown in Fig. 3a. Of course, if the armature is driven in the wrong direction or if the field loses its residual magnetism, no voltage will be generated and no braking will occur.

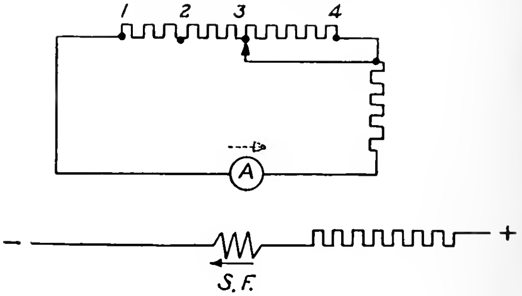

Fig. 6

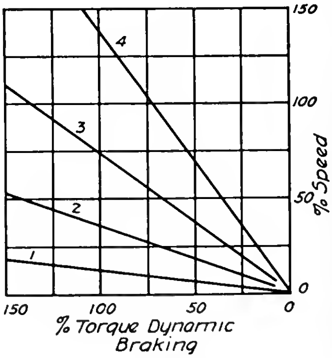

Fig. 6a

It can easily be seen that an almost unlimited number of combinations of the connections shown can be worked out, thus obtaining speed-torque characteristics to meet almost any condition which may arise. A good example of one such combination is shown in Fig. 8 where the first four points vary the resistance in the armature and field circuits while points *5* and *6* cut out the resistance in series with the motor. Many other combinations could be worked out and it would be endless to attempt to show them all or to calculate the speed-torque curves resulting from them.

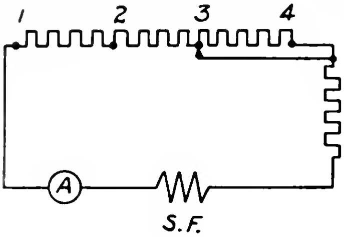

Fig. 7

A rather interesting connection is shown in Fig. 9, the characteristics of which are quite frequently misunderstood. It is often assumed that dynamic braking can occur when a motor is connected to the line with a resistance in series and another resistance in parallel as shown, and driven by an overhauling load. Such is not the case for, assuming no change in the direction of rotation, the current in either the field or armature (but not in both) must change in direction when going from motor torque to braking torque. An inspection of the connections shows that such a change is impossible; hence dynamic braking cannot be obtained with this connection unless the connection to the line is broken and the armature driven in the proper direction from the motor to pick up as a series generator. A resistance across the entire motor as shown does, however, give a better speed regulation by holding the voltage across the motor terminals to a lower value than would occur without it. Fig. 9a shows the effect of this on the speed-torque curves. The dotted curves show curves of a series motor with various amounts of resistance in series, but with none in parallel; while the solid curves show the characteristic curves obtained by paralleling the motor with a resistance and reducing the series resistance until the torque at starting is the same as given by the dotted curves. For any given torque the speed on the solid curves is much less than the speed given on the dotted curves, but it will be noted that the curves maintain their series characteristic and do not cross into the dynamic braking quadrant. Curve *5* is added to show the characteristics obtained when the motor is cut loose from the line and driven by an overhauling load in the proper direction to pick up as a series generator.

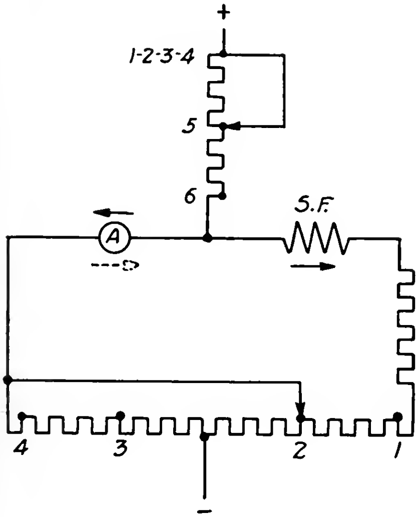

Fig. 8

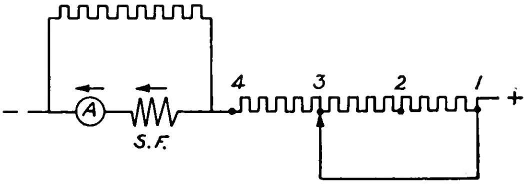

Fig. 9

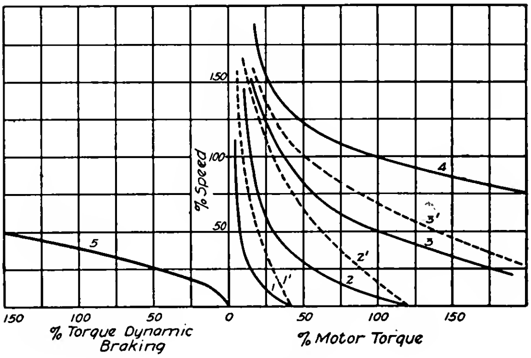

Fig. 9a

THE DEVELOPMENT AND EXTENT OF THE OPERATION OF OIL WELLS BY ELECTRIC POWER

By W. G. Taylor

Power and Mining Engineering Department, General Electric Company

For the drilling and operation of oil wells, as in most other lines of industry, the electric motor offers advantages in flexibility and economy over the steam engine and gas engine. The two-speed variable-speed induction motor has become practically a standard equipment for this service, as the large overload capacity and sturdiness of this type of motor render it specially suitable for the hard usage to which oil well equipment is subjected. The author reviews the introduction of the electric motor in the principle American oil fields and shows how it has steadily worked itself into favor and is to-day the most approved method of drive. Its application in the principal foreign fields is also briefly referred to.—Editor.

W. G. Taylor

THIRTEEN years ago the South Penn Oil Company made an extensive installation of motors at Folsom, West Virginia, to operate their producing wells, and they thus became the pioneer users of oil well motors in America. It was about five years later that they started and successfully completed the first oil well drilled by electric power in this country. These are not, however, the first installations on record, for even then there were a considerable number of oil well motors in operation in the fields at Baku, Russia, where electrification was started as early as in 1900.

Today the number of oil well motors actually or about to be installed in the United States, including equipments of all types for drilling, pumping, pulling and cleaning, and for operation of "powers" for jack-pumping, is as follows:

	Number of Motors	Combined Rated Capacity
Two-speed motors . .	865	18,475 h.p.
All other types, approx.	885	19,525 h.p.
Total, approx.	1750	38,000 h.p.

This does not include the motors for miscellaneous power purposes, which are extensively used wherever electric power is available, such as for sump and pipe line pumps, water pumps, compressors and machine shop drives. These applications are too numerous and widespread to be included within the scope of this article.

Almost without exception three-phase, 60-cycle, 440-volt power is employed for modern American installations.

West Virginia and Pennsylvania

At the time of the Folsom installation the two-speed type of induction motor was recognized as the most desirable to handle the work of both pumping the well and "pulling" the wire pumping line, rods and tubing, and accordingly motors of that type were used, with a capacity of 10/5 h.p. Cleaning out the wells, which was usually a matter of redrilling with a light string of tools, was performed with a few variable speed 10-h.p. motors of special design, which were transported from well to well as required. The drilling of new wells, which was later accomplished, was done with a 30-h.p. motor of similar special design.

Fig. 1. Well No. 1, Henry Talkington lease, South Penn Oil Co., Folsom, W. Va. One of the first electrically operated oil wells in America

It is seen that it was not attempted in those days to accomplish with one motor all of the work which the steam and gas engines were doing, as the requirements were unusual for motor drive, and oil well equipment such as is now widely used was not then on the market. Even the determination of the capacity of the machines required was to an extent uncertain, for it could not be definitely foretold what the ultimate operating conditions would be as a result of the use of motors. The installations of today employ larger motors in practically all cases, and the equipments have been so designed and perfected that they are as flexible in operation and as versatile in the work they perform as the engines they are replacing, over which they have many superior advantages.

The South Penn Oil Company generates its own three-phase, 25-cycle, 600-volt power by gas-engine-driven units, stepping it up to 13,200 volts and transmitting to nine substations, where it is distributed to the wells at 550 volts. The longest distance transmitted is approximately 15 miles. About 430 wells are supplied, one of the first to be electrically equipped being shown in Fig. 1. The motor at this well, Fig. 2, is accordingly of considerable historical interest.

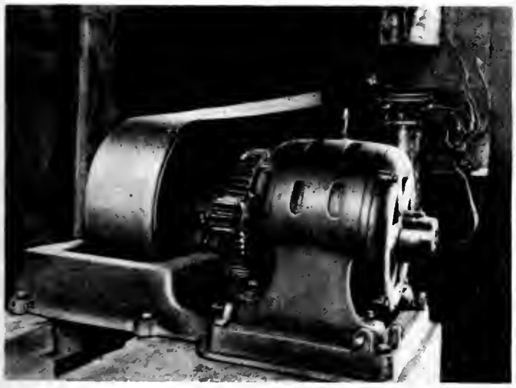

Fig. 2. An early type of General Electric two-speed oil well motor, installed at the well shown in Fig. 1, and still in operation after thirteen years of active service.

The rapid decline in well production in the Appalachian fields in the years following the installation at Folsom deterred further investments along that line, so that only a small amount of electrification of wells has since been done in that region. This can be readily appreciated from the fact that the average production in those fields is now only about from 1 to 1½ barrels a day per well, and a well which produces six or eight barrels is considered excellent. Such wells are pumped for only a few hours each day, some of them only an hour, and the power consumption and operating expenses for this reason are in most cases too low to warrant any change in motive power, even for a considerable gain in economy.

For several years in western Pennsylvania a number of direct current motors, from 12½ to 15-h.p. capacity, have been handling oil well pumping and pulling work, these being, as far as can be ascertained, the only direct current installations in the United States. Whatever ability they have demonstrated to do the work can be ascribed to the fact that they have not been required to do as heavy duty as is encountered in most fields, especially where the production per well is large and the time and work necessary to keep a well in good operating condition by pulling and cleaning are important factors in the cost of operation. The overload limitations and commutation characteristics of direct current motors in general make them decidedly inferior to induction motors for this class of work.

The Appalachian oil districts now have, it is estimated, about 525 oil well motors with a combined rated capacity of 5830 h.p.

California

It was several years after the beginning in West Virginia before oil men in other fields turned their attention to electric drive, but at length California operators became actively interested in the proposition. This resulted to a large extent from the decreasing price of oil, which was reducing their profits. The gain in economy possible from motor drive was evident from the glaring defects of standard and conventional methods of operating oil wells by steam and gas engines, these disadvantages being low engine efficiency, extreme losses in steam transmission, especially during cold weather, relatively high cost of attendance, almost prohibitive cost of water, and rapid depreciation of boilers. But any new method or system is extremely difficult of introduction in the oil fields because of the conservatism of the operators, so that oil well motors were slow in gaining a foothold in California, notwithstanding every advantage in their favor. The first permanent installation, a 20/6⅔-h.p., Y-delta back-geared machine for pumping, pulling and cleaning work was made by the Pacific

Light & Power Corporation on their lease near Los Angeles in the fall of 1910.

The San Joaquin Light & Power Corporation, operating in the San Joaquin Valley, early realized the possibilities of future load in the oil fields, and accordingly lost no time in extending their lines into the Kern River, Midway, Sunset, McKittrick, Lost Hills and Coalinga fields, thus opening the way for the extensive electrification which now exists.

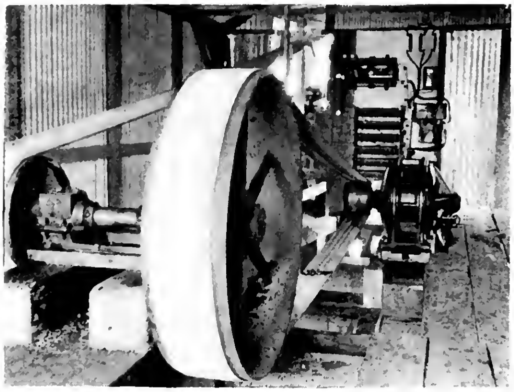

Fig. 3. Two-speed variable-speed 25/8 h.p. oil well motor installation for pumping, pulling and cleaning work in the Midway field in California

It was learned from the start that the operating conditions in California were considerably different from those encountered in the old eastern fields, and it was consequently necessary to study them as an entirely new problem. The back-geared motors first used were not fully satisfactory to the oil men because of the objectionable noise of the steel gears, and although fabroil pinions were later tried with success, a belted motor with countershaft (Fig. 3) rapidly grew in favor and is at present the accepted standard.

The Y-delta type of motor (Fig. 4), though excellent in some ways, has always been deficient in meeting all of the requirements of the service, not only in California but in most other fields. It has been only to a partial extent satisfactory to oil men because of the necessity of changing pulleys to get high pulling and bailing speeds, and because of the impossibility of "shaking up" a pumping well even by that method. Various schemes were proposed and tried out to obviate these difficulties, including two-speed geared countershafts, belt shifting arrangements, and modifications of the oil well rig itself, but all were either too clumsy and depreciated too rapidly, or failed to accomplish all of the desired results.

The real solution of the problem was the two-speed variable-speed induction motor (Fig. 3), which was introduced in the California fields in the fall of 1912 and perfected in its present form in 1913. This type of motor has conclusively demonstrated its ability to meet the full requirements and handle all the varied operations of pumping, pulling, cleaning, bailing, swabbing, redrilling and even deepening the wells. One motor is used for all this work, and the design is such as to result in excellent efficiency when pumping without sacrificing any ability to do the heavy roustabout work.

Experimental work in electrical oil well drilling in California began almost simultaneously with the introduction of pumping and pulling motors. Early in the spring of 1912 the scheme of using one main and one auxiliary drum controller for fine speed control was introduced with success and has been adopted for the 50 and 75-h.p. equipments which are standardized for work with standard cable-tools (Fig. 5). It is an interesting fact that when the first study of oil well requirements was made, it was felt that drilling operations offered more difficulties from the electrical standpoint than the remainder of the work, but the reverse soon proved to be the case. This developed from the fact that the pumping and pulling motor is obliged to do so many different kinds of work which call for widely divergent motor characteristics. On the other hand, it requires more time and effort to convert an operator to use electricity for any kind of drilling than to sell him four or five electric equipments for pumping, pulling and cleaning. His inherent and long-standing conservatism

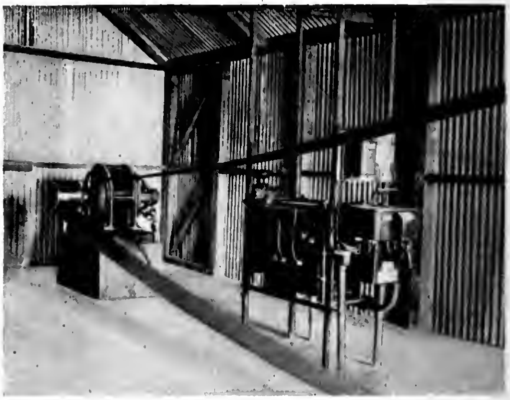

Fig. 4. A California installation of an oil well motor of the Y-delta type

toward any change in conventional drilling methods is responsible for this, and is not so surprising when one considers that these methods are the result of fifty-eight years of experience and development in connection with precarious work involving an expenditure of thousands of dollars for every well drilled. A large percentage of this investment is lost in case of failure to successfully complete the drilling work.

It is greatly to the credit of the drilling motor that not only is its record unstained by a failure of this nature, but exceptional records of fast time and economical handling of drilling work have been made. An instance of this is a 1495-foot well which was among the first to be electrically drilled in California. It was completed in 26 days, but as casing was handled only in the daytime, the actual net time of drilling was about 21 days, thus making an average of 71.2 feet per day. The power cost for this work was 10¼ cents per foot drilled. Up to the present approximately 100 wells have been electrically drilled in this state. One of the equipments has been in continuous service on drilling work since March, 1912.

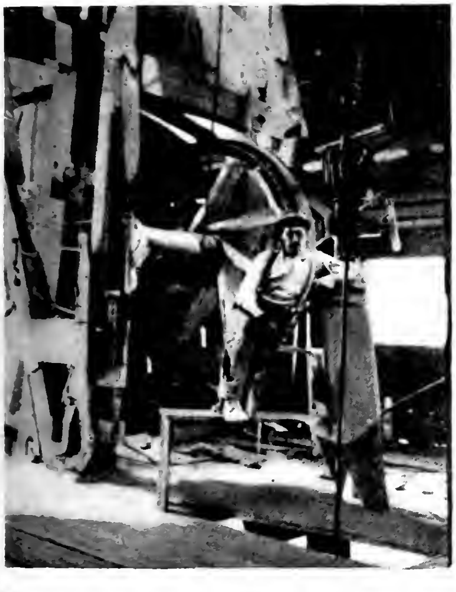

Fig. 5. Drilling a 1900-ft. oil well by electric power with standard cable tools in the Midway field in California

Rotary drilling is largely done by contract and the lease owner furnishes the contractor with power. The latter must have an outfit of universal application, regardless of whether electric power is available, and furthermore is not particularly interested in economical operation. Consequently it is the tendency to continue operating by steam power, but in spite of this several wells have been drilled with motor drive, and further work along that line is now being done. The equipment for operating the turn-table and draw-works duplicates that used for cable-tool work and this obviates any necessity of making changes to finish the hole with standard cable tools. The large companies who do their own drilling will very probably be the first to do electric rotary drilling extensively.

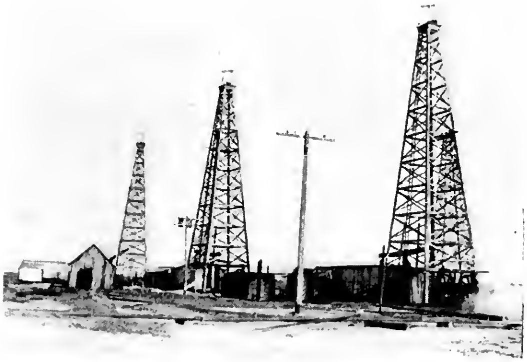

Fig. 6. A group of motor-operated oil wells in the Spindletop field in Texas. The farthest well is pumped by a jack operated from the middle well

Motor-driven "powers" for pumping a large number of wells in groups by pumping-jacks represent a power application which requires no special features for electric drive. This method is used largely for shallow well pumping, and more than 30 of these motors are in operation in California, having a rated capacity of nearly 900 h.p. Approximately 1000 wells are being so pumped. Portable motor-driven hoists were developed to supply the demand for equipments to pull and clean these wells, and several are in almost daily operation in the Kern River field and in the vicinity of Los Angeles.

There are in all approximately 850 oil well motors already or about to be installed in California, having a combined rated capacity of 23,100 h.p. In 1914 and 1915 the general depression in the oil business due to low oil prices halted nearly all development work of every kind, but 1916 saw a big revival which has greatly accelerated the demand for motor equipments.

Texas

The famous Spindletop field at Beaumont was in 1912 the next scene of the advent of oil well motors. This was due to the enterprise of the Beaumont Electric Light & Power Company, which had power lines passing the field. Both two-speed and single-speed induction motors of the variable speed type are now in operation, and several groups of wells are pumped by jacks operated from electrically-driven "powers." In all there are about 35 motors with a combined rated capacity of 625 h.p. Several of the wells are shown in Fig. 6.

Almost all of the drilling at Spindletop has been done by the rotary method, and electric operation has not been attempted. The decline of production and the small productive area in this field makes it improbable that there will be any further extensive application of electric drive.

Kansas

One of the most promising extensions of electric operation in the country is developing in the El Dorado and Augusta fields through the efforts of the Kansas Gas & Electric Company, which has extended its lines into these fields during the past year and has made preparations for a large addition to its load. The initial installation was made less than a year ago, yet by the end of the present year there will be more than 5200 h.p. capacity installed, comprising at least 175 machines. The two-speed variable-speed motor for pumping, pulling and cleaning has already established itself in first place. Electric drilling with standard tools has been introduced and will be extended.

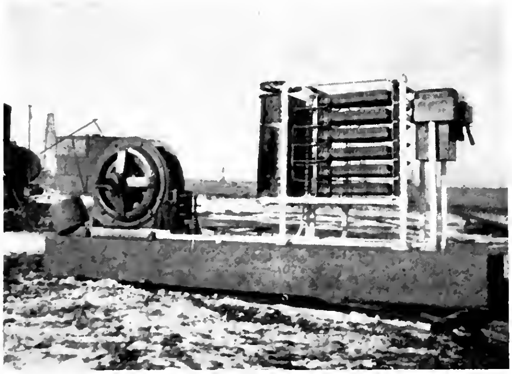

Fig. 7. A two-speed oil well motor equipment in Kansas, mounted on skids and completely wired ready for final location at a well near El Dorado

An original and unique method of putting in the apparatus is employed by the power company, which assumes the contract for making the entire installation. The motor and controlling apparatus are mounted on skids of timber, as shown in Fig. 7, and completely wired previous to being moved into the fields. The method is convenient and inexpensive, and the skids render the installation very rigid.

The 35-h.p. bandwheel "power" shown in Fig. 8 has been in operation nearly a year, and it is interesting to note that it pumps 32 wells.

Fig. 8. A 35-h.p. motor-driven bandwheel "power", pumping 32 wells in the El Dorado field, Kansas

Louisiana

Two notable installations exist in Louisiana, one in the northern part of the State at the edge of the Caddo district at Hosston, and the other in the Evangeline field in the south. Both were made in 1915 and both obtain their power supply from separate isolated alternating current power stations owned and operated by the oil companies themselves. The Badger Oil Company's station at Hosston consists of steam-engine-driven units supplied by oil and gas-fired boilers. The power station at Evangeline, owned by the Crowley Oil & Mineral Company, has generating units driven by high-compression oil engines (Fig. 9).

The Badger Oil Company is supplying power to between 25 and 30 wells, at which are installed squirrel cage motors ranging from 7½ to 15 h.p. capacity and designed only for pumping duty. In cases of emergency pulling has been accomplished with these machines, but for this work a 20-h.p. portable hoist motor is regularly employed by belting it through the back door of the motor house to the countershaft (Fig. 10). Though the country is none too level or clear in this locality, the portable hoist has admirably met the requirements, and the installation has produced a very material saving in operating expenses.

At Evangeline the Crowley Oil & Mineral Company uses the standard Y-delta oil well motor. In this and some of the other Southwestern fields the type of rig and the general operating methods used occasionally permit the use of this type of machine with complete success. This Company has at present fifteen electrically-operated wells, and can point to a substantial reduction in operating expenses as a result.

Oklahoma

Although Oklahoma as an oil producing state is now in the first rank, and immense oil developments have taken place in the past three years, the fields are not within easy reach of the lines of any power company, and electric power is consequently not yet extensively used. Only one installation of material size has so far been made, this consisting of a gas-engine-driven generating station supplying power to approximately 50 wells. Both Y-delta and two-speed variable speed oil well motors are in operation, but the latter type has demonstrated its superiority for the required work.

There is keen interest in electric operation among Oklahoma oil men, all of whom are watching developments in the near-by Kansas fields.

Illinois

While this State has no important electric extensions in its oil fields, some installations at Robinson are of interest. The wells are owned by individuals and are located within the city limits where the noise of engines is objectionable. This in connection with low first cost and convenience in operating has led to motor drive on about a dozen wells. Three horsepower motors are used for pumping, with unit pumping rigs designed particularly for the purpose.

Russia

With about 27 per cent of the 11,000 wells in the Baku district electrified, Russia has made the largest application of electric power in any oil field. 70,000 kw. in generating capacity is now required and at the present rate of increase in the load additional capacity will be needed before long. The present power is mostly obtained from steam-turbine-driven units, with oil-fired boilers, but there are also a few gas engine stations in the fields.

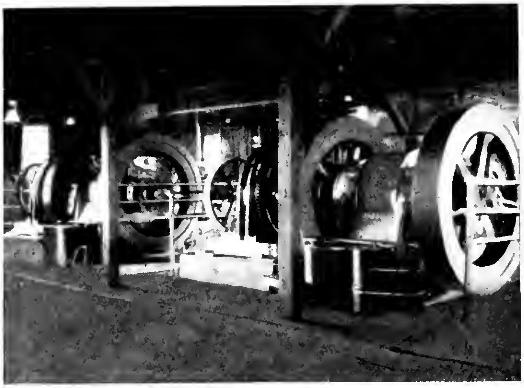

Fig. 9. The power station of the Crowley Oil and Mineral Co., Evangeline, La., showing two 75-kv-a. oil engine-driven generating units, now supplemented by a third

The development of the system has been along quite different lines from those followed in the United States. The power company was obliged to overcome immense difficulties in introducing electric drive, and as a result found it necessary to concentrate on a constant speed motor of very low cost and with simple control equipment. Even then, in view of the customary variable speed operation of wells with steam engines, there was a demand for a variable speed motor with control for reversing, which has been growing so strong that equipments of this type are being standardized. 95 per cent of the drilling at Baku is done by the Canadian "free fall" method, and with the rig as used for motor operation variable speed is desirable though not indispensable. Motors from 65 to 120 h.p. capacity are employed. After the well is drilled the motor is retained for operating it as a producer, this differing from the American practice of removing the drilling motor to a new well and permanently installing a machine specially designed for the work of production.

The American rotary method of drilling has been introduced at Baku, but it has not been ascertained whether electric drive has yet been attempted.

In line with the regulations of the Russian and Roumanian authorities applying to power transmission and distribution, as well as to the design and installation of oil well motors, the power supply, generated at 6000 volts, is stepped up and transmitted entirely underground at 20,000 volts and distributed underground at 2000 and 1000 volts.

Fig. 10. 20-h.p. portable motor equipment for pulling oil wells of the Badger Oil Co., Hosston, La.

Roumania

The last information obtained indicated that before the outbreak of the war in Europe there were over 200 oil well motors in Roumanian oil districts, having a capacity of about 14,000 h.p. The first installations are believed to have been made in the year 1908. Operating methods and motor equipments used are similar to those in Russia. It is interesting to note that the motors are of five different types, all but one being for constant speed operation and quite similar in design. The transmission at 25,000 and 10,500 volts and distribution at 1000 and 500 volts is by overhead lines, as the shifting nature of the ground does not permit the use of underground cables as at Baku.

Other Foreign Fields

In Germany, slip-ring oil well motors have been used in the Hanoverian petroleum districts at Wietze near Celle for many years, and in 1910 three-phase brush-shifting commutator motors were first tried. At least 25 of the latter, of 25 and 50 h.p. capacities, have been installed and it has been claimed that they have given full satisfaction over an operating period of three years or more in spite of severe working requirements.

For over a year the Burma Oil Company has been running a demonstration of standard American oil well motor equipments for drilling and for pumping, pulling and cleaning work in the Singu field in Upper Burma, India, and the results have exceeded the most favorable predictions and created great interest among oil men in Burma.

Oil companies in other foreign as well as domestic fields are either investigating carefully their own requirements for electric operation or have taken steps to introduce the most modern motor equipment for this work, and the indications consequently point to large future extensions.

BIBLIOGRAPHY

(Chronologically Arranged)

"Electric Drive for Oil Wells," by W. F. Patton, Jr., *Electric Journal*, April, 1911.

"Electric Motors for Oil Well Service," by S. G. Gassaway, *Journal of Electricity, Power and Gas*, January 13, 1912.

"San Joaquin Light & Power Corporation," by R. W. Van Norden, *Journal of Electricity, Power and Gas*, May 11, 1912.

"Electrifying the Oil Fields," by A. E. Wishon, *Western Engineering*, January, 1913.

"Electric Power in the Kern and Midway Oil Fields," by Warren Aikens, *Mining and Engineering World*, January 11, 1913.

"Electric Motors for Oil Field Service," by L. A. Somers, *Western Engineering*, February, 1913.

"Speed Reducing Gear for Electric Oil Well Drilling," by F. A. Williamson, *Western Engineering*, March, 1913.

"Electricity in the Oil Fields," by H. A. Russell, *Western Engineering*, April, 1913.

"Electrical Energy in the Oil Fields," by A. E. Wishon, *San Joaquin Light & Power Magazine*, April, 1913.

"United Oil Company Decreases Operating Cost," by J. B. Carter, *San Joaquin Light & Power Magazine*, May, 1913.

"Motor-Driven Pumping Jacks," *San Joaquin Light & Power Magazine*, June, 1913.

"Cost of Pumping Oil by Electricity in the California Oil Fields," by S. G. Gassaway, *Western Engineering*, October, 1913.

"Electricity in Oil Well Drilling," by W. C. Johnson, *San Joaquin Light & Power Magazine*, October, 1913.

"Engineering Department Develops Valuable Idea in Oil Well Motor Operation," by C. L. Easton, *San Joaquin Light & Power Magazine*, February, 1914.

"Electric Drilling in the Oil Fields," by W. R. Johnston, *Electric Journal*, March, 1914.

"Die elektrischen Betriebe im rumänishen Petroleumgebiet," by L. Steiner, Berlin. *Elektrische Kraftbetriebe und Bahnen*, May 24, 1914.

"Drehstromkommutatormotoren bei der Petroleumgewinnung der Deutschen Mineral-Oel-Industrie-A.-G. in Wietze bei Celle," *Elektrische Kraftbetriebe und Bahnen*, May 24, 1914.

"Elektrische Antriebe für Petroleumgewinnung der AEG," *Elektrische Kraftbetriebe und Bahnen*, May 24, 1914.

"Methods of Oil Recovery in California," by Ralph Arnold and V. R. Garfias, *U. S. Bureau of Mines, Technical Paper No. 70*, May, 1914.

"Drilling and Pumping Oil Wells by Electricity," by W. G. Taylor, *General Electric Review*, June, 1914.

"Electricity Enables the Automatic Operation of Oil Lease in the Kern River Fields," *San Joaquin Light & Power Magazine*, June, 1914.

"Pumping Oil Wells by Electricity," by J. W. Thorne, *Stone and Webster Public Service Journal*, June, 1914.

"Petroleum Industry of California," by R. P. McLaughlin, *California State Mining Bureau, Bulletin No. 69*, October, 1914.

"Die elektr. Betriebe in der russischen Naptha-Industrie," by L. Steiner, Berlin. *Elektrische Kraftbetriebe und Bahnen*, October 4, 1914.

"The Selection of Control for Portable Drilling Rigs," by W. R. Johnston. *The Electric Journal*, December, 1914.

"Directors of English Oil Company Give Electricity Credit for Larger Dividends," *San Joaquin Light & Power Magazine*, December, 1914.

"Electric Operation of Oil Properties," by L. R. W. Allison, *Electrical World*, January 29, 1916.

"Motor Equipments for the Recovery of Petroleum," by W. G. Taylor, *Transactions of the American Institute of Electrical Engineers*, June, 1916.

"Electricity in the Oil Fields," *Electrical World*, December 30, 1916.

"Electricity in the Kansas Oil Fields," by Chas. A. Stanley, *Texas Utility News*, March, 1917.

THE CHARACTERISTICS OF INDUCTION MOTORS AS INFLUENCED BY CHANGES

By J. T. Appleton

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"What effect will this or that change in an induction motor have upon its operating characteristics?" Specific questions of this nature are asked daily by motor designers and users. The following article ably answers such questions as concern the more important features of motor operation; and the clear conception it presents of intricate relationships should make it a valuable article of reference to all who are interested in induction motors.—Editor.

J. T. Appleton

The characteristics of an induction motor are closely inter-related and dependent upon each other.

The design is a balance between the different characteristics, to obtain the most suitable values for each considering the class of service for which the motor is to be employed, and the most economical use of the material of construction.

The following are the characteristics of the induction motor:

Thermal,
Efficiency,
Power-factor,
Starting torque and corresponding starting current,
Full-load torque,
Running torque,
Maximum torque,
Maximum output,
Speed,
Slip.

Fig. 1 shows the characteristic curves for a 30-h.p., 3-phase, 60-cycle, 440-volt, 1200-r.p.m. motor.

By defining the different characteristics and noting the factors upon which each depends, the changes that will occur by variations in these factors can be studied.

An exhaustive analysis of all the functions which occur to cause changes will not be given in this article; however, the principal factors will be explained.

Thermal Characteristics

The thermal characteristic is the temperature rise or the heating of a motor. It is dependent upon the load the motor carries, the time of operation, the losses which occur, and the mechanical construction (particularly the degree of enclosure).

The time of operation or the service can be classified under continuous, short time, *on* or *off* for a certain percentage of time, or in accordance with a predetermined "cycle of duty." The last two classes can be calculated into an equivalent rating by considering the losses which occur with regard to the radiating ability of the machine.

The heat generated by the motor is proportional to the energy lost. The rate at which the machine can dissipate this by conduction, convection, and radiation depends upon the mechanical arrangement and the material of construction.

The energy lost is comprised of that due to the resistance of the winding and to that necessary to magnetize the iron portion of the circuit.

The resistance loss varies with the load and is proportional to the current squared multiplied by the resistance.

The iron loss can be assumed to be independent of the load, but it is dependent upon the applied voltage and the frequency. The core loss varies as the flux and the flux is directly proportional to the applied voltage and inversely proportional to the frequency.

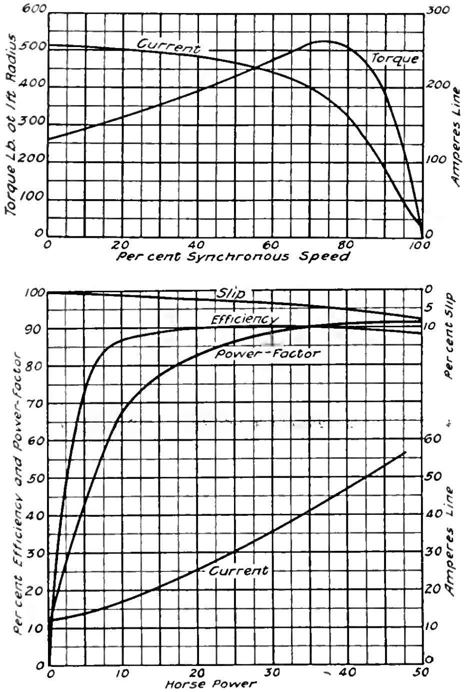


Fig. 1. Characteristic Curves of a 30-h.p., 3-phase, 60-cycle, 440-volt, 1200-r.p.m. Motor

Efficiency

The efficiency is the ratio of the useful output to the total input, or the ratio of the output to the output plus the losses.

The losses in an induction motor are:

- Copper loss, both stator and rotor,
- Core loss,
- Stray load loss,
- Brush friction and brush-contact loss (on motors other than the squirrel-cage type),
- Friction and windage.

The copper loss is proportional to the resistance of the windings and to the current squared. The current depends upon the load, and is inversely proportional to the voltage and to the apparent efficiency.

The core loss of an induction motor is chiefly in the stator. This is because the frequency in the magnetic circuit in the rotor is low and is the frequency of the slip of the motor, while the stator magnetic circuit operates at the full frequency of the supply system.

The core loss is subdivided under two heads, hysteresis and eddy current loss. The hysteresis loss is dependent upon the maximum value of the flux density of the iron in the magnetic circuit, and also upon the quality of the iron. The flux varies directly with a change in applied voltage.

The eddy current loss is due to the iron being an electrical conductor. The loss is reduced as much as possible by careful manufacture and assembly of the punchings. These currents are induced in the laminations by the varying flux. Thus any change in the flux density affects these losses.

The stray load losses include the eddy current loss in the stator copper and those losses which occur due to the flux varying under load. These losses are generally neglected, being small.

Brush friction is practically negligible. The brush-contact loss is equal to the current squared multiplied by the resistance between the brushes and the rings.

Windage and friction are dependent upon the peripheral velocity of the rotor and the rotative speed. The rotative speed or the revolutions per minute depends upon the frequency of the supply system.

Power-Factor

The power-factor of a motor is the ratio of the power to the apparent power, that is, the average value of the product of the instantaneous values of the current and voltage for a complete cycle to the volt-amperes. With sinusoidal current and voltage vectorial, it is the cosine of their difference in phase relation.

The power-factor of an induction motor is dependent upon the magnetizing current and the reactance of the machine.

It can be expressed approximately by the following equation:

$$P\text{-}F. = \frac{1}{\left(1+\left(\frac{IM}{I}+\frac{IX}{E}\right)^2\right)^{\frac{1}{2}}} \qquad (1)$$

The magnetizing current of the motor is the no-load current and is necessary to produce the flux. With a given motor, the flux is directly proportional to the applied voltage and is inversely proportional to the frequency.

The flux determines the ampere-turns necessary for excitation, the turns being fixed. The amperes are dependent upon the flux. The magnetizing current does not vary directly as the flux as it depends upon the degree of saturation of the iron; but, for a slight variation from normal, the current may be assumed to be influenced in the same relation as the flux.

The reactance of an induction motor is a function of the wattless energy component. It is due to the flux which does not cut both the stator and rotor windings and is therefore useless. It can be expressed as the leakage flux.

The reactance depends upon the physical construction of the motor, and is directly proportional to the frequency.

The power-factor therefore depends upon the load current, the applied voltage, the magnetizing current, and the reactance of the machine.

By substituting any changed values of these factors in formula (1), the resultant power-factor change can be observed.

Starting Torque and Current

The starting torque is the torque developed at the instant of starting. It is expressed in pounds at one foot radius or as a percentage of the full-load torque.

It is directly proportional to the resistance of the secondary and inversely as the impedance squared. It also depends directly on the square of the applied voltage, and inversely as the frequency. The torque also depends upon the number of poles and the method of connecting the stator windings. These last two factors are constant for a particular motor.

Assume

T_o equals the starting torque in pounds at 1 ft. radius,

r_1 equals the secondary resistance expressed in terms of the primary circuit,

E equals the applied line voltage,

Z equals the total impedance,

f equals the frequency of the circuit,

p equals the number of poles.

For a particular motor let K equal P multiplied by r_1 and by the factor for the stator connections.

Then

$$T_o = \frac{CK}{f} \frac{(E)^2}{(Z)^2} \tag{2}$$

where C equals a constant.

The impedance Z is equal to the square root of the total resistance per phase of both stator and rotor (R) squared plus the reactance (X) squared.

Thus

$$Z = \sqrt{R^2 + X^2} \tag{3}$$

The reactance X equals $2 \pi f L$ where L is equal to the inductance in "henries."

Thus

$$T_o = \frac{CK (E)^2}{f R^2 + 39.5 (f)^3 L} \tag{4}$$

Therefore the starting torque varies directly as the voltage squared and inversely as the frequency to the first power and the third power.

The starting current is equal to the voltage per phase divided by the impedance.

If in a wound-rotor type motor external resistance is added per phase in the rotor, which can be short circuited when up to speed, the impedance is increased and the starting current reduced.

Full-Load Torque

The full-load torque is expressed in pounds at one foot radius. It is the torque corresponding to the horse power exerted by the motor at one foot radius if it were running at synchronous speed.

If T equals the torque, then

$$H.p. = \frac{T \times \pi \times 2 \times r.p.m.}{33{,}000} \tag{5}$$

or

$$T = \frac{5250 \times h.p.}{r.p.m.} \tag{6}$$

Where r.p.m. equals revolutions per minute because one h.p. equals 33,000 feet per minute, the torque of the motor exerted at one foot radius travels through π multiplied by the diameter of the circle, which is 2 feet every revolution.

Running Torque

The running torque is the torque that would be developed by a motor at any speed. A motor operates at a speed between synchronism, and the speed at which maximum torque occurs, or on the stable part of the curve.

Thus, if the load to be carried by the motor is in excess of the running torque developed, it slows down until it reaches the speed at which there is sufficient torque to carry the load.

The running torque of a motor is dependent upon the voltage applied, the frequency, the resistance of both stator and rotor, and the reactance.

Assume

T_r equals the running torque,
s equals the percentage slip,
r_o equals the primary resistance.

Then

$$T_r = \frac{C\ (K')\ (E)^2}{f} \, \frac{r_1 s}{(r_1 + s\ r_o)^2 + s^2 X^2} \qquad (7)$$

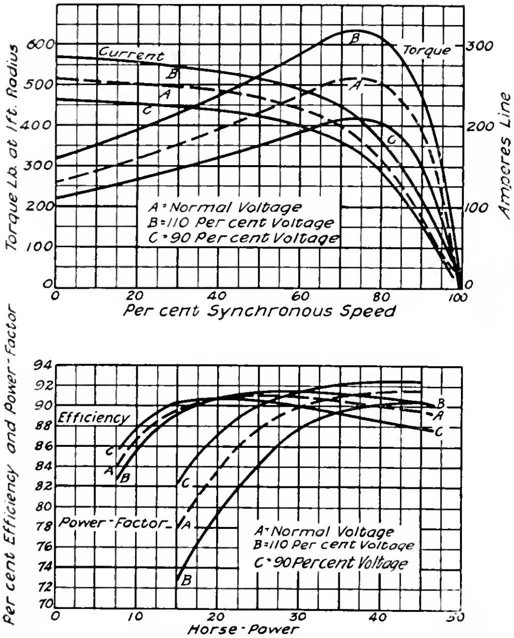


Fig. 2. Characteristic Curves at 10 per cent above and below normal voltage for the motor named in Fig. 1

Where K' equals the number of poles multiplied by the factor for the stator connections.

Maximum Torque

As the name implies, it is the maximum torque the motor is capable of exerting. It is directly proportional to the voltage squared, inversely proportional to the frequency, and inversely to the stator resistance and the total reactance.

If T_M equals the maximum torque, then

$$T_M = \frac{C'K'E^2}{f} \, \frac{1}{r_o + (r_o^2 + X^2)^{\frac{1}{2}}} \qquad (8)$$

Maximum Output

This is the maximum horse power the motor can exert and is different from the maximum torque and takes place at a different speed.

It is directly proportional to the applied voltage squared and is inversely dependent upon the total resistance and impedance of the motor.

Speed

The speed of a motor in revolutions per minute depends upon the number of poles and the frequency.

Thus

$$r.p.m. = \frac{120 \times f}{\text{number of poles}} \qquad (9)$$

Slip

The slip is the difference between the speed of the rotating field of the motor and the rotative speed of the rotor. It is proportional to the rotor resistance. At the same load it varies inversely as the applied voltage squared.

The voltage and frequency changes in the supply system are the most common in practice. Successful operation may be obtained provided the total variation of both voltage and frequency from the normal does not exceed 10 per cent.

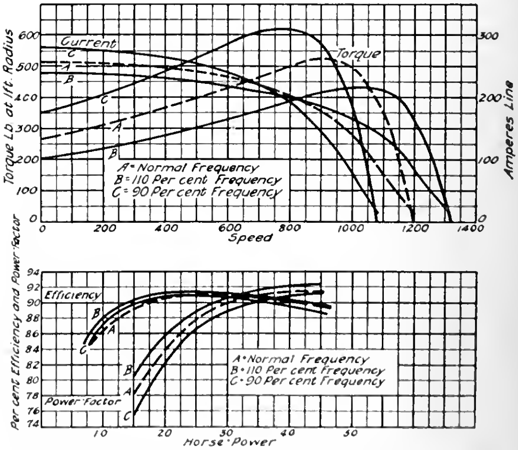


Fig. 3. Characteristic Curves at 10 per cent above and below normal frequency for the motor named in Fig. 1

Fig. 2 illustrates the variation in characteristics of the motor shown in Fig. 1 with 10 per cent greater voltage, and 10 per cent less voltage applied.

Fig. 3 shows the result of a 10 per cent variation in the frequency.

SYNCHRONOUS PHASE CONVERTERS

By E. S. Henningsen

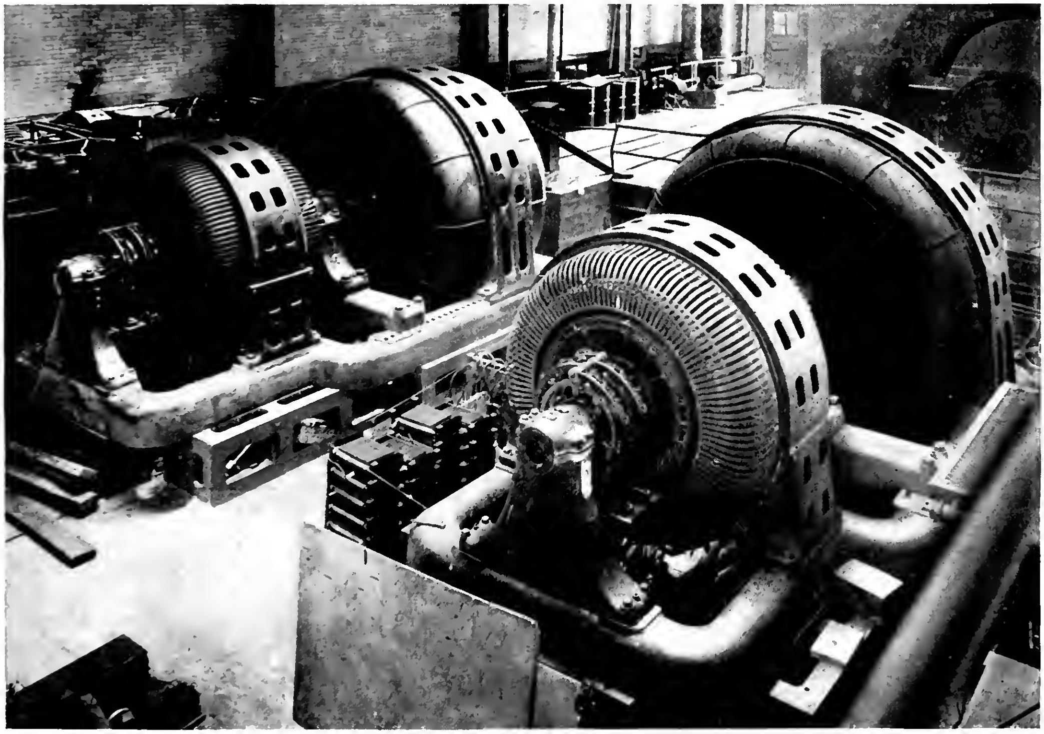
Alternating Current Engineering Department, General Electric Company

The heating of generators and unbalancing of voltages resulting from the connection of heavy single-phase loads, such as railway and electric furnace feeders, to polyphase systems created an urgent demand for apparatus to distribute such loads between the phases. The synchronous phase converter has been developed to relieve this condition, and its operation in units as large as 5000 kv-a. had been a thorough success. Mr. Henningsen discusses briefly the theory of the two types of synchronous converters, viz., the series-phase converter and the shunt converter, and indicates the fields of usefulness of each type. A comparison between these two types as regards simplicity, efficiency, and first cost, and between other means of supplying an equal amount of single-phase power concludes the article.—Editor.

E. S. Henningsen

The development of the synchronous phase converter as a practical machine marks the advent of a new type of synchronous apparatus as distinct as the series a-c. motor or the synchronous converter. Its practicability is attested to by the fact that two sets of 5000 kv-a. each have been operating since last October at the plant of the Philadelphia Electric Company, converting a single-phase railroad load the peaks of which often reach 24,000 kv-a.

The function of a phase converter set is to restore balance to a polyphase system which has become unbalanced by a single-phase load on one or more phases. This is accomplished by causing a certain phase (or phases) to act as a generator, while the other phases (or phase) act as a motor; the latter drawing from the lines to which they are connected the same power that the generator phase supplies to the line to which it is connected. The machine which executes this motor-generator action is called the "phase converter." When the electromotive forces that cause the phase converter to perform such a conversion are generated within the phase



Two 5000-kv-a. Synchronous Phase Converter Sets, Philadelphia Electric Company converter itself—in other words, when only one machine is used—it is called a "series phase converter." When an auxiliary generator is used to supply the proper electromotive forces, the set is called a "shunt phase converter" and the auxiliary generator is called a "phase voltage balancer."

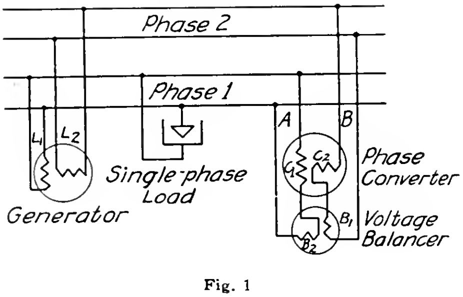


Fig. 1

Since the theory of phase balancing has been taken up in considerable detail in other articles (see reference p. 498) it will be only briefly considered here.

The Shunt Phase Converter

Consider a system, shown diagrammatically in Fig. 1, consisting of a quarter-phase generator and a phase converter set. Let the frame of the voltage balancer be set in such a position that its generated voltages are exactly in phase with those of the converter, and the set running light with the phase converter as a motor. Then in Fig. 2 the vector E_{L1} represents the maximum of the voltage of either phase L_1 or C_1. Likewise E_{L2} is the vector of the voltage of phase L_2 or C_2. If excitation is applied to the field of the voltage balancer, the voltage e_{B1} will be generated in phase B_1, and on account of the way the connections are made, will reach its maximum 90 deg. later than E_{L2}. Hence E_B represents the voltage of phase B. This voltage lags the line voltage by the angle ϕ. Hence phase B acts as a motor drawing power from phase 2 line. Likewise the voltage e_{B2} is generated in phase B_2, which, when combined with the voltage of phase C_1, gives the resultant E_A as the voltage of phase A. But E_A leads the line voltage E_{L1} by the angle ϕ; hence phase A acts as a generator supplying power to phase 1 line. Suppose a single-phase load of W kilowatts to be taken from phase 1, as shown in Fig. 1, and that the phase and magnitude of the voltage balancer voltages are adjusted so that phase A supplies $W/2$ kilowatts as a generator and phase B draws (neglecting losses) $W/2$ kilowatts as a motor. The generator must then supply $W/2$ kilowatts on each phase, or in other words, the generator will have a balanced two-phase load.

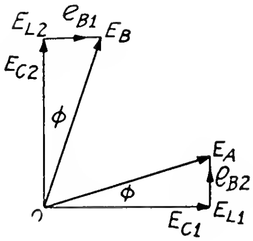


Fig. 2

In considering how a single-phase load is balanced on a three-phase system, the problem may be thought of either as a matter of supplying the proper currents or the proper voltages. Considering the voltages first; if a single-phase load at unity power-factor is taken from say phase 1-2 of a three-phase system, and this voltage (1-2) held constant by means of a voltage regulator, the voltages will of course be unbalanced and will take the position 1-2-3_a, Fig. 3. If by the addition of some external voltages, an unbalancing such as 1-2-3_b could be produced at no load and with 1-2 held constant, then the two unbalancings working together would neutralize and leave the balanced condition 1-2-3. Fig. 4 represents the vectors of the maximums of the phase voltages making up the triangle 1-2-3. Suppose the Y point to be opened for the insertion of the small voltages X_1, X_2 and X_3, as in Fig. 5, and suppose the connections to be made so that X_2 adds to E_2, X_1 to E_3, and X_3 to E_1. Then the resulting triangle is as shown in Fig. 6. Decreasing all voltages until 1-2 in Fig. 6 is equal to 1-2, Fig. 3, and transferring the triangle to Fig. 3, it will be found that the triangle 1-2-3

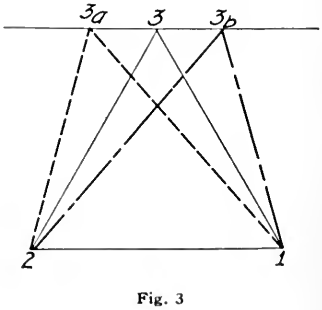


Fig. 3

Fig. 6, is identical with 1-2-3, Fig. 3. The voltages X_1, X_2 and X_3 can be obtained from a small machine (the voltage balancer) in series with the phase converter and connected, as in Fig. 7, so that the voltages add up correctly. It is easily seen that to balance any distortion caused by a single-phase load of any power-factor, simply means giving the voltages X_1, X_2 and X_3 the proper magnitude and phase position.

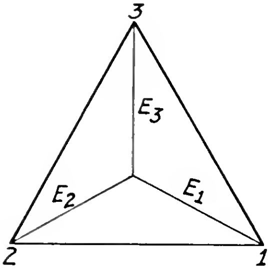


Fig. 4

Considering the problem from the standpoint of the currents, assume that by the addition of external currents of proper magnitude and phase the system can be balanced. It is then possible to construct the vector diagram from which the magnitude and phase of the necessary currents can be determined. Since the three-phase power must equal the single-phase load (neglecting losses) the three-phase current must equal the single-phase current divided by $\sqrt{3}$. The power-factor of the three-phase will of course be the same as the single-phase. The vector diagram of the system shown in Fig. 7, is represented in Fig. 8. E_1, E_2 and E_3 represent the maximums of the phase voltages of the generator, and I_1, I_2 and I_3 the maximums of the phase currents. I_{s1} is the vector of the single-phase current when flowing into the load from line 1 and I_{s2} when flowing into the load from line 2. The three-phase current lags the phase voltage by the same angle θ that the single-phase current lags its voltage. In order to complete the diagram it is necessary to add a current in line 1 equal to but reaching its maximum 60 deg. earlier than I_1, a current in line 2 equal to but reaching its maximum 60 deg. later than I_2, and a current in line 3 equal to but 180 deg. ahead of I_3. It will be noted that the diagram resolves into two equal, balanced, three-phase systems, but of opposite phase rotation. If, therefore, the phase converter can supply three-phase currents of opposite phase rotation, then any single-phase load can be balanced, providing these currents have the proper magnitude and phase. To obtain these currents suppose the rotor of the converter to be stationary and the balancer to be running with excitation on the field. There will be three-phase currents

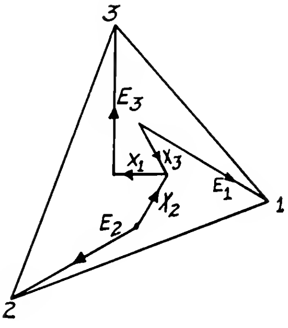


Fig. 5

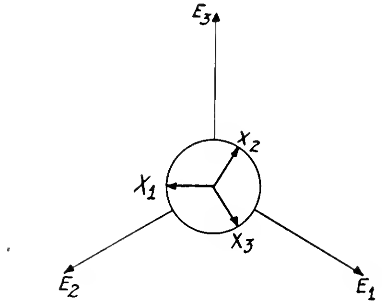


Fig. 6

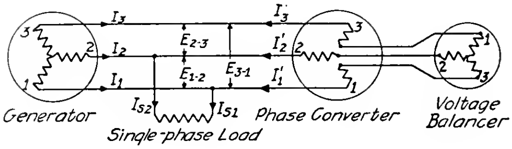


Fig. 7

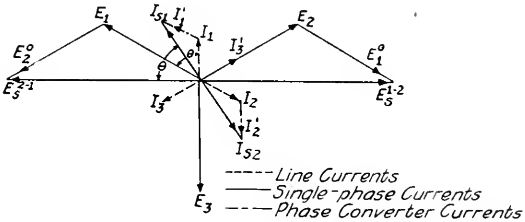


Fig. 8

induced in the converter squirrel cage, the magnitude of which will depend upon the impedance of the converter windings and the excitation on the balancer. If the rotor of the converter is now rotated against the phase rotation of the balancer, these currents remain the same as at standstill because the impedance increases with the frequency in the same way that the induced voltage does. These currents have a phase rotation opposite to that of the line because of the way in which the connections are made (see Fig. 7). When the set is running on the line the converter acts as an ordinary synchronous motor or condenser, and as soon as excitation is put on the balancer, currents of opposite phase rotation are induced in the squirrel cage. There are, therefore, two three-phase systems of opposite phase rotation in the phase converter, and as already shown the resultant of two such systems is a single-phase system. It is again only a question of giving the phase balancer the proper phase position and excitation to balance any single-phase load.

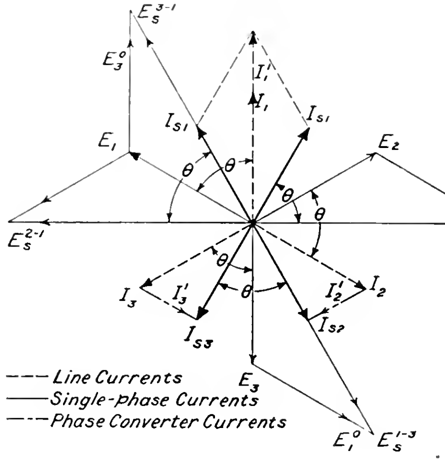


Fig. 9

Suppose in addition to the load in Fig. 8, there is an equal load on phase 2-3. Then the vector diagram will be as in Fig. 9. The single-phase current vectors are I_{s1} I_{s2} and I_{s1} I_{s3} lagging the single-phase voltages by the angle θ. Since, neglecting losses, the single-phase power $2E_{1-2}\ I_s$ must equal the three-phase power $\sqrt{3}\ E_{1-2}\ I$, the three-phase currents must equal $2/\sqrt{3}\ I_s$ and must lag their phase voltages by the angle θ. Hence I_1, I_2 and I_3 represent the maximums of the balanced three-phase currents. To complete the diagram it is necessary to supply I^1_1, I^1_2 and I^1_3. These then, are the phase converter currents and are equal in magnitude to the currents necessary to balance only one of the loads, as found in Fig. 8. Hence to balance either one single-phase load, or equal loads on each of two phases, requires a phase converter of the same size. However, the phase of the currents in the two cases is different.

The Series Phase Converter

Inherently, the series phase converter is a two-phase machine, and when used to convert three-phase to single-phase, an equivalent T-connection must be resorted to. This means the introduction of an auto-transformer. However, this auto-transformer need be only about 29 per cent of the size of a transformer whose rating corresponds to the single-phase load.

The general idea of the conversion can be easily seen from the connections, Fig. 10. Phase B of the phase converter is reversed with respect to phase A and is directly in series with the single-phase load. Phase A acts as a motor driving the converter and supplying energy for the generator phase B. The voltage generated in phase B will be the same as the line voltage; hence the voltage across the single-phase load will be the line voltage plus the phase converter phase voltage, or twice the phase voltage of the line. If phase A and B carry the same current, I, then the two-phase power is $2E_pI$. The single-phase load current must also be I, but the voltage is $2E_p$. Hence the single-phase power is $2E_pI$, equal to the two-phase power but the two-phases are equally loaded.

Fig. 11 shows the connections for three-phase to single-phase conversion. The current, voltage and power relations are as follows:

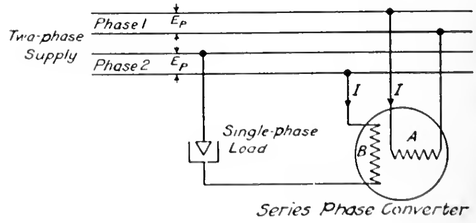


Fig. 10

	VOLTAGE		CURRENT		POWER
Phase A of ph. conv. . .	1.73	×	1	=	1.73
Phase B of ph. conv. . .	1	×	1.73	=	1.73
Single-phase	2	×	1.73	=	3.46
Three-phase	2	×	$1 \times \sqrt{3}$	=	3.46
Auto-transformer	2	×	1	=	2

The two-phases of the series converter are wound for different voltages, since the voltage impressed on the motor phase (*A*) is 1.73 times the voltage generated in the generator phase (*B*).

Applications

Since one phase of the series phase converter is in series with the single-phase load, this type of converter can only be used to balance load on one phase. If load is taken from a second phase, a second series converter will be required. In addition the capacity of such a unit must be the same as the single-phase load. However, with a single-phase generator the same thing applies—the capacity must be equal to the load and it can supply only one-phase. The cost of the series converter will be lower and the efficiency higher, than if a single-phase motor-generator or turbo-generator were used. The control apparatus required with the series converter is simple and cheap, requiring only that the machine be started up and synchronized as an ordinary synchronous motor in the smaller sizes, or by means of an auxiliary starting motor in the larger sizes. One phase is then reversed, after which the single-phase line switch may be closed. The balancing is automatic at all loads, there being of course a slight drop in voltage with the load due to the impedance of the converter windings.

While the control apparatus for the shunt phase converter is rather costly, the flexibility of such a machine is so great that in most cases it is to be recommended rather than the series type. Any amount of load at any power-factor may be taken from any or all of the phases of the polyphase system, and so long as the resulting unbalancing does not exceed the capacity of the set, balance will be automatically and practically instantaneously restored. For instance, if in a particular installation it is desired to operate one, two, or three 5000-kv-a. single-phase loads from a three-phase system, it would be necessary to use either a 15,000-kv-a. series phase converter, a 15,000-kv-a. single-phase generator, (either part of a motor-generator set or a turbo-generator) or a 5000-kv-a. shunt phase converter. By installing a complicated switching arrangement it might be possible to use a 10,000-kv-a. series phase converter or single-phase generator, and operate directly from the three-phase lines when all three of the loads were on. The 5000-kv-a. shunt phase converter would balance one, two or three of the loads as desired, because, as shown in Fig. 9, the phase converter currents when balancing equal loads on two phases are the same as when balancing only one such load. In addition, if at any time it was desired to add more single-phase load, the same shunt converter would take care of the unbalancing, providing the load could be distributed so that the net unbalancing was not greater than 5000 kv-a. No such arrangement would, of course, be possible with a series phase converter or single-phase generator. For this reason it is difficult to really compare the various machines that may be used for supplying a single-phase load. Table No. 2 has been prepared giving comparative costs and losses of phase converter, a motor-generator set, and a single-phase turbo-generator to supply 5000 kv-a. single-phase load. The exciter capacity and control apparatus is included. However, the comparison is hardly fair to the shunt phase converter because, as noted above, this same machine could be used if a second and a third block of 5000 kv-a. single-phase power were required at any future time.

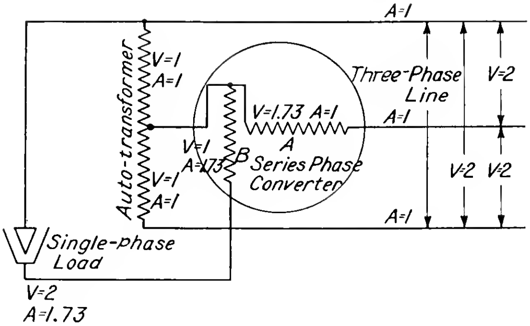


Fig. 11

	Losses	Cost
Shunt converter set	100	100
Series converter set without auto transformer	85	65
Three-phase motor, single-phase generator	186	118
Single-phase turbo-generator	123	96

Another consideration in favor of the shunt phase converter is the fact that wattless kv-a. can be obtained for power-factor correction exactly as in the case of a synchronous condenser. To supply an amount of wattless kv-a. equal to the kv-a. of the single-phase load, would increase the size of the phase converter about 60 per cent. No power-factor correction is possible with the series phase converter because one phase is reversed with respect to the other.

In conclusion, the field of application of the series phase converter is rather restricted, being limited to installations of single loads on one phase only. It possesses the advantages of being cheap, highly efficient, requires no expensive control apparatus, and its operation is automatic and most satisfactory. The shunt converter on the other hand automatically balances any kind of load on one or all phases. Whether the load be steady, or fluctuating rapidly and of varying power-factor as in the case of a single-phase railway load, the restoration of balance is practically instantaneous. Some doubt has been expressed as to the possibility of perfecting a control equipment that would be extremely sensitive to slight voltage changes and still allow no hunting between the control elements. However, the operation of the equipment at the plant of the Philadelphia Electric Company has proved that a perfectly satisfactory control has been developed that responds instantly to slight unbalancing of currents without any hunting of the regulators.

Reference:

W. J. Foster, *Power*, November 28.

E. F. Alexanderson and G. H. Hill, Proc. A.I.E.E., October, 1916.

R. E. Gilman, C. LeG. Fortesque, Proc. A.I.E.E., October, 1916.

5000 Kv-a. Shunt Phase Converter

ALTERNATING-CURRENT SINGLE-PHASE COMMUTATOR MOTORS

By L. F. Adams

Power and Mining Engineering Department, General Electric Company

This article constitutes a very comprehensive treatise on the theory and operating characteristics of the common types of single-phase commutator motors. All of these motors may be grouped under two headings, viz., those having characteristics similar to the direct-current series motor and those having characteristics similar to the direct-current shunt motor. A brief description is given of the commercially available motors of both classes; the main purpose of the article, however, being to describe in detail the characteristics of the five types of single-phase commutator motors as manufactured by the General Electric Company, which may be designated as the plain series motor, the plain repulsion motor, the varying speed brush shifting motor, the repulsion starting induction motor, and the repulsion induction motor. The discussion is entirely free from mathematics and a clear knowledge of the principles of each type is easily obtained with the aid of the numerous diagrams and characteristic curves.—Editor.

L. F. Adams

SINGLE-PHASE commutator motors were known before the polyphase induction motors found their enormous application in the electrical field, but on account of inherent troubles due to commutator wear and sparking of the brushes they had found no commercial field of usefulness. The advent of the induction motor turned the attention of investigators from the commutator motor and a number of years elapsed before this type of motor received any further attention. During the period of 1894 to 1900, the demand for a practicable single-phase power motor having good characteristics, during both starting and running, caused various engineers to take up actively the development of a commercially satisfactory single-phase motor. The efforts of developing the single-phase commutator motor necessarily resulted in a great many varieties which in general may be grouped into two classes, as follows:

(a) Those motors in which the resultant magnetomotive force providing the flux increases with the load. When operated from a source of constant potential the speed of such motors decreases with increasing load. They are termed series motors from the similarity of their characteristics to those of series-wound direct-current motors.

(b) Those motors in which the resultant magnetomotive force providing the flux is substantially constant, irrespective of the load. When operated from a source of constant potential the speed of such motors is approximately constant. The speed may, however, be increased or decreased (independently of the load) by increasing or decreasing the voltage at the terminals of the motor, or by the provision of suitably disposed and connected auxiliary coils. Such motors are termed shunt motors.

Motors with Series Characteristics

(*1*) *Plain Series Motors.* This motor, Fig. 1, consists of a direct-current armature and a laminated field whose winding is distributed in slots like the ordinary induction motor stator. The armature and field are in series. This motor has a relatively poor power-factor.

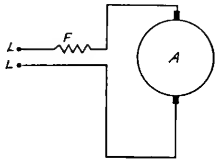


Fig. 1. Circuit of Plain Series Motor

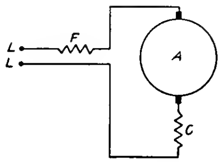


Fig. 2. Circuit of Conductively-compensated Series Motor

(*2*) *Conductively-Compensated Series Motors.* This motor, Fig. 2, consists of a direct-current armature and a laminated field like the plain series motor, and in addition a compensating winding connected through one set of brushes in series with the main winding. The magnetomotive force of the compensating winding is in the same space phase as the magnetomotive force of the armature but in the opposite direction and thus improves the power-factor.

(*3*) *Inductively-Compensated Series Motor.* This motor, Fig. 3, contains the same windings as those of Fig. 2, but here the compensating winding is short circuited. Compensating currents are induced in the short-circuited compensating coil just as current is induced in the short-circuited secondary of a transformer. As in Fig. 2, the action of the compensating winding is opposite, but in the same space phase as the armature and therefore results in an improved power-factor.

Conductive compensation is preferable, as it permits control and adjustment of the compensating magnetomotive force, and therefore, when desirable, over compensation can be obtained.

(*4*) *Plain Repulsion Motor* (*Thomson Motor*). This motor, Fig. 4, consists of a laminated field and a direct-current armature upon which a pair of brushes are short-circuited. These brushes are given a location some fifteen or twenty degrees from the space phase of the magnetomotive force of the stator winding. No electrical connections exist between primary and secondary windings. The motor has the characteristics of a series motor in that its speed decreases with increasing load.

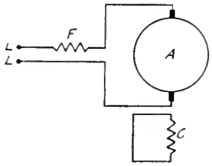


Fig. 3. Circuit of Inductively-compensated Series Motor

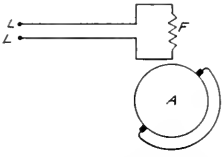


Fig. 4. Circuit of Plain Repulsion Motor (Thomson Repulsion Motor)

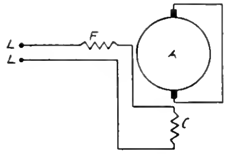


Fig. 5. Circuit of Atkinson's Repulsion Motor

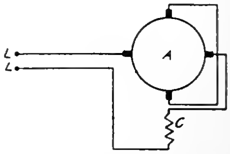


Fig. 6. Circuit of Compensated Repulsion Motor. (La Tour, Winter and Eichberg)

(5) *Atkinson's Repulsion Motor.* This motor, Fig. 5, is derived from the Thomson repulsion motor by replacing the stator winding by the windings at right angles to each other, the space phase of the resultant magnetomotive force being at an angle to the brushes.

(6) *Compensated Repulsion Motor. (LaTour, Winter and Eichberg).* This motor, Fig. 6, is derived from the Atkinson repulsion motor, Fig. 5, by eliminating the field winding from the stator circuit and making the armature winding assume its function by means of two auxiliary brushes.

(7) *Compensated Repulsion Motor with Transformer, (Winter and Eichberg).* It would not be convenient to wind the armature of Fig. 6 with the particular number of turns which is suitable for the field excitation. Consequently, it becomes necessary to supply the excitation from the secondary of a transformer whose primary is in series with the compensating winding, Fig. 7. This arrangement has the further useful feature of permitting speed control by varying the point at which the field excitation circuit is tapped off from the secondary of the transformer.

(8) *Déri Brush Shifting Motor.* In this motor, Fig. 8, the speed is varied by varying the position of the brushes. Two of the brushes which lie in the axis of the stator winding are fixed in position. The other two brushes are mounted on a movable yoke. For any given brush position the speed decreases with increasing load. Thus the motor has series characteristics.

Motors with Shunt Characteristics

(9) *The Arnold Repulsion Starting Induction Motor* consists of a single-phase stator and a direct-current armature. The connections at starting are those for a repulsion motor, as shown in Fig. 4, the brush axis standing at an angle with the axis of the stator winding and the brushes being short-circuited. This connection gives high torque at starting. When a certain speed is attained a centrifugal governor acts to short-circuit all the commutator segments, and in some cases to remove the brushes from the commutator. The motor then operates like a squirrel-cage induction motor and maintains approximately constant speed at all loads.

(10) *The Schuler Motor* consists of a single-phase stator and a direct-current armature, carrying on one side a commutator and on the other side three collector rings. The motor starts up as a repulsion motor and when up to one-half speed the polyphase resistance connected to the armature through the slip rings is thrown in, and is gradually short-circuited as on a slip ring induction motor as the commutator runs up to full speed. The brushes on the commutator are not completely short-circuited, but have a fixed resistance interposed between them.

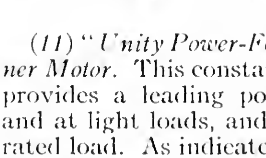


Fig. 7. Circuit of Compensated Repulsion Motor Supplied from a Variable Ratio Transformer (Winter and Eichberg)

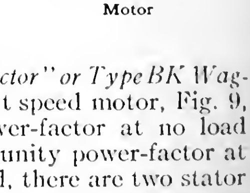


Fig. 8. Circuit of Déri Brush Shifting Motor

(11) *"Unity Power-Factor" or Type BK Wagner Motor.* This constant speed motor, Fig. 9, provides a leading power-factor at no load and at light loads, and unity power-factor at rated load. As indicated, there are two stator windings; viz., the main one, *F*, producing the initial field magnetization, and the other one, *C*, controlling the power-factor or compensat-

ing the motor. During starting the switch (2) is open so that only the stator winding *F* is in circuit. The motor consequently starts up with good torque as a series motor. The rotor slot design is shown in Fig. 10. During starting the squirrel-cage winding (3) is more or less inert, as it is protected by the magnetic bridge (4) shown in Fig. 10. The upper winding (5) in Fig. 10 is called a "commutated" winding, and is simply a direct-current winding connected to a commutator in a manner usual in direct-current motor armatures. As speed is acquired the activity of the squirrel-cage increases, and it contributes a torque which increases very rapidly as synchronism is approached, but falls suddenly to zero at or near actual synchronism. An automatic switch (2) controlled by centrifugal force closes the circuit of the compensating winding *C* when a sufficient speed has been obtained. If connected to tap (6) in the compensating winding the motor will operate with unity power-factor under most loads. If the end of the compensating winding (7) is connected to the switch (2) then the motor will operate with leading power-factor at no load and with unity power-factor at full load. An interesting magnetic bridge construction which has also been used in this motor is shown in Fig. 11.

(*12*) *General Electric Company's Repulsion Induction Motor, Type RI.* This motor, Fig. 12, consists of a single-phase stator and a direct-current armature with two sets of brushes on the commutator, one set of which is short-circuited and the other pair connected to the compensating winding.

Numerous other combinations of series and shunt motors have been proposed and in some cases actually built either in this country or abroad, but it would be futile to undertake here an enumeration of the dozens of variations in the above fundamental types of single-phase commutator motors.

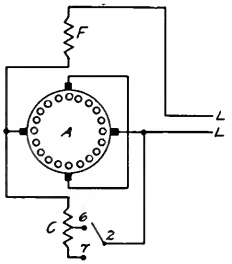


Fig. 9. Circuit of "Unity Power-factor," or Type BK Wagner Motor

The General Electric Company at present build five of the types of motors briefly outlined, and this paper will be confined to a discussion of the theory and characteristics of these five types of motors.

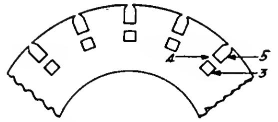


Fig. 10. Laminated Magnetic Bridge Between the Two Rotor Windings

Fig. 11. Inductively Responsive Magnetic Bridge Between the Two Rotor Windings

1. The plain series motors, Type SDA.
2. The plain repulsion motor, Type R.
3. The varying speed brush shifting motor, Type BSS.
4. The repulsion starting induction motor, Type RSA.
5. The repulsion induction motor, Type RI.

The Plain Series Motors, Type SDA

The plain series wound single-phase motor closely resembles the ordinary continuous current motor and is used on both single-phase and continuous-current circuits. The difference between the ordinary continuous-current and the single-phase types are partly constructural, partly differences of design. It is obvious that, in order to prevent excessive eddy current losses and to enable the field

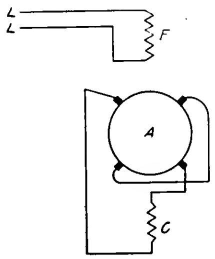


Fig. 12. Circuit of General Electric Company, Type RI, Motors

magnet to develop its full magnetic flux, the core of the field magnet must be laminated throughout.

In Fig. 13, (Fig. 1 reproduced) is given the diagram of connections of a plain series wound single-phase motor.

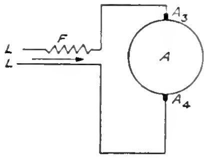


Fig. 13. Circuit of Plain Series Motors

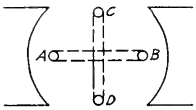


Fig. 14. Position of Coil in Field

A is the armature, F the field winding and L, L, the line terminals. The arrow indicates the direction of the field flux which, as in a continuous-current motor, is at right angles to the line of the brushes.

Since in this type of motor the armature is connected in series with the field it is obvious that the armature and field currents must necessarily be in phase with each other, so that the armature current reaches its maximum value at the instant of maximum field intensity. So long as the iron is well below saturation, i.e., within the range of approximately constant permeability, the torque at any instant is proportional to the square of the current. From this it follows that the motor will exert equal torque when supplied in one case with continuous current of amount i, and in another with single-phase current whose root mean square value is i. In the first case, however, the torque is a steady one; in the second, a rapidly fluctuating or pulsating one.

Although the series motor on alternating-current circuits operates on the same principles as the corresponding direct-current motor, several things happen inside the motor when fed by alternating current, by reason of the varying magnetic field produced thereby, that are not found in the direct-current motor. The characteristics of the alternating-current motors are:

1. An electromotive force generated in the armature winding by the alternating magnetic field, in addition to the electromotive force generated by the rotation of the armature.

2. A local current circulating in the armature coils short-circuited by the brushes, due to the electromotive force in (1).

3. An iron-loss occurring in the entire magnetic circuit due to alternating magnetic field.

4. An active electromotive force existing between the turns of the field coils—what may be called the counter electromotive force of the field coils.

1. *The electrically-generated electromotive force.* With an alternating field there are two distinct electromotive forces generated in the armature coils; the first by the movement of the coil through the field with a maximum value when the coil is in the position AB (Fig. 14) and a zero value in the position CD; and the second by the alternating magnetism, with the maximum value occurring when the coil is in the position CD and a zero value in the position AB. The first, or mechanically-generated electromotive force, is proportional to the speed; the second, or electrically-generated electromotive force, is proportional to the current frequency. While these two electromotive forces exist in the armature winding, only one, viz., the mechanically-generated electromotive force, appears at the terminals of the motor. The reason for this is shown by Fig. 15. In this sketch the directions of the electromotive forces in each part of the winding, at one instant, are shown by the arrows, the full arrows representing the mechanically-generated electromotive force and the dotted arrows the electrically-generated electromotive force. On the two sides of the line CD the mechanically-generated electromotive force is in opposite directions, and on the two sides of the line AB the electrically-generated electromotive force is in opposite directions. It is evident from Fig. 15 that so far as the outside circuit is concerned the electrically-generated electromotive force neutralizes itself and plays no part in determining the current taken by the motor. This is only true when the brushes are on the neutral points. The electrically-generated electromotive force is of only theoretical interest, except for its effect on the armature coil short-circuited by the brush, as explained in the following paragraph.

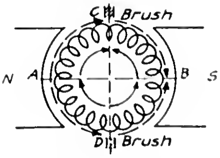


Fig. 15. Distribution of Electromotive Forces in Armature

2. *The local armature current.* At each brush there is a local circuit in which the electrically-generated electromotive force is

not neutralized. A current results which, if not prevented, affects commutation and increases the motor loss. Fig. 16 shows this local circuit made up of an armature coil and the brush. It is seen that when the coil is short-circuited by the brush it is in the position of maximum value of the electrically-generated electromotive force, corresponding with the position *CD* (Fig. 14). This local circuit may be compared with the short-circuited secondary of a transformer, of which the field is the primary. The loss occasioned by the local current appears as a part of the energy component of the field voltage, the action being the same as in a transformer.

3. *The alternating current iron loss.* The total iron loss occurring in the motor may be divided in two parts—that occurring in the armature and pole-faces due to the rotation of the armature, and that occurring in the entire magnetic circuit due to the alternating magnetic field. The former is analogous to the iron-loss occurring in a direct-current motor, and for that reason may be called the direct-current iron loss. It is supplied mechanically, its effect being to increase the frictional torque of the motor. The latter will be called the alternating current iron loss. This is supplied electrically by an increase in the energy component of the voltage of both armature and field.

4. *The counter electromotive force of the field coils.* The three properties of the alternating current motor, already considered, are chiefly of interest to those concerned with the design of the motor. For instance, the presence of an electromotive force in the coil short-circuited by the brush introduces a problem for the designer to solve, and when he has solved it, its action is of no further importance. On the contrary, the existence of a generated electromotive force in the field coils is a thing with which the man who operates the motor is very actively concerned. The field coil of the alternating current motor is simply a choke coil, and has generated in it the familiar counter electromotive force of self-induction. This counter electromotive force affects the operation of the motor in two ways:

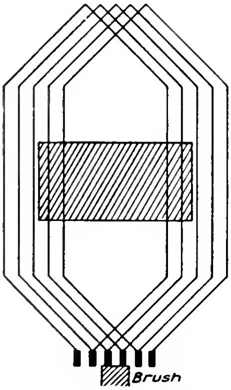


Fig. 16. Local Circuit Consisting of Coil and Brush

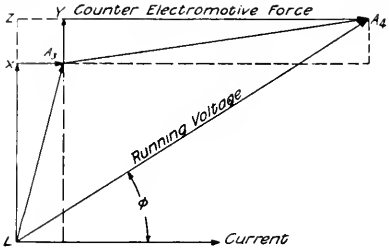


Fig. 17. Voltage Diagram of the Plain Series Motors

(A) It introduces a voltage in the alternating-current motor that is not present in the direct-current motor, which increases the total voltage required to run the motor, particularly at starting. This voltage, however, is very nearly at right angles with the armature voltage, so that the different voltages are not directly added and subtracted; that is, the numerical sum of the armature voltage and field voltage is not equal to the total voltage of the motor, as measured across the terminals.

(B) It increases the seriousness of a short circuit in the field coil. With direct current a short circuit simply means cutting out the short-circuited turns; it does not usually put the motor out of service. With alternating current, however, it is obvious that this counter electromotive force will cause a destructive current to flow in the short-circuited turns, burning them out and opening the motor circuit. This is taken care of in the motor by additional insulation in the field coils.

A more detailed explanation of these effects can be made most clearly by a diagram of the motor voltages.

Fig. 13 represents the motor circuit and Fig. 17 the voltage diagram. The two sketches are similarly lettered, so that the line L-A_3 in Fig. 17 represents the voltage across the field F in Fig. 13. Starting at one terminal L, and with the direction of current as shown, the field voltage is the line L-A_3. It is made up of two components, the electromotive force used in overcoming the counter electromotive force of self-induction L-X, and the electromotive force representing the losses supplied by the field X-A_3; or, in other words, of the inductive component L-X, and of the energy component X-A_3. It is seen that the energy component is small compared with the inductive component, which makes the field voltage nearly 90 degrees ahead of the current. The line A_3-A_4 is the armature voltage. This is also the resultant of energy and inductive components A_3-Y and Y-A_4. In the armature the energy component is larger, since it represents, in addition to the armature losses, the energy transformed into mechanical work. It is also seen that the armature self-induction is small compared with that of the field. The total voltage of the motor is L-A_4 and is the resultant of the field and armature voltages. It is considerably smaller than their numerical sum. The total voltage is also the resultant of the total induction component, L-Z, and of the total energy component Z-A_4. The angle ϕ represents the phase difference under running conditions.

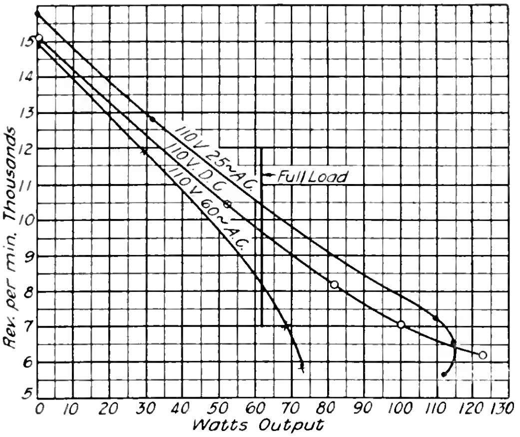


Fig. 18. Output Curves of ½ h.p., 8000 r.p.m., 110-volt Universal Motor

These motors are especially adapted for high speed work in connection with any appliance requiring high speed operation. Unlike shunt or induction motors where speeds are nearly constant for all loads, the speed of series motors varies with the load, the no-load speed usually being limited by the designer to from 2½ to 4 times the full load speed. The Type SDA motors are rated at full-load speed, and therefore if a motor runs slow it is almost a certain indication that it is overloaded, provided the voltage and frequency of the circuit are correct. If the motor runs too fast it is probably underloaded. The curves shown in Fig. 18 show the variations in speed with different outputs for the motor operated on a direct-current circuit and on 25 and 60 cycles alternating-current circuits.

In a series motor an increase in the frequency of the circuit will cause a decrease in the speed, and an increase in voltage of the circuit will cause an increase in speed. Since this is true, it is evident that a series motor to run at its rated speed must be applied to a load which is very close to that for which it is rated, and furthermore, that the load should be approximately constant. If a device does not necessarily have to be operated at a certain speed, it is not necessary to use as much care in selecting the horse power rating of a Type SDA motor; but on the other hand, if a definite speed is required it is necessary to furnish a motor with special windings to give the exact power.

The standard motors are made in speeds from 1800 to 3000 r.p.m., in outputs of 1/200 to 1/15 horse power, and are wound for either 110- or 220-volt circuits except for the 1/200 horse power which can only be wound for 110 volts. The standard motors are connected for counter-clockwise rotation, facing the commutator. The direction of rotation may be reversed by interchanging the leads at the brushes. The starting current is approximately three times the full load normal running current.

THE PLAIN REPULSION MOTOR
TYPE R

Electromagnetic repulsion was studied in detail by Professor Elihu Thomson, and these studies led to the invention by him of the repulsion type of single-phase commutator motor. If a ring of conducting material be placed around the upper end of the core of an alternating-current electromagnet held in a vertical position, the ring is projected up-

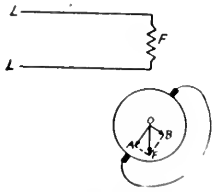


Fig. 19. Circuits of Repulsion Motor

wards as soon as the current is turned on. Again, if an alternating-current electromagnet be placed with its axis horizontal, and a disk of copper be suspended in front of it by a string attached to a point near the edge so that the disk hangs with its plane vertical, then upon switching on the current the disk will both swing away from the magnet and turn so as to make its plane parallel to the magnetic field. It was found that a closed secondary circuit placed near a primary circuit conveying an alternating current will tend to move so as to reduce the magnetic flux passing through it to a minimum. The motion, if allowed to take place, may be a motion of translation, or of rotation, or a combination of both. These effects receive an important application in the type of single-phase motors known as the repulsion motor.

The repulsion type of single-phase commutator motor was originally invented by Professor Elihu Thomson in 1887. In its simplest form it is shown in Fig. 19, *L* and *L* are the terminals of the field winding, which is entirely disconnected from the armature. The brushes are displaced from the neutral position through a certain angle, and are short-circuited. The two parallel halves of the armature winding, together with the short-circuiting cable connecting the brushes, form a closed conducting circuit. If an alternating current be sent through the field winding, the closed circuit of the armature, being placed in an alternating field, will, in accordance with the principle just mentioned, tend to move so as to render the alternating flux through it a minimum. Now the algebraic sum of the alternating fluxes through the various turns of the armature winding will clearly be zero if the brushes be placed in the neutral position. Hence, with the brushes displaced as shown in Fig. 19, it is evident that, if for a moment we suppose the brushes to be rigidly attached to the commutator and free to revolve with it, the armature and brushes will move bodily in a clockwise direction (this motion resulting in a decrease of the algebraical sum of the fluxes through the various turns of the winding) until the neutral position is reached, when the algebraical sum of the fluxes through the armature coils will vanish, and with it also the torque. If, however, we fix the brushes in their original displaced position, the armature will move, and since the brushes retain their position, the torque will be maintained and continuous rotation will result.

We may here note at once one of the results due to the short-circuiting of the coils as they pass under the brushes. It will be seen that, whereas the magnetic axis of the armature winding as a whole is along the line joining the brushes, the magnetic axis of a coil undergoing short-circuit by a brush is at right angles to the line of brushes, the plane of the coil being parallel to this line. Hence, regarding the short-circuited coil as an independent closed circuit placed in an alternating magnetic field, it follows that this coil will tend to move so as to bring its plane into parallelism with the field (or its magnetic axis at right angles to the field). From this we see that the coils short-circuited by the brushes exert an opposing torque. We have, in fact, to deal with two independently short-circuited circuits in the case of the armature of a repulsion motor; one of the circuits, which produces the driving torque, consists of all the armature coils not under cover of the brushes and short-circuited en masse by the cable connecting the brushes; while the other, as already explained, consists of the coils independently short-circuited by the brushes, which give rise to a torque opposed to the torque developed by the winding as a whole. If the cable connecting the brushes be removed, the torque due to the winding as a whole vanishes, and we are left merely with the torque due to the independently short-circuited coils under the brushes. Therefore, the motor will now rotate in the opposite direction.

We here come across one of the differences between the series and repulsion types of commutator motor. In the series motor the currents due to the transformer electromotive force in the short-circuited coil do not directly affect the torque, since the brushes are in the neutral position. But in the repulsion motor the transformer electromotive force gives rise to currents producing an opposite torque.

Since the armature is entirely disconnected from the field, the latter may be wound for a very high voltage—up to 6000 volts—a step-down transformer being thereby dispensed with. This is an advantage which the repulsion motor possesses over the series motor, as the latter cannot be wound for voltages above 300.

The value of the torque will clearly depend on the angle through which the brushes have been displaced from the neutral line. It is easy to see that there are two extreme positions for which the torque vanishes.

One of these is along the neutral line, and the other at right angles to it. Between these two there is a certain position corresponding to maximum value of the torque. This position is found in practice to correspond to a displacement of the brushes from the true neutral line through about 20 degrees. The motor exerts its maximum torque at starting, and this torque decreases with decreasing current and with increased speed.

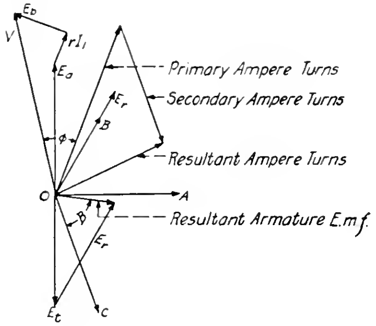


Fig. 20. Vector Diagram of Repulsion Motors

Reversal of rotation evidently occurs when the brushes are shifted to the right or left of the true neutral (in line with the field) and also when shifted through the false neutral (at right angles to the field); that is, the motor comes to rest at the position of zero torque, and when the brushes are shifted further starts up in the opposite direction.

The total flux of Fig. 19 passing through the armature may be resolved into two components, one of which, OA, is along the line of brushes, while the other, OB, is at right angles to it. The transformer electromotive force (or electromotive force due to alternations of flux) in the armature is due entirely to the component OA; while the rotation electromotive force arising from the rotation of the armature in the field is due entirely to OB. Again, the ampere-turns due to the armature can only affect the component OA, which will therefore be nearly in phase with the resultant of the field (or primary) and the armature (or secondary) ampere turns. But since the armature current is nearly in opposition of phase to the field current, the resultant ampere-turns will be nearly in quadrature with both armature and field currents. Thus the flux component OA will be nearly in quadrature with the field current. The component OB, on the other hand, which is uninfluenced by the armature current, will be nearly in phase with the primary current. Hence the two components OA and OB will be nearly in quadrature, as represented in Fig. 20.

In the armature we have two electromotive forces. One of these, denoted by Et in Fig. 20, is due to transformer action and lags 90 degrees behind the flux OA; while the other, Er, is due to rotation of the armature in the flux OB, and is, therefore, in phase with OB. The vectorial addition of E_t and E_r give us the resultant armature electromotive force. The armature current will lag behind this resultant electromotive force by a certain angle B, whose value depends on the armature leakage flux. In order to maintain the flux OA, a given number of resultant ampere-turns will be required, which will be slightly in advance (owing to hysteresis and eddy-current losses) of OA. By adding to the resultant ampere-turns the armature ampere-turns with the sign reversed, we obtain the primary or field ampere-turns. The flux OB will lag slightly behind the field current.

The electromotive force polygon for the field winding is now easily constructed. The flux OA induces an electromotive force in the field winding which lags 90 degrees behind OA, and which has to be balanced by a component E_a of the impressed potential difference. To balance the resistance drop, we require a component rI_1 in phase with the field current, r being the field resistance. Lastly, to balance the electromotive force induced by the flux OB, and by the field leakage flux, a component E_b in quadrature with this flux will be required. The resultant of E_a, rI_1, and Eb gives us the total impressed potential difference, V. The power-factor is given by $\cos \phi$.

When the motor is at rest the rotation electromotive force E_r vanishes, so that the resultant armature electromotive force becomes identical with E_t, and the armature current vector will lie to the left of E_t. As a result, ϕ will be large and $\cos \phi$ small. With increasing speed the resultant electromotive force vector will rapidly swing forward in a counter-clockwise direction, and the power-factor will rapidly increase. Therefore, the power-factor is low at starting and rises rapidly as the speed increases.

In the vector diagram of Fig. 20 we have, for the sake of simplicity, neglected the effect of any currents which may be induced by transformer action in the short-circuited coils under the brushes. It is clear that if the conditions of operation are such as to give rise to such currents, these latter will tend to reduce the flux component *OB* (Fig. 19) to which they are due, and in order to balance their effect an additional component will be required in the primary current. As in the case of the series motor, the effect of such currents is to increase the power-factor and lower the efficiency of the motor; but in the repulsion motor a further effect is produced, a lowering of the driving torque.

In the short-circuited coils of a repulsion motor, as in those of a series motor, we have three distinct electromotive forces, the reactance, the transformer, and the rotation electromotive force. The problem of obtaining sparkless running resolves itself into that of causing the resultant of the reactance, transformer and rotation electromotive forces in the short-circuited coil either to vanish, or at least to assume a sufficiently small value. It is obvious that by making each of the three components very small, the resultant will necessarily be also small. This end is practically attained by a very thorough subdivision of the winding, i.e., the use of as many commutator segments as possible, and by the use of narrow carbon brushes, so that only one coil is short-circuited at a time The first expedient reduces all the electromotive forces in the coil; the second reduces the reactance electromotive force, but has no effect on the transformer and rotation electromotive forces.

The transformer electromotive force is due solely to the component *OB* of the armature flux, as is at once evident by a reference to Fig. 19. This electromotive force is, therefore, in quadrature with *OB* and lags 90 degrees behind it. Since, however, *OA* lags nearly 90 degrees behind *OB*, Fig. 20, the transformer electromotive force in the short-circuited coil will be approximately coincident in phase with *OA*. On the other hand the rotation electromotive force in the short-circuited coil is due entirely to the component *OA* of the flux (Fig. 19) and, by Lenz's law, is in direct phase opposition to it. From this follows the highly important result that in a repulsion motor the transformer and rotation electromotive forces in a short-circuited coil are nearly in direct phase opposition, and hence will more or less completely neutralize each other.

If the conditions are such that the rotation electromotive force completely neutralizes the transformer electromotive force, the commutation will be as good as in a continuous-current motor. Now, this state is practically reached at synchronism; for at synchronous speed a rotating wave of flux is produced, and since the armature is stationary with respect to this rotating flux wave (both travelling at synchronous speed) the only electromotive force in the coils undergoing commutation is the reactance electromotive force.

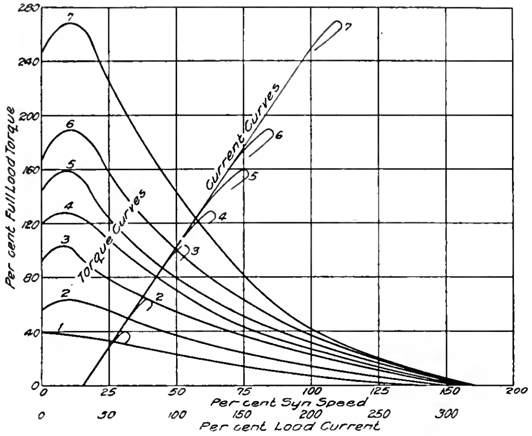


Fig. 21. **Torque-speed and Torque-current Curves for Different Values of Resistance in Series with a 7½ h.p., 1200 r.p.m., 220-volt, Crane and Hoist Motor**

The speed of synchronism is, however, the only speed at which exact neutralization of the transformer and rotation electromotive forces in the short-circuited coil take place. At speeds below synchronism the component *OB* of the armature flux predominates, and the transformer electromotive force overpowers the rotation electromotive force, while at speeds above synchronism the opposite effect takes place. The range of practically sparkless commutation in a repulsion motor is thus limited to a comparatively narrow range of speed on either side of the speed of synchronism. Hence, a repulsion motor is best adapted for running at a fairly constant speed in the immediate neighborhood of synchronism. In this respect it differs from the series motor, which will run well over a wide range of speeds, provided the speed exceeds a certain limit.

Motors of this type are used to drive Davidson & Ventura exhaust fans. Being of the repulsion type they have ample starting torque to start the fans under excessive line drop and with minimum starting current. The series characteristics protect the motor from heavy overload, for when an exhaust fan is installed in a duct system or the air outlet is restricted in any way the power to drive the fan increases very rapidly if the speed is held constant. The drooping speed characteristics of the Type R motor make it impossible to overload the motor more than 25 per cent, even though the air delivery is entirely cut off. Another decided advantage of the repulsion motor for fan service is the possibility of obtaining speed control by inserting resistance in series with the field winding.

Another application of motors of this type is for crane service. Varying speed is obtained by the insertion of resistance in the field primary circuit and reversed by a reversal of the field winding. Fig. 21 gives the torque-speed and torque-current curves for different values of resistance connected in series with a motor of this type, rated 4 poles, 7½ h.p., 1200 r.p.m., 220 volts. As this is a 60-cycle motor, the windings have been designed in such a way that the full-load speed (1200 r.p.m.) equals approximately two-thirds of the synchronous speed, which is 1800 r.p.m.

The Varying Speed Brush Shifting Motor, Type BSS

The single-phase motor of this type is known as the Déri type, or modification thereof, and is used for hoists, printing press drives, silk spinning, and in fact for all service where a motor of varying speed with series characteristics is applicable.

The torque of a motor depends on the diameter and axial length of its rotor, the number of conductors, the current, and the field. The torque is commonly varied by variations in the current and field strength, but in the type of repulsion motor provided with brush displacement gear it is also possible to vary the ratio of active field conductors to active rotor conductors.

By shifting the brushes out of the neutral, that is, by reducing the number of active conductors in which an electromotive force is induced by rotation with the same field strength, the speed has to be increased in order to induce the same electromotive force of rotation which again has to balance the energy voltage.

In regard to brush shifting, special reference should be made to the motor according to Fig. 19, which again has been represented in Fig. 22.

If the line of the brushes make an angle α with the axis of the field winding and OF represents the total magnetomotive force yielded by this winding, then we can resolve OF into two components, one, OA, being along the line of the brushes and the other, OB, at right angles to this line. By shifting the brushes we increase one of the components and simultaneously decrease the other. There are two positions in which the torque vanishes, viz., for α equals zero, in which case the field is zero, and for α equals 90 degrees, in which case the armature current is zero. In case α equals 20 to 30 degrees, the torque will be a maximum. (For a more detailed theory see Repulsion Motor, page 494).

Since the motor, according to Fig. 22, is very sensitive in regard to the position of the brushes, an arrangement has been made for reducing the effect resulting from a certain displacement of the brushes. Fig. 23 represents this arrangement for the Déri motor which has four brushes for two poles, two of which are stationary, 3–4 and two movable, 1–2. Assuming that the position in which the line of the brushes 3–4 corresponds to a certain speed, then after the brushes have been shifted over an angle 2 α, according to Fig. 23, the axis of the armature will have been shifted over an angle of α only.

An important difference between the ordinary type of repulsion motor and the Déri motor may be pointed out. While in the former all the rotor conductors carry current, in the Déri motor currents circulate only in the groups of conductors included between the fixed brush sets and those movable brush sets to which the fixed sets are connected, there being no current in the remaining conductors. Thus, in Fig. 23, currents will only circulate in the parts of the winding included between 1 and 3 and between 2 and 4, there being no current in the portions included between 1 and 4 and 2 and 3.

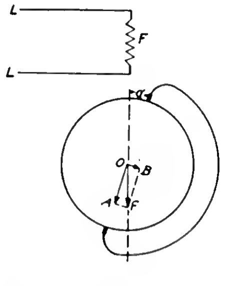


Fig. 22. Repulsion Motors

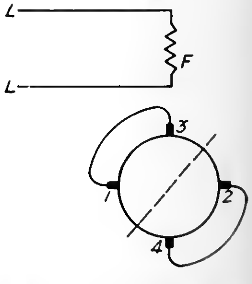


Fig. 23. Circuits of One Type of Déri Brush Shifting Motors

Another scheme uses four brushes for two poles, which, however, are moved simultaneously, keeping the same relative position to each other. In this case, a part of the armature, i.e., the conductors between the brushes 2 and 3, is always ineffective in regard to generation of electromotive force, whereas with the Déri motor, this part is ineffective at certain speeds only. The advantage of the arrangement is that the brushes are standing in such a position that less trouble is caused by the induction of an electromotive force which affects the commutation of the short-circuited coils under the brushes.

The simplest way of explaining the action of a motor of this type is to suppose the armature winding replaced by two equivalent windings which are in space quadrature, and which, while independent of each other magnetically, must be regarded as electrically connected in series. The magnetic axis of the one winding is coincident with the axis of the field winding, while the axis of the other winding is in space quadrature with the field winding. The first winding alone is subject to the induction action of the field flux, and plays the part of the secondary of a transformer of which the field winding forms the primary. For this reason this winding is called the transformer winding. The second winding, which is not directly affected by the field flux, may be termed the quadrature winding. The relation of the two windings to each other and to the field winding is indicated diagrammatically in Fig. 24, where *F* is the field winding, *T* the transformer winding of the armature, and *Q* its quadrature winding.

Any flux produced by the current in the quadrature winding will be in time phase with the current in the transformer winding and will produce accelerating torque at the rotor.

First, consider the action taking place in the motor at starting. The field flux induces an electromotive force in the transformer winding and this electromotive force may be regarded as impressed on the quadrature winding and as producing a current in it which gives rise to a quadrature or cross flux. In Figs. 25, 26 and 27 are represented diagrammatically the changes taking place in the ampere-turns of the transformer and quadrature components of the armature winding as the angle α of brush displacement is steadily increased. In these diagrams, not only the number of turns but also the width of the turn is roughly represented. If we suppose that all the turns are reduced to the same standard width, then the variation in the transformer turns is as shown by Curve I, in Fig. 28, and the variation in the quadrature turns as shown by Curve II. Under normal working condition the angle α lies between 120 and 150 degrees.

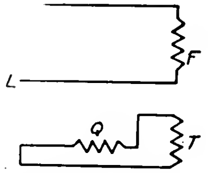
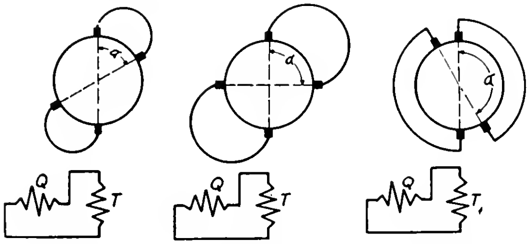


Fig. 24. Diagram of Equivalent Windings



Figs. 25, 26 and 27. Resolution of Rotor Windings for Various Angles α

The electromotive force impressed on the quadrature winding will follow the same law as Curve 1, while for a given impressed electromotive force the current will vary inversely as the square of the number of turns in the quadrature winding. A consideration of the curves of Fig. 28 will thus show that between 0 and 90 degrees the torque increases but slowly; beyond 90 degrees somewhat more rapidly; and beyond 150 degrees with very great rapidity. The motor is thus capable of exerting an exceptionally powerful starting torque, which, however, will be limited by considerations regarding sparking. Both when the axes are together and when they are separated by 180 space degrees, the torque is zero. In the former case the transformer flux is zero, while in the latter case there is no quadrature effect. If $\alpha = 0$ degrees, there are no currents in the rotor, and none in the coils short-circuited by the brushes. The stator takes a nearly wattless current which is about one-third of the normal load current. Hence the stator may

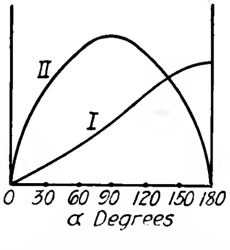


Fig. 28. Variation of Transformer and Quadrature Turns with α

be connected directly across the supply mains.

Next consider the action of the motor when running. Under speed conditions there are produced two electromotive forces which affect the value of the secondary current, and, therefore, alter the torque which for each position of the brushes varies directly with the square of the current in the armature. One electromotive force appears at the transformer axis and the other at the quadrature axis. The former is proportional to the product of the speed and the quadrature flux, and the latter varies directly with the product of the speed and the transformer flux. These two electromotive forces have such values and time-place position as to tend to decrease the armature current with increase of speed. Therefore, with constant primary voltage at any given speed the current and torque can be varied over a wide range by merely shifting the brushes. The torque decreases with increasing speed, rapidly at first, then more and more slowly, so that the speed-torque curve approaches the axis of speed in an almost asymptotic manner. These machines possess the speed-current and speed-torque characteristics of the direct-current series motors.

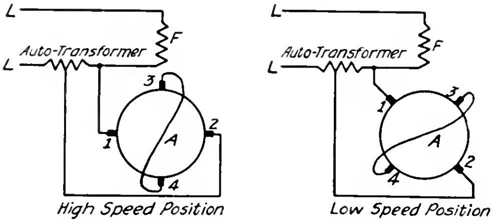


Fig. 29. Varying Speed Brush-shifting Motors, Type BSS

In the neighborhood of synchronous speed a rotating field is produced and sparkless running obtained for all brush positions. Now the quadrature field at speeds below synchronism increases but slowly with increasing brush displacement, and decreases slowly at speeds above synchronism. For the above reasons the effect of changes in brush displacement on commutation is relatively slight.

The brush-shifting motor, known as the Type BSS, consists of a single-phase field or stator and a series drum wound armature with energy and compensating circuits, Fig. 29. The brushes resting on the commutator are divided into two groups, one known as the "energy brushes," which are short-circuited, and the other group known as the "compensating brushes," which are connected to the compensating winding. The compensating winding consists of a tapped off portion of a series auto-transformer which is connected externally in series with the main field of the motor.

It will be recalled that in the plain repulsion motor, Fig. 22, we resolved the stator winding into two components, one of which is along the line of brushes and the other at right angles to it. The motor field flux is excited by the current flowing in the motor field turns as represented by the component in the line of brushes. Now, if we add another set of short-circuited brushes 1 and 2, the axis of which is perpendicular to the axis of brushes 3 and 4, Fig. 30, a current will flow through the armature circuit formed by the brushes 1 and 2, which will neutralize the current in the motor field turns so that the motor field flux disappears but for the small amount maintained by the leakage reactance and resistance of the armature circuit. Hence this motor will exert scarcely any torque at start, but when brought up to speed will operate essentially the same as the single-phase squirrel cage induction motor.

If we connect the compensating brushes 1 and 2 of Fig. 30 in series with the line, we obtain the so-called series compensated repulsion motor, Fig. 31, which has series characteristics. Instead of connecting these brushes directly in series with the stator winding, we can do this over a series transformer, Fig. 29. The motor operates like the repulsion motor, with the difference that the field flux is excited by ampere-turns which are partly located on the armature and partly on the stator. As in the repulsion motor there are two positions of the brushes in which the torque vanishes and the current taken from the line is very small. By shifting the brushes, the motor field turns can be varied, which results in a variation of the speed. The action of the motor is similar to that of a direct-current series motor, in which the

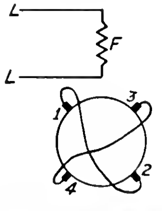


Fig. 30. Circuit of Single-Phase Induction Motor

number of turns in the series field winding would be varied. The motor is designed in such a manner that the brushes are in the live neutral when it is carrying its full load at full speed. In this brush position the motor field flux is provided by the armature compensating turns only, which are connected in series with the line.

The transformer has the same effect as an increase of the magnetic reluctance of the path of the motor field flux at the low speed. This means that, due to the reduction in the field drop with a certain brush shift and line voltage, the motor can draw more current from the line and the torque will be increased as long as the reduction of the motor field flux is not carried on too far. The reduction of the motor field flux will further result in improved commutation at low speed. As soon as the motor runs above synchronous speed the voltage appearing at the compensating brushes reverses its direction, and hence the flux in the transformer will be opposite to the line current, and the secondary ampere-turns of the transformer will have to be larger than the primary ampere-turns. The larger the magnetizing current of the transformers the sooner the motor field flux will increase with increasing speed, in spite of the reduction of line current, and thus the speed can be limited. The increase of the secondary current flowing in the energy circuit, 3–4, with increasing speed helps in limiting the speed. The transformers are usually designed so that the no-load speed is not over 150 per cent of the synchronous speed.

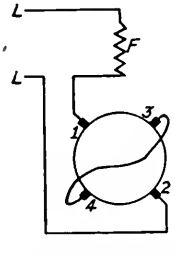


Fig. 31. Circuit of Series Compensated Repulsion Motors

The current required for exciting the flux of the transformer can be larger than the line current. In that case, when running below synchronous speed, part of the excitation will be furnished by the secondary turns of the transformer and the current in the armature compensating circuit will be reversed so that the ampere-turns yielded by it are opposite to the ampere-turns of the stator field turns. Part of the excitation required by the flux of the transformer is transmitted by transformation from the stator field turns to the armature compensating circuit and flows from there to the secondary of the transformer.

Since the primary of this transformer is connected in series with the line, a part or all of the torque-producing flux is excited by the armature, depending on the brush shift, thus making it possible to operate this motor at nearly unity power-factor at full load and full speed. In case it is desired to run the motor counter-clockwise, in a brush position in which the motor has the same characteristics as in the brush position α in which the motor runs clockwise, the brushes should be shifted clockwise over $180-2\alpha$ degrees. On the plain repulsion motor it would only have been necessary to shift the brushes over $2\ \alpha$ degrees counter-clockwise to obtain the same result. But in the compensated repulsion motor this cannot be done, as the armature compensating circuit and stator field winding buck one another. Nevertheless, it is possible to obtain counter-clockwise operation by shifting the brushes far enough counter-clockwise, but the power-factor and commutation will be inferior. A reversed compensation results in low starting torque, reversed direct of rotation, and a very high no-load current. If the compensating circuit is open it is evident that the no-load speed will be excessively high.

The electrical characteristics of the brush-shifting motor are excellent. Its efficiencies and power-factors are well maintained throughout the entire range, as shown in the curves Fig. 32. The efficiency of the motor, though somewhat lower for the highest speed than that of an equal constant speed motor on account of the commutator losses, is at lower speeds considerably higher than the repulsion induction motor with resistance control, due to the fact that there is no direct loss in external resistance. The efficiency at half speed and full load torque is approximately ten points lower, and at half speed and half torque approximately 15 points lower than at full speed and full load torque. The power-factor at high speed is the same as the constant speed, Type RI motor, but decreases at the lower speeds, dropping approximately 30 points under half speed.

The starting characteristics of this type of motor are excellent. The motor may be accelerated as slowly as or rapidly as desired, by slowly or rapidly moving the brushes from the "off," or slow speed position. Fig. 33 shows that a starting torque of any required value may be obtained. The starting current increases with the torque. At a slow speed position 100 per cent starting torque may be obtained with approximately 100 per cent current. Fig. 34 shows the speed-torque characteristics of a motor of this type. An inspection of the curve will show that the accelerating torque equals or exceeds the starting torque, and therefore this motor will bring up to speed any load which it will start.

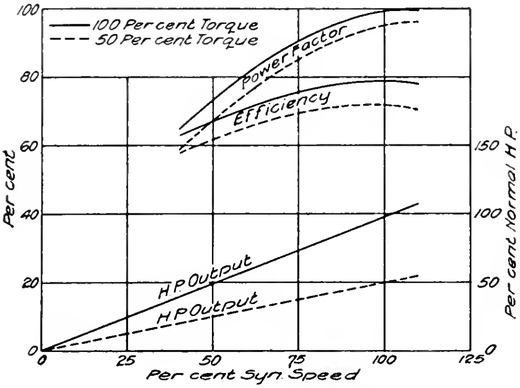


Fig. 32. Performance Curves for a Single-phase Varying-speed, Brush-shifting Motor

The speed and load characteristics are similar to those of the alternating three-phase wound rotor type, or the direct-current motor with armature control; i.e., the speed varies with the load, decreasing when the load increases and vice versa. In applications demanding varying speed, care should be taken to "motor" closely; i.e., the horse power rating of the driving unit should compare as nearly as possible with the power required by the driven machine at normal speed. For example, if a 5 h.p. motor is applied to a machine having a demand of only three horse power, the load torque will not be sufficient to decelerate the driving unit when the brushes are shifted to the lower speed points. Shifting the brushes will cause little speed variation under no load. However, whenever an induction motor with resistance control has satisfactory speed-torque characteristics, the brush-shifting motor will have the same, and in addition is more stable at the lower speeds. Refer to Fig. 34. As the Type BSS motor is a series motor, it has inherently a high no-load speed, but due to the compensating winding, as explained elsewhere, the no-load speed is limited to about 50 or 60 per cent above synchronous speed. The normal motor is designed to operate against full load torque with a speed variation of 2 to 1. Greater speed range can be obtained by specially designed windings, and in some cases a larger frame is required as the heating at the low speeds is the limiting factor in almost every case. On fan and similar loads, where the torque drops off rapidly with decrease in speed, the necessary reduction in speed is secured by a wider shift of the brushes than when the load is heavy. The load must be one of approxi-

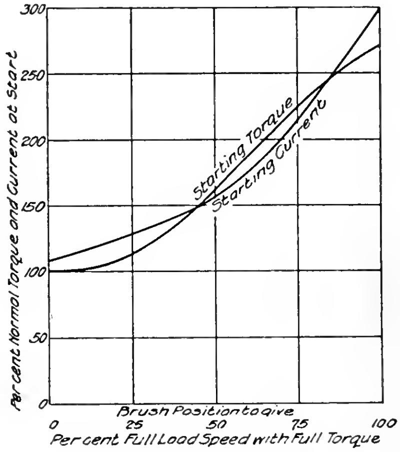


Fig. 33. Starting Curves for a Single-phase Varying-speed, Brush-shifting Motor

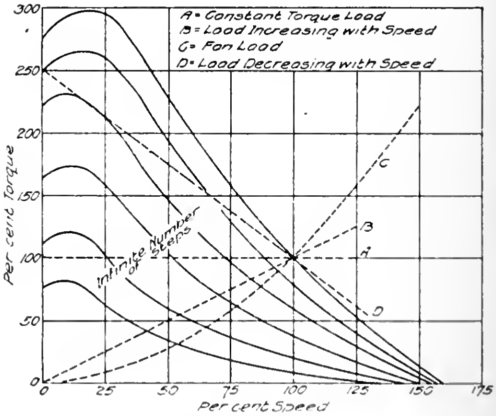


Fig. 34. Speed-torque Curves for a Single-phase Varying-speed, Brush-shifting Motor

mately constant value, for with the brushes fixed in one position the speed will change with a change in the load.

The motor can be started up with the brushes in any position, but generally they are in a low speed position in order to draw a minimum amount of starting current from the line. As the speed variation is obtained by shifting the brushes away from the running position, it is evident that it is only necessary to supply a line switch for connecting the motor to the circuit and a means for shifting the brushes. This may consist of a handle with sector mounted on the brush yoke, or a light chain or rods with universal joints attached to the yoke and to a handle on a controller. This last system of control permits extreme flexibility in mounting, as the chain or rods may be of any length and may be taken around any number of angles. The controller itself may, in addition to moving the yoke, serve as a switch for opening the line circuit at the "off" position. All the varying speed brush-shifting motors are reversible; but reversible or non-reversible controllers are furnished, depending on the service. The speed may be adjusted in an infinite number of steps. The simplicity of operation is an attractive feature in this motor.

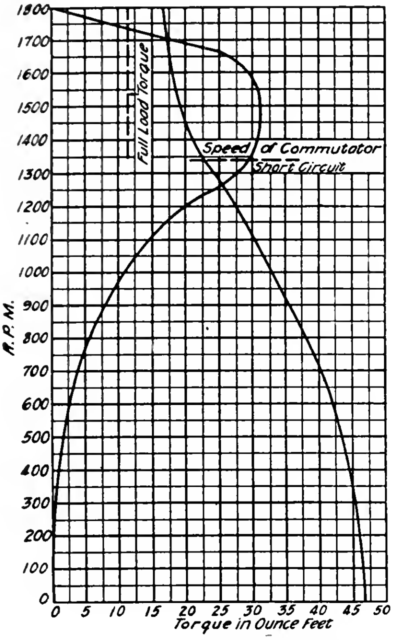


Fig. 35. Speed-torque Curves of ¼ h.p., 1800-r.p.m., Single-phase, 60-cycle, 110/220-volt Repulsion Induction Motor, Type RSA

The Repulsion Starting Induction Motor, Type RSA

For general applications requiring approximately constant speed the simple single-phase induction motor with squirrel-cage rotor is capable of giving good results. The inherent weakness of this motor is its poor starting torque. Now, the repulsion motor, *Type R*, is capable of exerting a powerful torque. If the good starting qualities of the repulsion type of motor could be combined with the satisfactory running qualities of the induction type, a motor would be obtained which would be satisfactory for numerous applications.

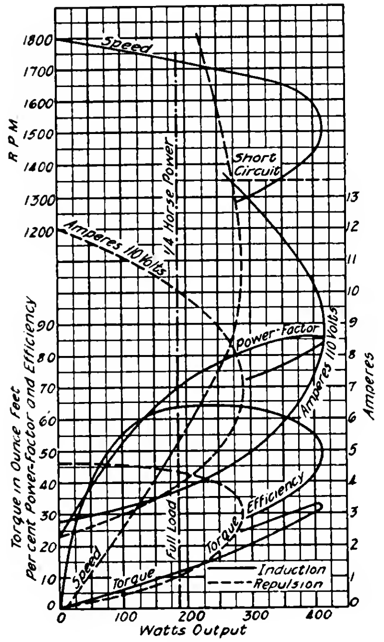


Fig. 36. Performance Characteristics of ¼ h.p., 1800-r.p.m., Single-phase, 60-cycle, 110/220-volt, Repulsion Induction Motor, Type RSA

In the Type RSA motors the motor is provided with an ordinary continuous-current winding having a commutator, and at starting the brushes short-circuit the winding as in the repulsion motor. A powerful starting torque is thereby obtained. When the speed exceeds a certain limit, a centrifugal mechanism operates to short-circuit the commutator and the motor then runs as an induction motor with the familiar induction motor characteristics.

These motors will easily develop two to three times the full load torque at starting, with approximately three times the full load normal running current. The maximum running torque is twice full load torque.

The direction of rotation is easily reversed by merely shifting the brushes on the commutator. Figs. 35 and 36 show the speed-torque curves and performance for this type of motor.

Repulsion Induction Motors, Type RI

This motor, Fig. 37, consists of a single-phase distributed stator winding, and in addition a small auxiliary winding called the compensating winding, consisting of a few coils wound with a small pitch and located in the center of the poles. The armature is substantially a direct-current armature, short-circuited along one axis by a set of brushes called the energy brushes and excited along an axis at right angles to the energy circuit by the compensating winding. The theory of operation will best be understood by considering the elements whose combined action results in the performance of the repulsion induction motor. These elements are:

The Repulsion Motor.
The Commutator Induction Motor.
The Compensated Commutator Induction Motor.

The Repulsion Motor. Fig. 38 represents diagrammatically a bipolar repulsion motor. The primary member F is shown as a simple gramme ring. The secondary member A is provided with a winding connected to the segments of a commutator on which one set of brushes 3-4 is short-circuited upon itself and displaced by the angle α from the magnetic axis. In the working diagram, Fig. 39, the primary and secondary windings are shown as circles F and A. L and L represent the primary terminals. The dotted lined *c-d* and *e-f* are drawn through the brushes 3 and 4 respectively.

Assume that the armature is at rest and current is applied to the primary winding F and in the direction as represented by the arrow. Due to the transformer action a current will flow in the secondary winding in an opposite direction, as indicated by the arrow h. The field produced by the total ampere-turns of the primary winding F is in the direction of the primary terminals *L-L*, while only a portion of the secondary ampere-turns produce a field in the same direction. Thus the portions of the secondary winding which lie to the left and right of the dotted lines *c-d* and *e-f*, respectively, produce a field in the direction of the line of the primary terminals *L-L*. However, the field produced by the ampere-turns of the secondary winding inclosed between the lines *c-d* and *e-f* is at right angles to those lines. This is the torque-producing field, which is substantially proportional to the armature currents. Therefore the torque creates a tendency in the motor to run away, similar to the effect in the direct-current series motor. (For a more detailed theory of the repulsion motor see Repulsion Motor, page 494.)

The Commutator Induction Motor. This second element is derived from the repulsion motor, Fig. 38, by adding a second set of short-circuiting brushes 1–2 displaced by 90 degrees from the brushes 3–4, Fig. 40. In order to simplify the explanation the brushes 1–2 in Fig. 41 are shown at right angles to the line of the primary terminals *L-L* instead of at right angles to the brushes 3–4 (the operation of the motor is practically not affected by shifting the brushes 1–2 a small amount).

It has been shown in Fig. 39 that with one set of brushes on the commutator a field is produced by the ampere-turns of the secondary windings included between the lines *c-d* and *e-f*. With the second set of brushes 1–2 this field will be more or less damped out by the currents which it produces in the secondary winding and which are indicated by the arrows i. If the connection between the brushes 1–2 is of low resistance, it is evident that the cross-field on the line *k-l* may be so nearly damped out as to form a negligible factor in considering the starting torque. Assuming that this cross-field is substantially damped out and destroyed, the torque will be produced by the field parallel to the line of the primary terminals, *L-L*, in co-action with the secondary currents. This field is the resultant of the ampere-turns of the whole primary winding and of those portions of the secondary winding outside of the lines *c-d* and *e-f*.

It has been stated above that a slight shift in the position of the brushes 1–2 has little effect upon the starting torque of the motor. This is now evident, since it may be seen from Fig. 41 that a shift of these brushes merely alters the current distribution in the secondary winding at those points which are least effective in producing a torque in conjunction with fields in the line with the primary terminals *L-L*. As soon as the motor starts electromotive forces are induced in the secondary winding by its field. An electromotive force due to this cutting is produced in the secondary winding between brushes 1–2.

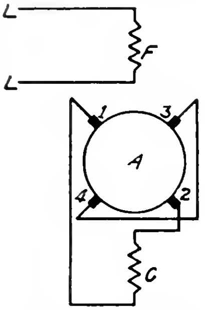


Fig. 37. Compensated Repulsion Induction Motors, Type RI

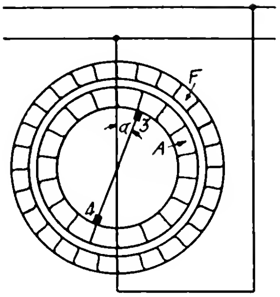


Fig. 38. Bipolar Repulsion Motors

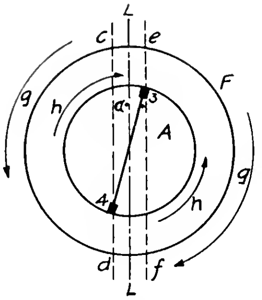


Fig. 39. Working Diagrams of Bipolar Repulsion Motors

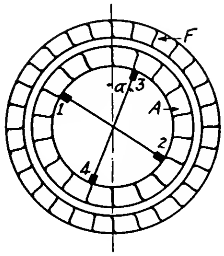


Fig. 40. The Commutator Induction Motor

This electromotive force reduces the current indicated by arrows *i* and diminishes the effectiveness of the damping action of these currents upon the cross-field. At a certain speed this induced electromotive force reaches such a value that it causes current to flow between the brushes 1–2 in the opposite directions to that indicated by arrows *i*, and this current obviously assists instead of damping out the cross-field of the motor. The cutting of this field by the armature winding between the brushes 3–4 produces a counter electromotive force which reduces the armature currents and thereby alters the field in the line *L-L*. Near synchronism the two fields on the lines *L-L* and *k-l* are equal and produce a resultant revolving field. Therefore, by the application of the two sets of brushes on the commutator an induction motor element is introduced into the machine, whereby induction motor characteristics are obtained.

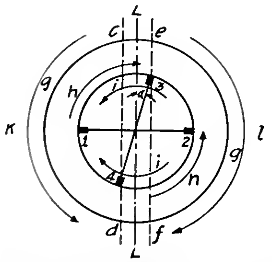


Fig. 41. Working Diagram of Commutator Induction Motor

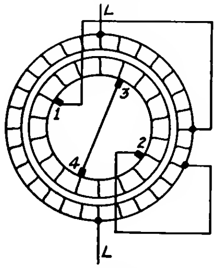


Fig. 42. Compensated Commutator Induction Motor

The Compensated Commutator Induction Motor. The arrangement embodied in the compensated commutator induction motor involves, in addition, the connection of an auxiliary source of electromotive force to the secondary winding of the motor in such a manner as to compensate for the magnetizing component of the primary current, thereby allowing the motor to operate at a very high power-factor. Fig. 42 shows diagrammatically the insertion of a small auxiliary electromotive force derived from a few turns of the primary circuit. Referring to Fig. 37, it will be seen that the compensated electromotive force may be also obtained from a separate auxiliary circuit instead of utilizing the auto-transformer principle, as shown in Fig. 42.

At starting the conditions will not differ very much from those of the non-compensated arrangement, as the auxiliary electromotive force will be overwhelmed by the electromotive force induced in the secondary winding by the fluctuating field component along the axis upon which the auxiliary electromotive force is impressed. However, when the motor speed approaches synchronism, the electromotive force due to the transformer action is reduced, and the auxiliary electromotive force will then act to force currents through the secondary winding which will produce an auxiliary magnetization and assist the magnetomotive force of the primary field. Evidently the compensating electromotive force will be so chosen as to allow the motor to operate at nearly unity power-factor when running near synchronism, but evidently it may be over-compensated or under-compensated, if desired.

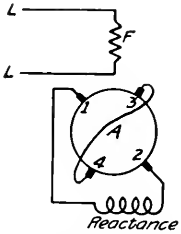


Fig. 43. Non-Compensated Repulsion Induction Motor

Referring to Fig. 40, it was shown that this arrangement develops low torque at starting. If a reactance is inserted in the circuit 1–2 as shown in Fig. 43 this will limit the current flowing in that circuit, and therefore the effect of the brushes 3–4 will become more prominent, i.e., the motor will become more like a repulsion motor. This is the non-compensated type of repulsion induction motor. It is evident that the starting torque depends upon the value of the reactance, and therefore by changing its value special high torque motors can be obtained.

This reactance at the same time raises the no-load speed above the synchronous speed, because it limits the flux excited along the axis of the brushes 1–2. This flux induces a rotation voltage between the brushes 3–4, and in order to get the same generated voltage to balance the impressed voltage the speed has to be increased according to the decrease of the flux. Therefore the motor can operate above synchronous speed by a considerable amount depending upon the value of the reactance.

Since the field of the motor can be built up to any desired value by properly proportioning the secondary circuits, including compensating winding, it is easy to see that shunt characteristics may result and the machine may be run at speeds appreciably away from synchronism; the free running speed for any connection being, of course, that at which the counter electromotive force, when resolved with the resistance and reactance drop, equals the impressed electromotive force. In general, the effect is similar to that of varying the resistance in the armature of a polyphase induction motor. An increase in the compensating voltage applied gives an increased slip above synchronism at no-load, an increased starting torque, and a larger factor of regulation.

It is advantageous to use as the reactance for giving the desired torque and speed characteristics to the motor, a coil of proper phase and proportion in the field of the machine. This coil is the compensating winding described above, which in addition to varying the torque and speed characteristics produces a regenerative excitation within the motor, thus improving the power-factor. It is plain that a wrong polarity of connection in this compensating circuit will result in a reduction of power-factor below that which the plain repulsion motor would give, with a corresponding reduction in efficiency because the instantaneous polarity of generated current depends upon the direction of rotation. It is therefore necessary in reversing the motor to reverse also the polarity of the compensating winding.

If we consider the commutating characteristics of this machine, it will be noted first that individual coils short-circuited by one of the energy brushes are not in an inductive position but have only the generated voltage to cause sparking; and second, that due to the rotating magnetic field the voltage actually generated in these coils at synchronous speed is zero. Therefore, under this particular condition no tendency for sparking exists. Each of the compensating brushes short-circuits coils in an inductive position, but due to the general short-circuit of the armature by the energy brushes, including those coils, the tendency to sparking at these brushes from this cause is slight. Moreover, these compensating brushes have to carry only the smaller exciting current of the machine, which is another condition improving the commutation. In general, since the maximum voltage found on the commutator is that of the compensating voltage of 20 volts maximum, and since all energy in the secondary which might appear in bad commutation has to be transformed through the air gap, it would be impossible to obtain a condition of flash-over or severe arcing, such as may occur in direct current machines.

The vector diagram of the compensated repulsion induction motor is shown in Fig. 44; 1 is the impressed electromotive force, while 2 is the electromotive force in the rotor across the energy brushes due to the transformer action; 4 is the auxiliary electromotive force impressed on the compensating brushes which feeds the inductive circuit of the armature, giving a current and flux component 5, perpendicular to the energy brushes or in the direction of the compensating brushes and in phase with the magnetizing current 3. Now when the armature is rotating it cuts this flux and the resultant electromotive force will appear at the short-circuited or energy brushes, and this generated electromotive force 6 will be in phase with 5. 7 is the resultant electromotive force of 2 and 6, and 8 is the armature current which lags behind the resultant electromotive force by the angle α; 9 is the line current and |is the resultant of the magnetizing current 3 and the armature current 8.

By a manipulation of the field winding these motors may be furnished to operate under full load at approximately 20 per cent above or below synchronous speed, retaining under these conditions the constant speed characteristics of the straight induction motor. By changing the compensating circuit it is possible to obtain a high starting torque with the drooping torque characteristic and limited speed. This drooping torque characteristic and high starting torque may also be obtained by the insertion of a reactance external to the compensating field circuit.

When full starting torque is not required, or it is desired to reduce the starting current, a starting rheostat in series with the field winding may be used. The rheostat or starter is not necessary for the protection of the motor, as any size may be thrown directly on the line.

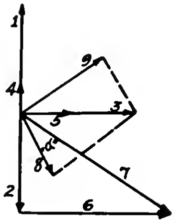


Fig. 44. Vector Diagram of Compensated Repulsion Induction Motor

The speed-torque and speed-current characteristics of the Type RI motors are given in Fig. 45, which show that the initial torque decreases but slowly as the motor comes up to speed, insuring rapid acceleration and a minimum of line disturbance during the starting period. These characteristics resemble very closely those of the polyphase induction motor, as shown in Figs. 46 and 47. The accelerating torque and maximum breakdown torque are somewhat higher than the corresponding values of the polyphase motor to allow for the excessive line drop which may occur in single-phase lines. The Type RI motor will therefore successfully accelerate any load which would be accelerated by a polyphase induction motor of like rating, even taking into consideration the greater line drop occurring in the single-phase lines.

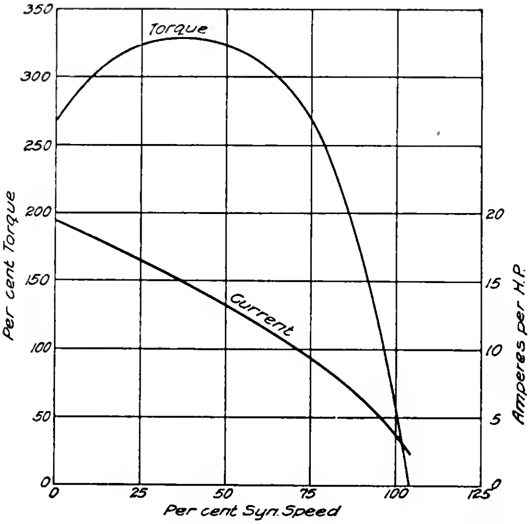


Fig. 45. Speed-torque and Speed-current Curves of a Typical Type RI, Single-phase Constant-speed Motor

Erroneous ideas of the value of the starting current required by any motor are likely to be formed by giving that value in per cent of normal full load running current. The actual conditions at start are known by giving the starting current in amperes. The normal full load running current of a motor of any rating varies over a considerable range, depending upon its power-factor and efficiency. Therefore there can be no direct comparison of starting current if it is expressed as a percentage of this variable normal current. It will be noted that in these curves the current is expressed in amperes per horse power. The RI motor draws about 18 amperes per horse power at 220 volts from the line when developing its starting torque, which is approximately 250 per cent of the normal rated torque.

High torque induction motors, i.e., squirrel cage induction motors with high resistance rotors, are occasionally required to accelerate heavy loads. As explained elsewhere, in corresponding applications on single-phase circuits special high torque in Type RI motors may be secured from standard motors by the single expedient of attaching to the standard motor a small reactance coil connected in the compensating circuit. As in the polyphase induction motor, an increase in starting torque means a poorer speed regulation, decreased efficiency, and lower starting current (refer to Fig. 48).

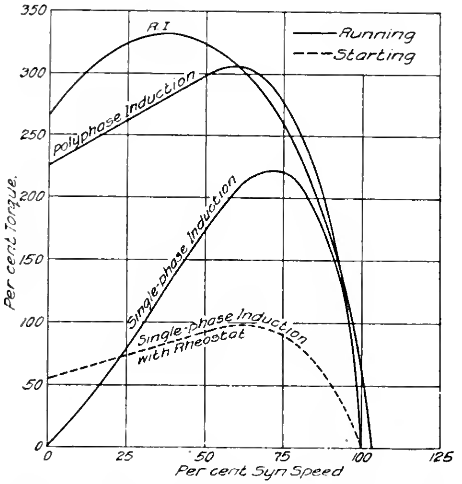


Fig. 46. Speed-torque Curves for Comparison of Single-phase and Polyphase Motors

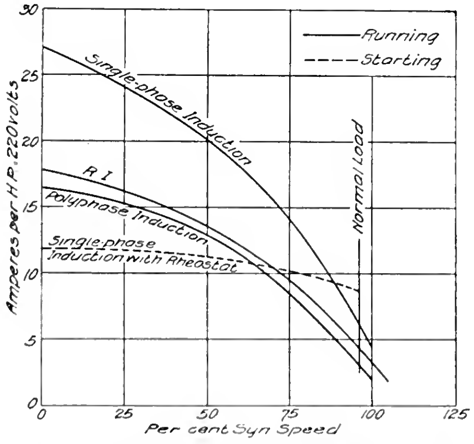


Fig. 47. Speed-current Curves for Comparison of Single-phase and Polyphase Motors

Increased torque may also be obtained by shifting the brushes. As the normal running position of the brushes is less than the maximum starting torque position it is evident that a greater shift of the brushes will increase the starting torque, but at a sacrifice of speed regulation as in the polyphase induction motor. This is illustrated in Fig. 49. (See also Fig. 48.)

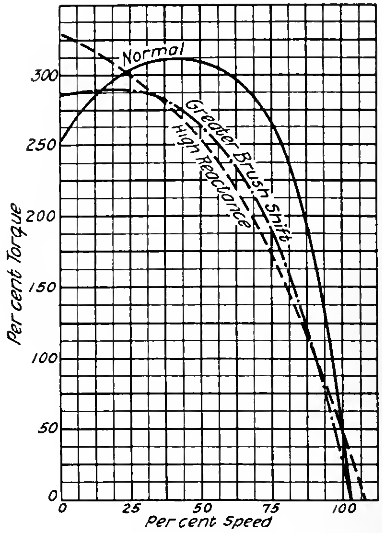


Fig. 48. Comparison of Speed-torque Curves of Type RI Motors

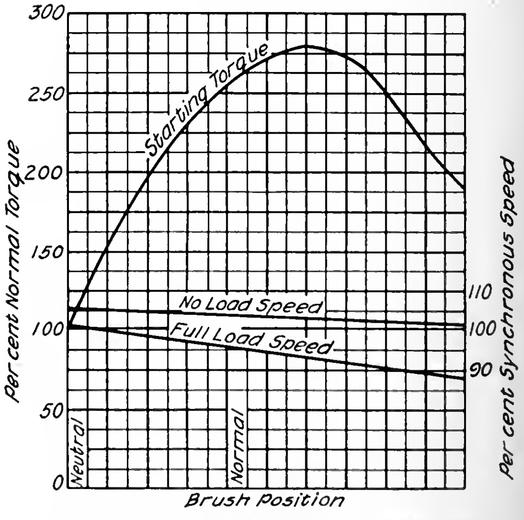


Fig. 49. Effect of Shifting Brushes on Constant Speed, Type RI Motors

Fig. 50 shows the performance characteristics of this type of motor. As it is of the compensated type, the power-factor of the motor is approximately unity and retains a high value throughout the whole range of normal operation. The efficiency is also well sustained throughout the working range from half load to load and one quarter.

As shown in Fig. 51, the horse power output of the Type RI motor is practically the same as that of the polyphase induction motor.

The regulation of Type RI motors is approximately 8 to 10 per cent, and compares favorably with that of direct-current motors. In very few cases is a better regulation necessary in small motors, and when required close speed regulation can be furnished by the use of special windings.

Varying Speed

It is possible to obtain varying speed by shifting the brushes, as the torque and speed depend upon the amount of brush shift. This is rarely done, however, as it is more convenient to use a resistance in series with the field or preferably to connect a resistance or reactance in the energy circuit. By the insertion of resistance in the energy circuit a number of series characteristics equal to the number of steps of resistance may be obtained. This acts in a manner very similar to the slip ring type of induction motor in which resistance is inserted in the rotor circuit. Somewhat below one-half speed and with full load torque the motor is unstable. Fig. 52 shows the effect of varying speed by resistance in the secondary circuit. It will be noted that the motor has a breakdown point at about one-half synchronous speed. As in the slip ring induction motor, the efficiency at the low speeds is rather poor, and therefore for most applications requiring varying speed motors the varying speed brush shifting motor, Type BSS, is recommended.

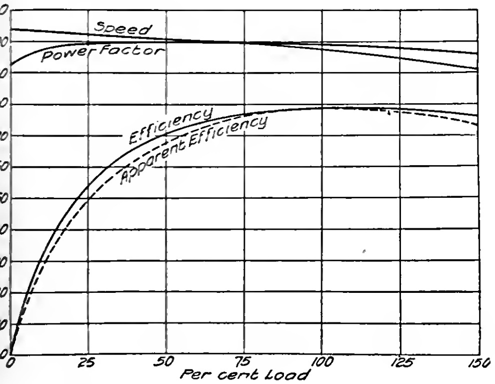


Fig. 50. Performance Curves of a Type RI, 5-h.p., 1800-r.p.m., 60-cycle, Single-phase, Constant-speed Motor

Reversible Motors

The desired direction of rotation of the constant speed motor is obtained by shifting the brushes relative to the field winding.

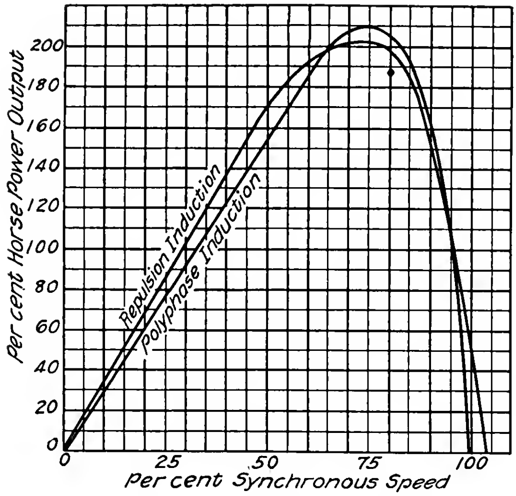


Fig. 51. Comparison of Speed-output Curves of Single-phase and Polyphase Motors

Suppose, however, that the motor is wound with an auxiliary winding at right angles to the field winding. It is evident that when the auxiliary winding is connected in series with the main winding the resultant field is shifted, giving a field equivalent to that obtained by shifting the brushes. In other words, the brushes may be placed permanently on neutral, i.e., in line with the main field and the field itself shifted to get clockwise or counterclockwise rotation.

If the motor is of the non-compensated type, i.e., has reactance only across the compensating brushes, only a two-pole double-throw switch is required. If it is of the compensated type, the compensating winding must be reversed so that a four-pole double-throw switch is necessary. Fig. 53 shows the connections for the non-compensated type, and Fig. 54 for the compensated type.

Reversible operation may also be obtained without the use of an auxiliary reversing winding by connecting the motor as a compound compensated induction motor. The brushes are placed in neutral and a two-pole, double-throw switch is used. Fig. 55 shows this arrangement for a 110-volt connection, in which the two circuits of the stator winding are connected in multiple. In the 220-volt connection, in which the two stator circuits are connected in series, the whole armature is used for the series excitation, as shown in Fig. 56. A reactance coil is shown in the secondary circuit, as this is sometimes necessary to secure sufficient torque. Fig. 57 shows the performance curves of this motor and for convenience of comparison Fig. 58 shows similar curves for a polyphase reversible motor.

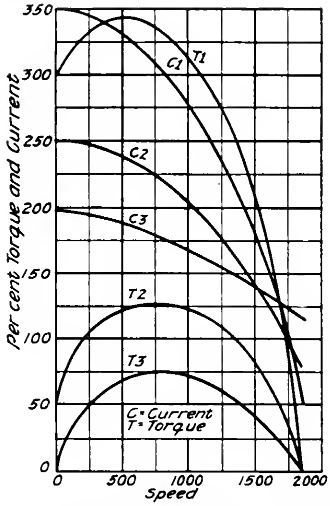


Fig. 52. Varying Speed of Repulsion Induction Motor by Resistance

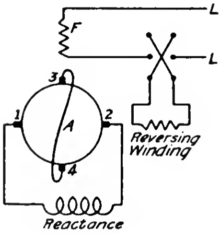


Fig. 53. Constant Speed Non-compensated Reversible Motor

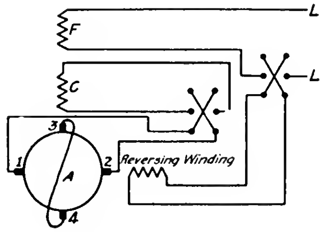


Fig. 54. Constant Speed Compensated Reversible Motors

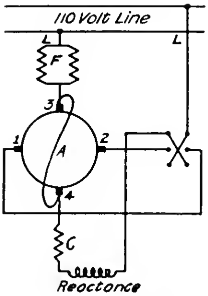


Fig. 55. Connections for Reversing Standard Type RI, 110-volt Motors

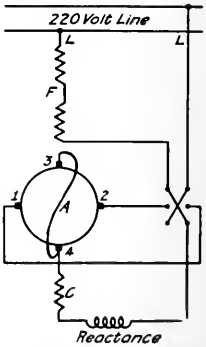


Fig. 56. Connections for Reversing Standard Type RI, 220-volt Motors

Adjustable Speed Motors

Adjustable speed motors, similar in operation to the shunt wound direct-current motors with field control, are usually designed to operate at from 50 to 150 per cent synchronous speed, giving a speed range of approximately 3 to 1 with full load torque.

By the insertion of either an external reactance or voltage in quadrature with the main line in the compensating circuit, the motor may be speeded up to approximately 50 per cent above synchronism. This corresponds to the field weakening method of adjusting the speed of direct-current shunt motors. By the latter of these two methods, that is, by the insertion of a quadrature voltage in the proper direction, the speed of the motor may be reduced somewhat below synchronism; but of course in a normally designed motor the saturation of the iron limits the speed control in this direction.

Also, it is evident that a proper adjustment of the compensating voltage in line with the main field will improve the regulation and power-factor and prevent excessive losses in the various local circuits.

Since the field control method is limited in range, the natural method to follow in obtaining wide speed control with shunt regulation is to introduce across the energy brushes a positive voltage either bucking or boosting. It is evident that we can increase or decrease the speed, depending on the amount of voltage used. The speed variation does not depend on any condition of load, since the voltage is always constant and, therefore, the change in speed is secured independent of the local conditions. This may be compared quite closely to a direct-current shunt motor with variable voltage supplied to the armature. As mentioned, it is necessary in order to take full advantage of this method of speed control, to insert a corresponding voltage in the compensating circuit for each change in the energy circuit, so that the control is handled in two practically independent circuits. As these two circuits may be fed from separate coils of the same transformer, this does not introduce a serious hardship. The same high speed limit is reached with this method of control as with the field control method; that is, 50 per cent above synchronous speed. The low speed is not really limited, but the motor is unstable somewhat below one-half speed with full load torque. At high speed points the speed regulation is approximately 6 per cent, and at the low speed points under similar load conditions the speed regulation is approximately 20 per cent.

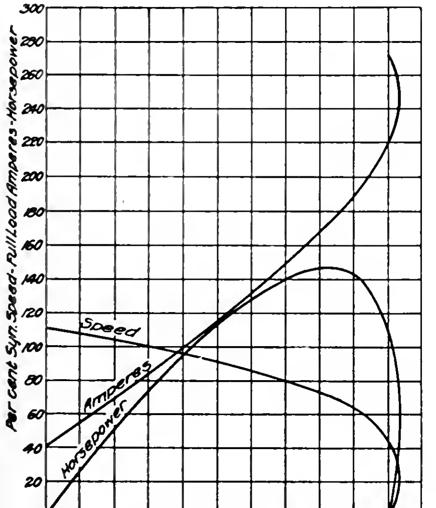


Fig. 57. Performance Curves of a Single-phase Reversible Motor

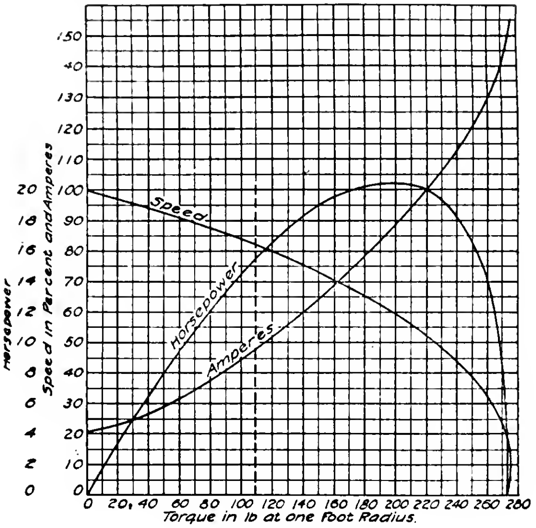


Fig. 58. Performance Curves of a Polyphase Reversible Motor

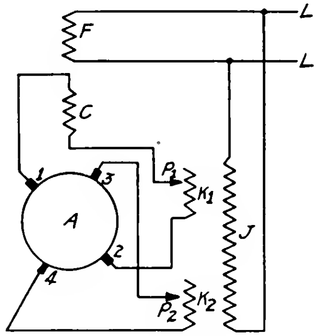


Fig. 59. Adjustable Speed Repulsion Induction Motor

Fig. 59 shows the arrangement of circuits; *J* is the transformer primary, and *K1* and *K2* are the transformer secondary; *F* is the motor field; *C* is the compensating winding; and *A* is the motor armature. It will be seen that the movable contact points *P1* and *P2* are simultaneously shifted, varying the voltage in the energy circuit and at the same time adjusting the compensation for the resultant change in speed. The shifting of the contact points *P1* and *P2* is readily accomplished by a dial or drum controller.

By supplying a 4-pole double-throw switch and making use of a reversing winding in the motor an outfit may be furnished giving equal speed regulation in both directions of rotation. Figs. 60 and 61 show torque curves and operating characteristics at different points of the controller and with varying torques.

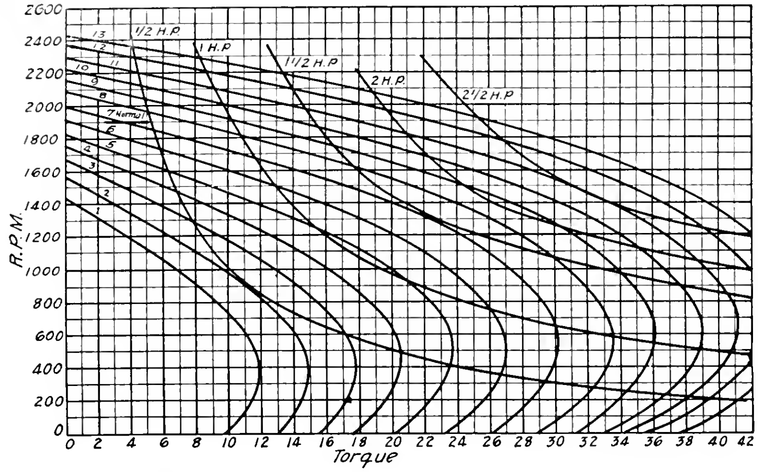


Fig. 60. Speed-torque Curves of 1-h.p., 1800-r.p.m., Adjustable Speed Motors

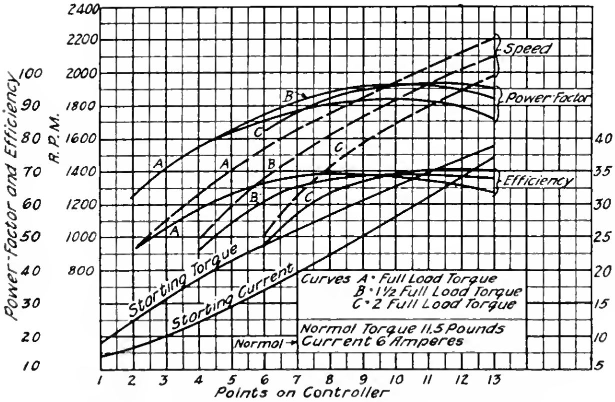


Fig. 61. Operating Characteristics of 1-h.p., 1800-r.p.m., Adjustable Speed Motor

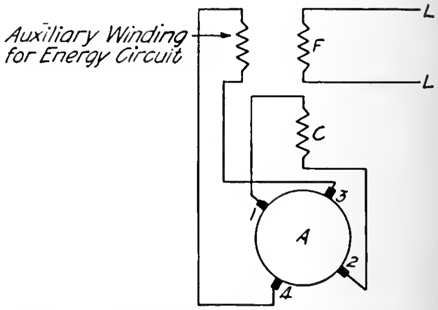


Fig. 62. Adjustable Speed Repulsion Induction Motor with Energy Secondary

As previously mentioned, the constant speed motor can be made to operate at 20 per cent above or below synchronous speed by the use of special windings. This is quite evident now when we consider how adjustable speed may be obtained. By the addition of an auxiliary winding it is possible to obtain a voltage for the energy circuit taken from the field winding. This is evidently merely a modification of the adjustable speed motor. The circuits are shown in Fig. 62. The advantage of this arrangement is that the same speed can be obtained for different frequencies. That is, if a machine operates at 1800 r.p.m., 60 cycles, and it is desired to operate on 50 cycles, the scheme whereby a voltage is impressed across the energy brushes from the field winding will permit of obtaining 1800 r.p.m. on 50 cycles.

ELECTRIC ARC WELDING

By H. L. Unland

Power and Mining Engineering Department, General Electric Company

The intense heat of the electric arc renders it specially applicable to the cutting and welding of metals. As about three-fourths of the heat is generated at the positive electrode, direct current is much superior to alternating current and is used almost entirely for this work; the piece to be worked on being made the positive electorde and either carbon or metal being employed for the negative. The author discusses the principal factors involved in electric arc welding and cutting, and mentions a number of cases where the process may be employed to advantage. Some of the results that have been obtained are illustrated and a table is included to assist in estimating costs, which of course are dependent upon the local charges for power and labor.—Editor.

H. L. Unland

Electric arc welding is a process whereby the heat of an electric arc is used for modifying metallic objects in two ways; first, by adding metal or jointing other pieces by binding them together with the added metal; and second, for removing metal by melting it away or for entirely cutting off sections in this manner.

The intense heat of the electric arc has been appreciated practically ever since its discovery, and its use for fusing metals was an early development. However, it did not come into commercial use until about ten years ago, and then only on a small scale. In the last four or five years the use of the process has rapidly increased until now it is employed in practically all industries where iron and steel are involved. Arc welding is now used in connection with mines, foundries, steel mills, steam and electric railways, locomotive plants, car shops, ship yards, marine repair shops, general repair shops, tank shops, automobile plants and other manufacturing plants of various types.

In order to use this process it is necessary to have an electric circuit by means of which continuous current can be made to flow through an arc established between the piece of metal to be operated upon, briefly called the work, and an electrode held and manipulated by a workman. The work is connected to one terminal of the circuit, and the electrode by means of flexible cable and suitable holder to the other terminal. The electrode is momentarily brought in contact with the work and then withdrawn, which causes the arc to form. If the arc is not lengthened too greatly it will hold, and by moving the electrode the arc can be moved about over the work. For this work the current varies from a minimum of 25 amperes for very light work to a maximum of about 1000 for heavy cutting.

In an electric arc, about three-fourths of the heat generated is liberated at the positive electrode, which has a tendency to bring this point to a temperature higher than that of the negative terminal of the arc. In an alternating current arc the current is reversing at a rapid rate and the terminals of the arc thus change polarity, being alternatively positive and negative. It is obvious that

Fig. 1. Hole in Side of Steamship Caused by Collision. Arc Welding Set Used in Making Repairs

in this case equal heats will be liberated at the two terminals and neither will approach the temperature possible if one were at all times positive. For this reason direct current is desirable and is now almost universally used for this purpose. Another reason is that the work is larger in size than the electrode and hence will conduct and radiate heat faster than the electrode. If equal quantities of heat were generated at the work and the electrode it is clear that the electrode would be much hotter than the work, and in order to bring the work to the proper temperature more power would have to be used, in which case the electrode would become too hot and burn or melt away too fast. By making the work the positive terminal of the arc, more heat is liberated at this point and the proper relation of temperatures obtained.

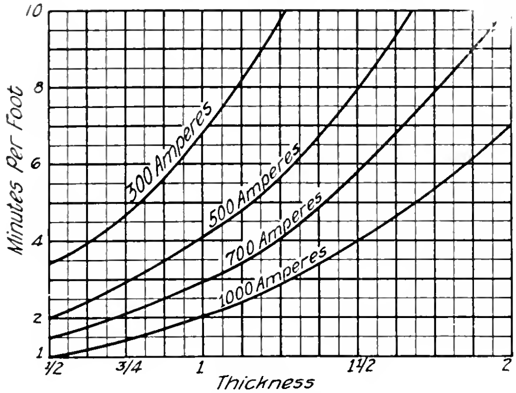


Fig. 2. Cutting Speeds for Sheet Steel. Electric Arc, Carbon Electrode

A third reason is that an alternating current arc is difficult to maintain. The current passes through zero at each reversal and consequently the arc cools off greatly and is nearly extinguished each time. The arc must be held very short in order to keep it going.

When the carbon electrode is being used and the work is positive there is also a tendency to prevent carbon from being carried into the weld, thus helping to keep the weld soft.

At the present time practically all arc welding is done by using one of two methods which are commonly known as the carbon electrode method and the metallic electrode method. The carbon electrode method consists of using a pencil or rod of carbon or graphite as the electrode and maintaining an arc between it and the work. The arc fuses the metal of the work in a small pool at the point of impact, and by progressing along the work, allowing the molten metal to run off, metal can be removed or the piece can be cut entirely through. If metal is to be added, a rod of filling metal is fed into the arc by the operator. This filling metal melts off and unites with the molten metal of the work, the operation being much like soldering with a soldering iron. The arc is represented by the iron and the filling metal by the stick of solder. In this method the arc is held about one inch to one and one-half inches in length.

The metallic electrode method, however, utilizes a rod or wire of the filling metal as the electrode. The action of the arc in this case fuses the electrode and carries the molten metal in finely divided particles to the work. This metal is driven into the molten pool on the work and a firm union of the original metal and the added metal is formed. The arc in this case is short, about one-eighth inch in length, and for this reason more skill on the part of the operator is required to keep the arc length nearly constant in order to prevent too great variation in the arc length and consequent variation in the metal deposited.

The voltage drop across the carbon arc is about 40 volts and across the metallic arc about 20 volts. The electric arc is inherently unstable and in the majority of installations a constant voltage circuit is used with a resistance in series with the arc. By this means a practically constant value of current is obtained within the limits

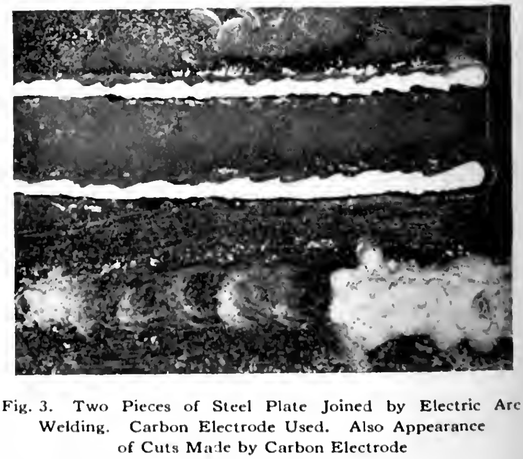


Fig. 3. Two Pieces of Steel Plate Joined by Electric Arc Welding. Carbon Electrode Used. Also Appearance of Cuts Made by Carbon Electrode

necessary for successful work. It has been found by experience that a line voltage of 60 is about a good average value and is successfully used in this way. This gives a margin of 40 volts for the metallic process and 20 volts for the carbon electrode. The metallic arc is more unstable than the carbon arc, and therefore requires more leeway in the matter of reserve voltage. However, voltages of from 40 to 90 are used.

In constant potential arc welding circuits having ballast resistance in series with the arc, any reduction in the current flowing, caused by the lengthening of the arc, will cause a decrease in the voltage drop across the resistance with a consequent rise in the voltage across the arc. Thus the tendency is toward constant power in the arc and therefore constant heat. Part of the heat is, of course, generated in the arc proper rather than at the points where it touches the work and the electrode, but the volume inclosing the entire arc is so small that the heat is practically concentrated at a point. This particularly applies to welding with the short arc of the metallic electrode. A constant current arc welding circuit with varying voltage is so arranged that practically constant current is obtained with varying arc length; the longer the arc the higher the voltage, and consequently the greater the power liberated.

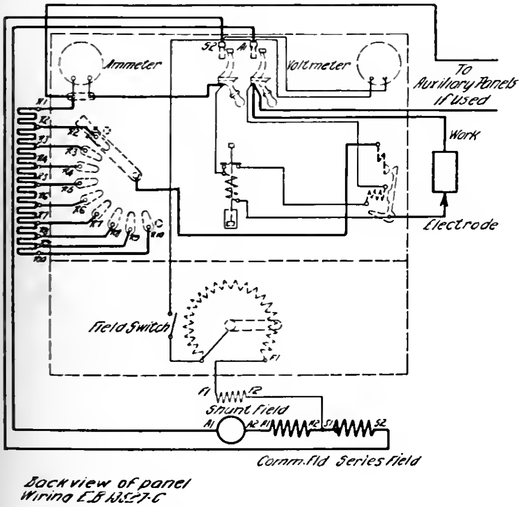


Fig. 5. Connections of Arc Welding Control Panel for Controlling Generator and One Welding Circuit

In cutting with the carbon arc the electrode is operated like a gas torch. The arc is held at one point on the metal until fusion occurs and the melted metal runs off, when the arc is slightly advanced, in this way gradually melting a path through the metal. The width of this groove will depend on the size of the electrode used and on the skill of the operator in keeping to a straight line. The cut will be slightly wider than the diameter of the electrode in order to allow the arc to be played on the bottom of the cut, and it will be wider for thick sections than for thin ones. The edges of the cut will not be smooth, due to masses of the molten metal not running away, and also to the fact that the arc will tend to jump from one point to another and cause an uneven cut. An illustration (Fig. 3) is given

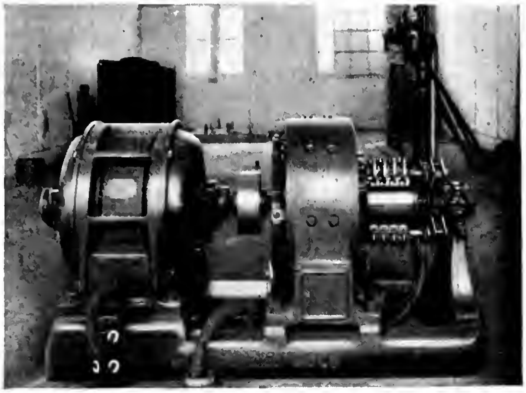


Fig. 4. 500 Amp. Electric Arc Welding Set with Control Equipment in Background

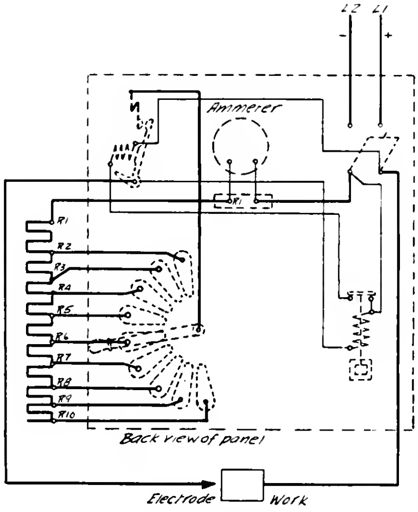


Fig. 6. Connections of Auxiliary Arc Welding Control Panel for One Welding Circuit

showing the appearance of cuts made by this method in ½ inch boiler plate. Fig. 2 shows the approximate cutting speeds for various values of current and thicknesses of metal. The cutting speed is lower than is possible with the gas process, but with a reasonable power rate the cost of cutting by the arc is much below the cost of cutting by means of gas in a great many cases.

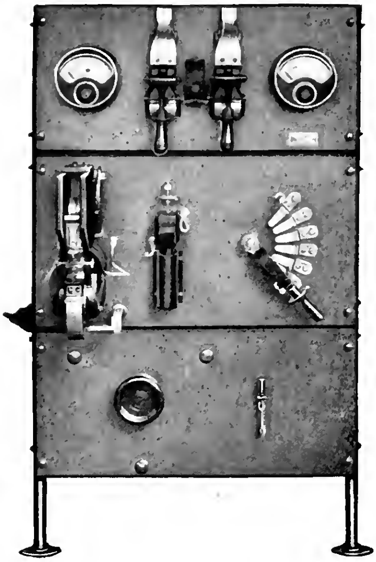


Fig. 7. Arc Welding Generator Control Panel with Welding Circuit Control

In welding by means of the carbon electrode, the arc is not held in one place long enough to melt entirely through the work, but is moved around in order to melt a fairly large pool on the work. A rod of filling metal, in general the same as the metal of the work, is held in the operator's hand and gradually fed into the arc and melted down onto the work. The added metal unites with the metal of the work and it all cools as one mass. For light welding the current will be from 100 to 250 amperes; for medium work it will vary from 250 to 350 amperes; and for heavy work up to 500 amperes will be required. Because of the fact that heavy current can be used it is possible to do very fast work by this method. A joint between two ½ inch steel plates as made by the carbon electrode is shown in the same illustration as the cut made by this method.

The metallic electrode can not be used for cutting but is used only for welding or building on metal. The weld made is slightly stronger and better looking than one made by the carbon electrode, but since the current used is much less the speed of welding is also lower. The thickness of the metal in the work determines the current value and also the diameter of the electrode which should be used. For heavy work, higher currents and larger electrodes are allowable. The table gives figures covering ordinary practice in regard to this type of welding. Vertical and overhead surfaces can be successfully welded only by this method, the operation being the same as for normal welding except that more skill on the part of the operator is required in order to keep the arc constant in this position. Such a weld will require about the same time and will have about the same cost as a double lap weld. The appearance of a weld made by the metallic electrode is shown in the illustration of a repair to a car wheel lathe head. (Fig. 11.)

Fig. 8. Castings in Shops Showing Heavy Risers Cut by Electric Arc

A low-voltage circuit is obviously desirable in order to reduce as much as possible the voltage drop in the series rheostat. It has been found that a 60-volt circuit is entirely satisfactory for this purpose except where a considerable number of operators are to work from the same circuit, when 75 volts is desirable on account of voltage drop in the lines. The generator should be wound to give this voltage with the minimum of variation with load, and should have good commutation characteristics to take care of the sudden variations in load due to the service.

The control circuit consists essentially of a series rheostat in circuit with the arc. (Figs. 5 and 6). Various refinements in the way of protective, indicating and regulating devices are added in order to improve the operation. The connections of the auxiliary panel illustrate this clearly. The heavy lines show the course of the welding current, while the light lines are the control lines for the protective equipment. It is seen that the welding circuit leads through a dial switch, for easily changing the resistance setting, and is closed by a contactor whose exciting circuit is controlled by a relay. The control circuit of the relay is connected so as to be virtually across that section of the series rheostat in use, as determined by the setting of the dial switch. Since the arc voltage is practically constant for any current value, the voltage across the series rheostat will also be constant.

The relay is so set as to operate when this voltage exceeds a predetermined value, which can only be caused by the current increasing in the same proportion. The operation of the relay causes the contactor to open the welding circuit. If the electrode is in contact with the work the relay and contactor will remain open, but as soon as the electrode is lifted the circuits automatically resume their operating position, rendering it unnecessary for the operator to leave his work to close any switches. The

APPROXIMATE FIGURES COVERING SPEEDS, ELECTRODES, CURRENT AND COSTS FOR BUTT WELDING SHEET METAL BY METALLIC ELECTRODE. DOUBLE LAP WELDS WILL BE APPROXIMATELY THE SAME AS TWO BUTT WELDS. POWER 3C PER KW. HR. LABOR 30C PER HR. ELECTRODE 5C PER LB.												OXYGEN 2C. CU. FT. ACETYLENE 1C. CU. FT.
Thickness of metal Inches	Dia. Electrode Inches	Speed per Hour Feet	Amps.	Mean KW. at 60 V.	Mean KW. at 70% Eff.	Approx. Electrode per Hour Lbs.	Power per Hour cts.	Labor cts.	Electrode cts.	Total per Hour cts.	Total per Feet cts.	Total Cost per Ft. Oxy. Acetylene Process cts.
$\frac{1}{16}$	$\frac{1}{16}$	20	High 40 Mean 30 Low 25	1.8	2.6	.9	7.8	30	4.5	42.3	2.12	1.78
⅛	⅛	16	75 50 30	3.0	4.3	1.4	12.9	30	7.0	49.9	3.12	4.66
¼	⅛ or $\frac{3}{16}$	10	125 100 70	6.0	8.6	3.1	25.8	30	15.5	71.3	7.13	13.3
⅜	$\frac{3}{16}$ or ¼	6.5	150 125 100	7.5	10.7	3.6	32.1	30	18	80.1	12.3	36.1
½	¼	4.3	175 140 120	8.4	12.0	3.8	36	30	19	85	19.8	much higher
⅝	¼	2.8	195 155 125	9.3	13.4	3.4	40.2	30	17.0	87.6	31.3	"
¾	¼	2.0	200 160 125	9.6	13.8	2.4	41.4	30	12.0	83.4	41.7	"
1	¼	1.4	200 160 125	9.6	13.8	2.7	41.4	30	13.5	85.9	61.3	"

The figures given in the table for power, labor and material are more or less arbitrary for comparative purposes, and may be changed to suit local conditions.

relay is fitted with an oil dashpot to provide a slight time delay in order not to operate on the momentary increases of current which are incident to the welding operation and which cannot be avoided. The main control panel includes, in addition to the welding equipment, the necessary devices for controlling the generator. The welding circuit on the main panel may be of any capacity up to that of the generator, or it can be omitted and the panel used only as a generator panel. In this case all the welding would be done from auxiliary panels located at the proper points about the shop.

Fig. 9. Repairing Locomotive Piston Rod by Electric Arc Welding

Units of small size, up to and including 400 amperes capacity, can be mounted complete with panels and rheostats on a platform truck for portable use, and can be arranged for use by one or two operators simultaneously. This arrangement is very desirable in some cases, as it is much easier to carry the set to the work than the reverse

Around mines, due to the heavy service, there is a great deal of repair work to iron and steel equipments connected with the hoists, structures, machinery, transportation equipment, etc. A great deal of this work can be done by the arc process, saving time and cost over any other method. In foundries, by means of this process, risers are cut off, steel castings are repaired by welding cracks, blow holes, sand holes, etc., and by building on pads and lugs, filling low spots due to slightly shifted cores, and making other repairs which prevent the castings being sent to the scrap pile. Large scrap metal is cut up so that it can be handled, and a large amount of repairing to the machinery can be readily done.

The rough usage and heavy service to which steel mill equipment is subjected provides an immense amount of repair work of the class for which the arc welding process is best suited. Frames, shafts, cranks, wobblers and parts of all kinds of machinery are continually giving way, and unless a spare part is available much time and expense are involved. Time is particularly valuable in this work and the rapidity with which a weld

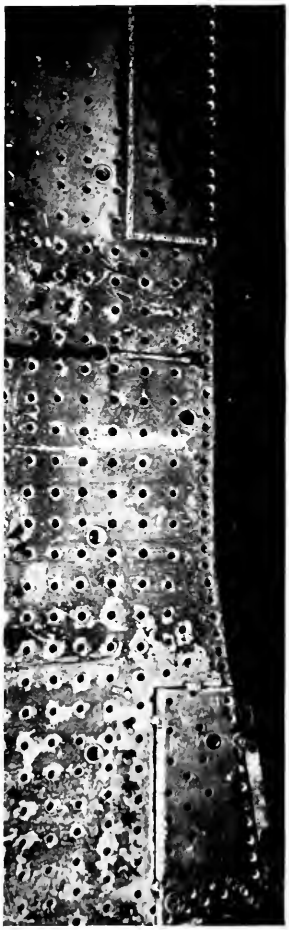


Fig. 10. Patches Arc Welded on Corners of Locomotive Fire Box Shell

can be made electrically is a strong point in favor of its use. In many cases the weld can be made in place, by the use of a portable set or by merely extending the welding cables from a stationary welding set.

In practically all the important shops and round houses of the larger steam railroads, one or more arc welding sets are installed. Repairs are made to all parts of the locomotive equipment. Flat spots on the wheels are built up, broken side frames welded, defective tube sheets patched or removed and new ones welded in, cracks inside or outside of the fire box are welded or patched, etc. The possibilities are innumerable. Nearly all railroads have made it standard practice to weld the locomotive tubes to the tube sheets. Where this is done, it is found that in practically all cases the locomotive is run for the full life of the tube before leaks develop at the tube sheets. In this way, the periodic performance of sending the locomotive to the shop to have the tubes rolled in is avoided. This continual rolling also has a tendency to weaken the ends of the tubes as well as to expand the holes in the tube sheets. Arc welding sets are, therefore, required by locomotive companies who make locomotives for these roads, and in a short time it is probable that all railroads will insist on this type of construction.

Fig. 11. Cast Iron Head of Car Wheel Lathe Repaired by Electric Arc

Fig. 12. Welding Oil Stills by Means of Electric Arc

Fig. 13. Welding Air Compressor Intercoolers by Electric Arc Process

The use of steel cars, both passenger and freight, is rapidly increasing, and this affords an enormous field for the use of electric arc welding in both the construction and repair of these equipments.

Electric railways find a great use for arc welding in track maintenance. Low spots in the rails are welded, rail joints that have been hammered down are built up, and worn switches and crossovers are repaired. A set, mounted on a large truck or wagon, the motor being driven from the trolley circuit, can be most advantageously used. The work can be done either at night or during the day in the interval between the passage of cars if enough time is available. In the repair shop, the arc can be used to repair car frames, flat wheels, motor frames, shafts, etc.; in fact, it is usually found that more unthought-of work is available than the set can handle.

In shipyards, the construction and repair of steel vessels will provide a great amount of work for an arc welding set. In a number of the larger harbors, arc welding sets are installed on barges which are towed to the ship, and by means of cables taken through port holes repairs are made to any part of the ship or machinery. On account of the saving in time possible by this method, large premiums are paid to these repair companies and the equipments are kept busy. Fig. 1 shows a repair job where an arc welding set was shipped more than a thousand miles at the expense of the contractor, who also paid a rental of twenty-five dollars a day for the use of the equipment in the repair work.

Fig. 14. Locomotive Side Frame showing Defective Section cut away for Filling in with Electric Arc

In the Journal of the Society of Naval Engineers it is stated that after the fight off the coast of Chile, the British cruiser "Glasgow," with a number of holes near the water line, put into Rio de Janiero for repairs. An arc welding set was found and in less than twenty-four hours patches were welded outside the hull, and the cruiser put to sea taking the arc welding set along.

The manufacture of tanks and similar structures is rapidly and cheaply taken care of by welding. Strong, tight joints are made with the least expense. If necessary the metal can be both cut and welded by the arc. Steam, oil and refrigerating piping can be welded and made absolutely tight. Complicated pipe connections can be welded instead of being made by using special or numerous pipe fittings. A large steel water main was laid some years ago for an eastern city but after acceptance it was found that leaks had developed along almost the entire length. At the present time the joints in the entire line are being welded by the arc.

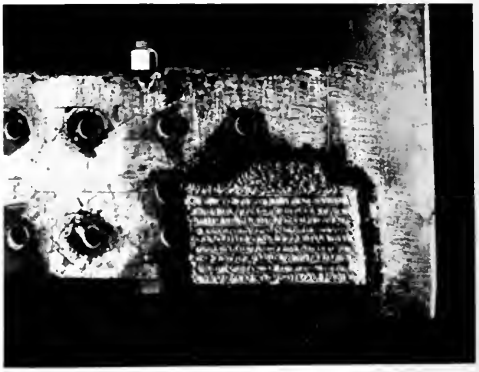


Fig. 15. Showing Repairs made to Locomotive Frame of Fig. 14

The points brought out above show the flexibility and adaptibility of the arc welding process for many kinds of manufacturing and repair, and with very little study it will be found that in practically any place where iron or steel is used to any extent an arc welding equipment will prove a valuable addition to the equipment and will probably supersede some of the methods now in use.

Fig. 16. Section of a Smoke Stack. Seams Welded by Electric Arc Welding Process. Metal ¼ in. Boiler Plate

WATERWAY TRANSPORTATION FOR GENERAL ELECTRIC COMPANY TRAFFIC

By Robert H. Rogers

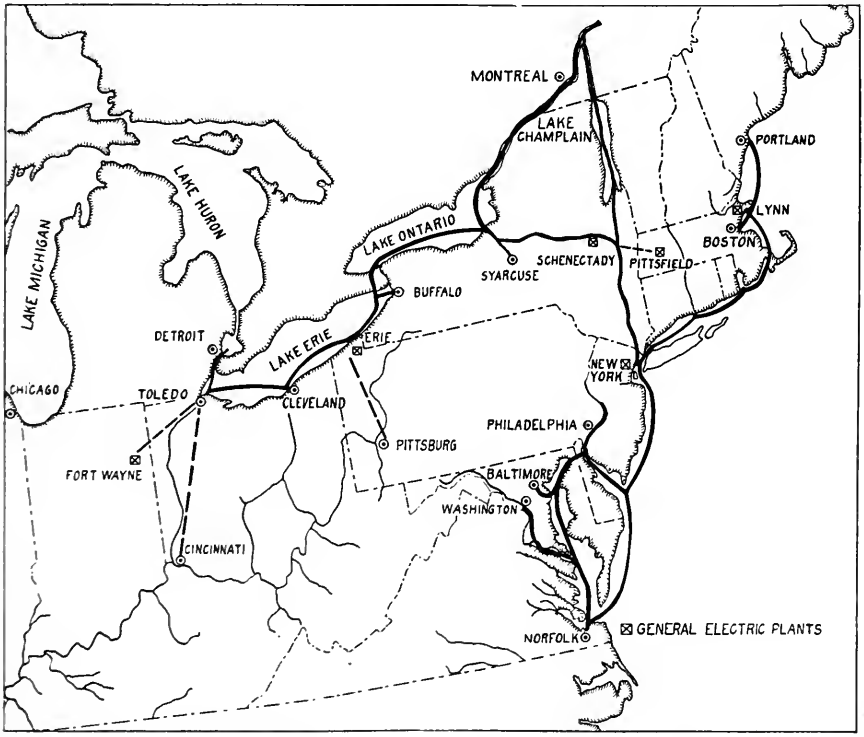
Power and Mining Engineering Department, General Electric Company

The completion of the New York State Barge Canal, which passes through Schenectady, the home of the General Electric Company's largest plant, has caused a great deal of consideration to be given to the possibilities of waterway transportation for the incoming and outgoing shipments of the Company, specially with respect to traffic between plants. Some figures showing the proportions and character of these shipments are given, and the extent to which waterway transportation may be availed of. Suitable boats will be necessary before this method of freight transportation can be made a success, and the author includes plans for a boat that will fulfill all ordinary requirements. Terminal facilities are equally important, and a simple plan of a proposed terminal for the Schenectady Works is also shown.—Editor.

R. H. Rogers

THE New York State Barge Canal has been completed and is in use between the Great Lakes at Oswego and tide water at Troy, and north to Lake Champlain. It provides a waterway of twelve feet minimum depth and the locks will pass a single craft of 3000 tons, or 100 car loads capacity. Large rivers and lakes form so much of the canal that boats can make practically as good time as on the Hudson River or Long Island Sound. This new waterway serves to connect the various works of the General Electric Company with each other, with sources of raw materials, and with great shipping centers, and it gives direct access to the most intensely cultivated industrial area of America.

The growth of general freight traffic has been phenomenal and railroads are being hard pressed to even approach the service that they could formerly render. On a certain well-known railroad, freight traffic has increased 70 per cent in ten years. In general, freight movements increase four to five times as fast as the population. Naturally, with its steady growth, the movements of goods to



The Relationship of Water Routes General Electric Plants and Shipping Centers is Indicated by this Chart and from the General Electric plants has reached a formidable total.

With so much local and general welfare depending upon the uniform and uninterrupted flow of materials to and from its plants, it is natural that a second avenue for traffic should be sought in order to make more certain the continuity of all inter-related processes. Again, railroad clearances put restrictions upon the design and fabrication of large units.

For these reasons and for others less vital, attention is being given to the possibilities of floating an appreciable percentage of General Electric traffic through the natural and artificial waterways that have so recently become available.

The State Barge Canal is Very Different from the Popular Idea of a Canal in that Lakes and Rivers Form its Greater Part

This Serves to Show the Great Size of the Locks. The Terminal Slip at the Schenectady Plant is Planned to Be Lock Size

Traffic

The movements of freight involved are those of raw materials bound toward the various plants; partly finished products enroute between plants; and finished products going to customers or to the district warehouses.

It is a surprising fact that for every ton of finished product shipped out there are two and one-half tons received; hence in tonnage the shipments are only 40 per cent of the receipts. The raw materials are generally of the lower classes of freight and come largely in bulk. However, regardless of its class, its prompt delivery is of vital importance and a cessation, say in the delivery of coal, would be disastrous in the extreme.

The receipts at the Schenectady Works during a typical year (1915) were 307,000 tons made up of about 150,000 tons of coal, 22,000 tons of pig iron, 16,000 tons of copper, 17,800 tons of lumber, 21,000 tons of sand, and 80,000 tons of merchandise including sheet steel, steel shapes, and castings. The receipts at all the other plants aggregated almost exactly the same as the Schenectady Works. The total receipts probably represented 25,000 car loads.

The shipments from all the plants exclusive of interplant shipments during the same period aggregated 243,208 tons of which the Schenectady Works contributed 111,000 tons. The total outward shipments probably made nearly 50,000 car loads.

The figures for all classes of traffic movements for 1916 and 1917 are so much greater

TABLE I

Destination	ORIGIN OR SHIPPING CENTER						
	Near Lake Erie Ports	N. Y. State	N. Y. Bay	L. I. Sound	Boston District	Chesapeake Bay North of Norfolk	Norfolk and South and West
Fort Wayne Works		2100	3400	450	900	600	
Erie Works	3700	8100	7900	1260	780	1150	
Schenectady Works	160000	17700	17400	1800	5800	8100	22000
Pittsfield Works	25000	4100	4800			4550	
Sprague Works							
Lynn Works	3000	720	8400	3050		5200	20000
Totals	191700	32020	41500	6560	7480	19600	44000
Grand total	342460						

than for the three previous years that a special study is required to cover the best methods for relieving the extraordinary traffic conditions that now prevail.

Possible Water Borne Freight: Inbound

A comprehensive survey of the fields of origin of raw materials and their central shipping points as related to the existing waterways that touch or closely approach the various plants shows that a large percentage of this traffic can be moved by water all the way, with another large portion that would require short rail hauls to make the water route available. Table I which has been complied from Transportation Department data indicates the tonnage that might be moved under hatches.

Of the grand total shown, the proportions of all water and part rail and water mileage is estimated as follows:

Tons	Per Cent of Total	AVERAGE MILEAGE	
		By Water	By Rail
200000	60	400	
85600	25	400	90
57000	15	400	160

Possible Water Borne Freight: Outbound

Table II is representative of the inter-works shipments; shipments to customers, domestic and abroad, and to district warehouses, as shown by Transportation Department data.

The distribution of these outbound shipments is estimated to be:

Tons	Per Cent of Total	AVERAGE MILES	
		By Water	By Rail
60000	60	320	
25000	25	300	100
15000	15	300	150

An examination of these tables will show well balanced traffic which should maintain a good "load-factor" on the floating equipment, while the enormous quantity available will make it possible to select for cargoes those things which are most profitable to handle and carry or which are most essential for positive delivery at a specified time.

Waterways

Lake Erie will for some time be the most westerly waterway to be used (unless an occasional trip is made to Chicago) and gives access to Buffalo, Erie, the Erie Works, Cleveland, Toledo and (via the Detroit River) Detroit. The Fort Wayne Plant is 90 miles southwest of Toledo, and Pittsburgh is 90 miles south of Erie.

While the lakes are subject to violent storms, the ports are close together and with due care an able boat does not assume abnormal risks.

The Canadian Welland Canal gives access to Lake Ontario and no tolls are charged for its use. The Barge Canal meets Lake Ontario at Oswego where an ample harbor and fine terminals are located. The canal makes use of the Oswego River and Oneida Lake, then a short land cut to the Mohawk River which is used to within a mile and a half of the Hudson River.

The Schenectady Plant is on an eleven mile level and has a harbor and state terminal adjacent to the property line with a natural wing channel bordering the plant for its entire length.

The Hudson River is twenty-one miles to the eastward and the Pittsfield Plant is overland twenty-eight miles east of the Hudson River at the nearest point. The Barge Canal through the state to Buffalo will be completed in May, 1918, and will

TABLE II

Origin	DESTINATION OR SHIPPING CENTER						
	Toledo for South and West	Chicago and Beyond	Niagara Frontier and Erie	New York	Phila.	Chesapeake Bay	Boston and Lynn
Fort Wayne Works..........			540	950	720	510	680
Erie Works..................	1120			2100	1260	650	2620
Schenectady Works.........	3500	7550	4800	18820	3500	2100	5200
Pittsfield Works............	1850	2120	1100		1700	900	210
Sprague Works.............	600	450	260		720	285	110
Lynn Works.................	2940	3800	2100	3700	24200	810	
Totals....................	10010	13920	8700	25570	32100	5255	8820
Grand total	104375						

make the second route possible to Lake Erie from mid-state.

New York Harbor gives contact with the Sprague, Newark, and Harrison Works, and with the domestic and export warehouses as well as the coastwise and export piers, and also the New York Navy Yard.

Bordering New York Bay and the Sound are the origins of much of the higher classes of raw materials. The Cape Cod Canal gives a safe route to Boston Harbor and the Lynn Works. By way of the Jersey Coast and the Delaware River access is had to Philadelphia and another rich field of raw materials. The League Island Navy Yard, the New York Shipbuilding Co., Wm. Cramp & Sons and many smaller ship yards are located about Philadelphia and entrance is made there to an intense industrial area. The Delaware and Chesapeake Canal give entrance to Chesapeake Bay and Baltimore. This bay also leads to Norfolk, Newport News and to Washington, up the Potomac River. Access to Norfolk, a great coal, lumber, and pig iron center, is also possible by the outside route down the coast.

The Thousand Foot State Terminal Wharf Adjacent to the Schenectady Works. The Area of this Terminal is Seven Acres

Looking Toward Schenectady Works from State Terminal. Arrow Shows Proposed Location of Slip and Great Crane

The only waterway placing a limitation on capacity, speed, and model of ship is the Barge Canal which has a depth of twelve feet and head room under bridges of fifteen and one-half feet. The locks are 310 feet long in the clear and 45 feet wide, all electrically-operated. They are manned by civil service engineers and the operations of the locks are precise, safe, and rapid—the usual time per lock being from seven to eleven minutes. From the Schenectady Works to the Erie Works on the west, and to New York on the south, there are only 70 miles of restricted land cuts where top speed is not possible. The distances by water and character of the waterways is indicated in Table III.

The Lakes and Barge Canal will be closed to navigation from three and one-half to four months in winter, but the Lynn, New York, and Norfolk traffic need not be interrupted.

Projected Waterways

A sea-level canal across New Jersey is likely to be dug within a few years, which will give a short cut inside to Philadelphia and the Delaware River, thereby avoiding the dangerous Jersey Coast. A canal from Pittsburg to Lake Erie has long been considered and now bids fair to become a reality. The tonnage both ways over this route would be tremendous and the distance and elevations are not serious.

A Toledo-Chicago Canal is possible and is periodically agitated. It would pass through Fort Wayne and would cut off a long stormy route around the lower Michigan Peninsula. Channel improvements are under way in the Mystic and Malden Rivers which will enable large boats to dock at the General Electric steel foundry at Everett, Mass., which is now served by lighters. The channel has just been deepened and the bridge spans widened to 50 feet approaching the River Works at Lynn, and there is now 18 feet of water at the Works' wharf at low tide, the tide range being 10 feet.

Boats

With traffic so diversified in commodities and commercial requirements, it is hardly likely that one type of boat will meet all conditions in an acceptable manner. Low grade bulk commodities are available in big cargo units and can move slowly with no definite date of delivery; on the other hand, finished apparatus for many destinations cannot wait for consolidation into large cargoes and it must move fast and be delivered at a specified time. Another phase is presented by the manner of handling and carrying the various classes as, for instance, the hold for economically handling coal would not be the best possible for package freight.

The crucial point which calls for all the ingenuity and experience of the marine architect is to make a type of boat that can handily navigate the restricted Barge Canal and yet be safe on the Great Lakes or the Atlantic Coast. Once worked out, such boats would greatly enhance the value of the Barge Canal making it virtually a "ship canal" which may believed should have been provided by the Federal Government.

In general, the greater a boat's capacity the lower are the charges against it per ton-mile; but, as in many engineering problems, a compromise must be struck between fineness of lines, ability to manouver well, bulk capacity, free board, power, crew's quarters, overhead charges, and a dozen other items in the realm of the marine architect. A design has been prepared which seems to embody everything needed to meet the general conditions and which will handle the bulk of the ordinary traffic.

The Mohawk Here is Forty Feet Deep and the Locks are Over Ten Miles Apart

This general traffic boat will be about 260 ft. long, 43 ft. beam and 23 ft. deep with a shelter deck the entire length giving about 8 ft. head room. Hatches 16 ft. by 28 ft. through both decks will give access to the hold, and side ports will facilitate the handling of package freight to and from the main deck. The speed will be 10 knots (11½ miles per hour) with 750 h.p. applied by electric motors to twin screws. Two Scotch boilers over oil burners will furnish steam for a Curtis turbo-generator. The dead weight carrying capacity will be roughly 1200 long tons on 10 ft. draft and 3000 tons on 17 ft. draft and the available space for cargo will be about 85,000 cu. ft. or the equivalent of 50 box cars.

Many of the Great River Stretches Offer No More Resistance to Navigation than Long Island Sound

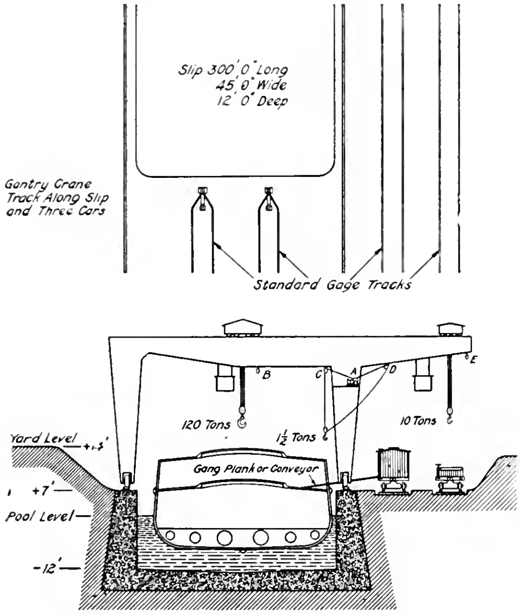
The boat will have electric auxilaries, portable conveyors, and other handling facilities, pilot-house control for driving motors, water ballast tanks, and will be unique among the cargo carriers. The designer says: "She can go anywhere in the Great Lakes or from Galveston to Halifax."

Much consideration is being given to the merits of tugs and tow barges for the economical transfer of coal and sand which are used in such quantities as to require entirely special treatment. With a tug and three barges (designed to fit a lock) constituting a tow, there would be required eight such units

TABLE III

Route	Miles	Ocean	Lake	River	Dug Canal
Toledo to Erie	174		100%		
Erie to Schenectady	400		58%	28%	14%
Schenectady to New York	175			98%	2%
New York to Lynn	270	93%		4%	3%
New York to Philadelphia	240	77%		23%	
New York to Norfolk	315	100%			
Lynn to Norfolk	525	100%			

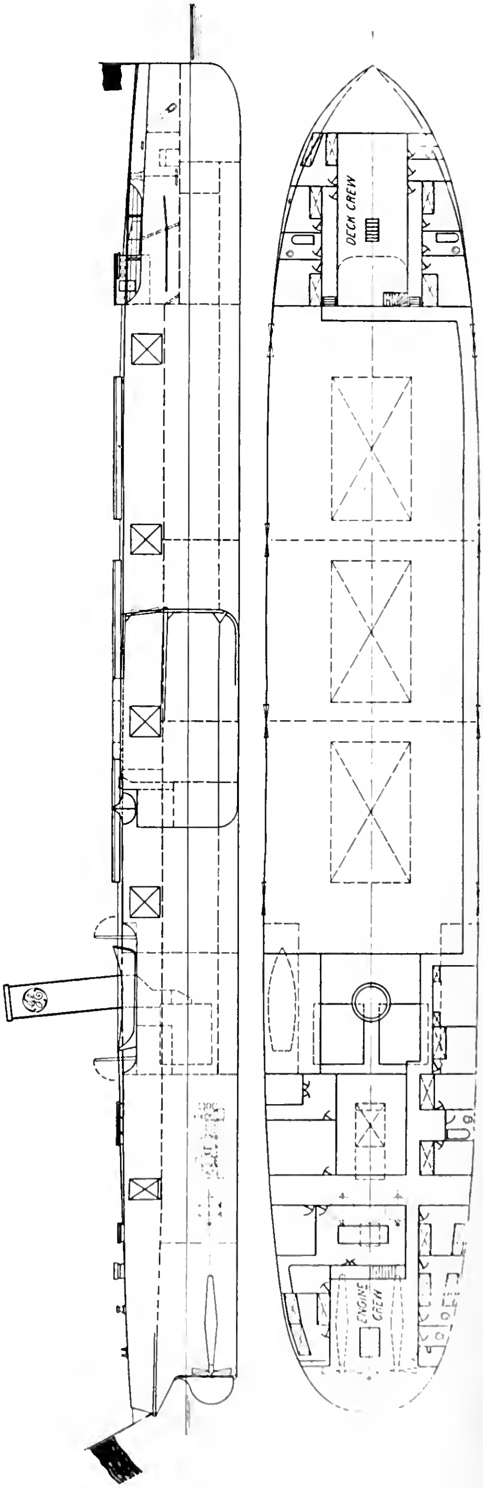
working steadily to supply the Schenectady Works with a year's quota of coal during the eight months of open navigation. Coal and some other commodities for the Lynn Works present similar conditions.



Section and Part Plan of a Proposed Terminal Unit at the Schenectady Plant

Coal barges for convenient handling could be 150 ft. long, 22 ft. wide, and 14 ft. deep, carrying 720 tons on a 10-ft. draft. The lock size unit of tug and three barges would carry 2160 tons. The economy of such boats is found in the absence of structural interference with loading and unloading, the small crew required per ton of cargo, and in the fact that the power plant (the tug) can be kept constantly busy. For certain special work it may be possible to use car floats upon which cars can be run and towed to their destination.

The fast high class traffic between the Schenectady Works and New York which amounts to 20,000 tons each way in 8 months is so constituted that frequent sailings under moderate cargoes are "indicated." For instance, 150-ton boats could be scheduled to leave the Schenectady Works at 5 p.m. Tuesdays, Thursdays, Fridays, and 1 p.m. Saturdays arriving in New York eighteen hours later, thus giving express service and in unit cargoes which are not too large to deliver intact at a single destination. Such



This Represents a Type of Boat that Makes the State Barge Canal a "Ship Canal," in that She Can Carry a Cargo from Duluth to Any Point on the Atlantic Coast, Three Thousand Tons Maximum Capacity, Length 160 Feet boats could be fashioned from private steam yachts that no longer answer their original purpose.

Terminals

The success of a line of boats, at least from the financial standpoint, depends upon how quickly and how cheaply the cargoes can be put in and taken out and upon the preparatory or consequent movements that are necessary. Fortunately, at most of the plants public or private docks are available, and at most places where delivery will be taken in bulk materials the handling facilities are highly developed.

For discharging bulk freight at the plants and for storing and reclaiming the materials, special rigs will be required consisting of bucket towers or bridges. Locomotive cranes equipped with grab buckets and magnets may also find a place.

Package freight will be power trucked, conveyed or whipped according to the local conditions and weight of the packages. The very heavy units will require the provision of huge cranes such as are seen at sea ports and navy yards

On this account, a special terminal is required at the Schenectady Works, the preliminary plans for which call for a slip of canal lock size; i.e., 300 ft. by 45 ft. and 12 ft. deep. Extensive rail facilities will be placed and the tracks and slip will be spanned by a gantry crane of probably 120 tons capacity. Light fast rigs will also be provided for handling small stuff, so that the boats will be detained only the shortest possible time.

One would believe that the shipments from factories of this kind would run much higher in weight per cu. ft. than the average marine cargo which figures 40 cu. ft. per ton or 50 lb. per cu. ft. but, as a matter of fact, the shipments including everything only run about 22 lb. per cu. ft. The average package weight is only 270 lb., and a 300-lb. range would include 40 per cent of the total weight shipped and 75 per cent of the pieces. These figures show the preponderance of small packages and indicate the extensive use of portable conveyors and fast light whip hoists. The very heavy parts usually attract the most attention in the way of handling facilities, but the small packages if properly speeded up, being in the great majority, show savings in time and cost that would justify primitive methods for the heavy articles if both classes could not properly be provided for.

Advantages

It is often remarked that slow moving low-grade stuff may be shipped by water advantageously, implying that water shipments are necessarily slow. As a matter of fact water traffic is much more rapid than ordinary rail freight because, once on the way, it keeps going and its progress must be slow indeed to break even with the halting way of the freight car.

On none of the routes considered is marine service expected to be inferior to rail and in some cases it will equal the costly express service which is more often resorted to than is commonly believed. Dispatch may therefore be put down as a valuable attribute of the contemplated system.

The provision of an additional means for bringing in raw materials and taking out finished products is an insurance against serious delays that has a value which cannot be estimated.

The aggregate saving in freight and express charges will be the most tangible item, in that it can be shown in definite figures.

The improved service that can be rendered to customers because of all these advantages is, after all, the thing that makes it most worth while.

SHORT CIRCUIT CURRENTS ON GROUNDED NEUTRAL SYSTEMS

By W. W. Lewis

Power and Mining Engineering Department, General Electric Company

This article outlines briefly a method of calculating single-phase short-circuit current on a grounded neutral system. In the solution of all problems of this character certain assumptions and simplifications are necessary in order to permit of handling at all, and therefore in this article line resistance and capacitance have been neglected, also the effects of the currents flowing in distorting the alternator voltage, etc. However, the solutions give fair approximations and it will undoubtedly later be possible, as knowledge is gained of the subject, to apply modifications that will permit of solutions approaching still closer to the correct results.
—Editor.

W. W. Lewis

THE manner of calculating short circuit currents on transmission systems has been described quite fully.* The methods thus described have dealt with three-phase or balanced currents; that is, in a three-phase system, it has been assumed that all three phases were short circuited simultaneously and that equal currents flowed over each line to ground. The manner of calculating the short circuit current is, briefly, to determine the per cent reactance of the combined circuit from the generators to the fault. This total or combined per cent reactance divided into 100 gives the number of times normal current flowing into the fault. The normal current in this case is that current upon which the per cent reactance of the various portions of the circuit is based. By means of the calculating table, described in the October, 1916, General Electric Review, the most complicated problems of this nature are readily solved.

Of late years the tendency has been more and more toward the operation of systems with transformers connected in Y and neutral grounded on the high voltage side. Now when a ground occurs on the line, a three-phase short circuit does not result but rather a single-phase short circuit. In this case the calculation of the short circuit currents may be quite involved, especially if the system is at all complicated. A brief outline of the method used in handling such problems will be given.

Referring to Fig. 1: Let G represent a generator; T_1 a transformer with high-voltage winding connected in Y and neutral grounded; T_2 a transformer stepping down the voltage for the load L. The ohmic reactance of the generator is represented by x_1; that of the stepdown transformer by x_2; that of the grounded transformer by z; that of the portions of line from transformer to the point A by y_1 and y_2; and that of the total length of line by y. E is the normal high tension voltage. All reactances, etc., are expressed in terms of their high-voltage equivalents.

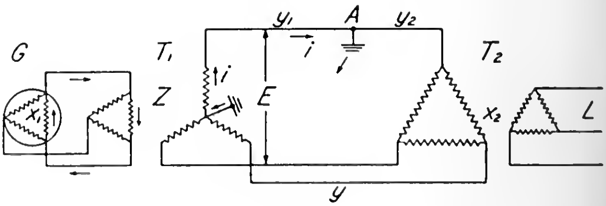


Fig. 1

Assume a ground at A. Then currents will flow as indicated by the arrows. The value of the current is expressed by the following equation:

$$i=\frac{0.577\,E}{x_1+z+y_1} \qquad (1)$$

or expressed in per cent reactance based on the normal three-phase line current I

$$i=\frac{100\,I}{\%\,Ix_1+\%\,Iy_1+\%\,Iz} \qquad (2)$$

Now consider the arrangement of Fig. 2, i.e., ungrounded transformer T_1 at the generating end and transformer T_2 with grounded neutral at the load end. The short-circuit current will flow as indicated by the arrows. The delta winding of transformer T_2 serves to cause equal in-phase currents to flow in each leg of the Y. The voltage drop in each part of the circuit is in phase with the voltage of the short circuited

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* See especially two articles in the June, 1916, General Electric Review, viz.: "Approximate Solution of Short Circuit Problems," by E. G. Merrick, and "An Approximate Method of Calculating Short Circuit Current in an Alternating Current System," by H. R. Wilson.

leg *a b*, and the total voltage drop is equal to *c d* or 0.866 *E*. The following equations may be written from the Fig.

$$0.866\,E = i(x_1+x_2+y+2\,y_1)+e$$

$$2(e-iz)=i(y_2+z)$$

from which we find

$$i=\frac{0.866\,E}{(x_1+x_2)+\frac{3}{2}\,y+\frac{3}{2}\,y_1+\frac{3}{2}z} \qquad (3)$$

or expressed in per cent reactance based on normal three-phase line current *I*

$$i=\frac{100\,I}{2/3(\%Ix_1+\%Ix_2)+\%Iy+\%Iy_1+\%Iz} \qquad (4)$$

Based on these fundamental equations it is possible to solve problems in cases involving a number of generating stations, a network of lines, etc. As the number of generating stations increases, however, the equations increase in complexity and the solution becomes quite laborious. The labor is lessened somewhat by representing the network by an equivalent circuit with the component parts expressed in per cent reactance and solving either by the slide rule or by the calculating table. In no case, however, can the solution be made as simple as for a three-phase short circuit, because with the three-phase short circuit it is only necessary to go from the generator to the point of short circuit, while with the single-phase short circuit it is necessary to make the round trip from the generator to the grounded transformer and back to the generator. An example will illustrate this.

In Fig. 3 let G_1 and G_2 represent generators, T_1 and T_2 transformers with isolated neutrals, and T_3 a transformer with grounded neutral.

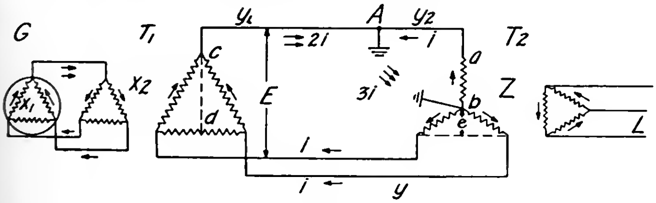

Fig. 2

Let the ohms reactance and the per cent reactance, based on 10,000 kv-a. at 100,000 volts, be as follows:

$x_1 = 150$ ohms   % $Ix_1 = 15$
$x_2 = 50$ ohms   % $Ix_2 = 5$
$x_3 = 180$ ohms   % $Ix_3 = 18$
$x_4 = 60$ ohms   % $Ix_4 = 6$
$y_1 = 40$ ohms   % $Iy_1 = 4$
$y_2 = 30$ ohms   % $Iy_2 = 3$
$y_3 = 20$ ohms   % $Iy_3 = 2$
$y_4 = 100$ ohms   % $Iy_4 = 10$
$z = 70$ ohms   % $Iz = 7$

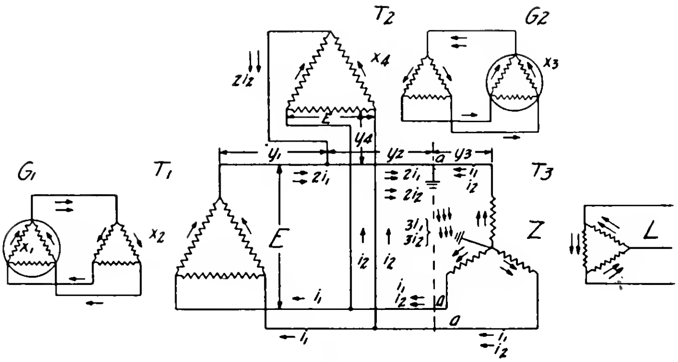

Fig. 3

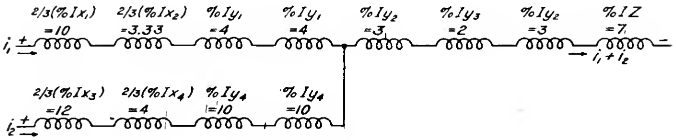

Fig. 4

Then for a three-phase short circuit at the dotted line *aaa* the short circuit current would be found as follows:

$$15+5+4=24.$$

$$18+6+10=34.$$

$$\frac{1}{\frac{1}{24}+\frac{1}{34}}=14.1.$$

$$14.1+3=17.1$$

$$i_{sc}=\frac{100}{17.1}\times I_{nor}=5.85\times 57.7=338 \text{ amp.}$$

For a ground on one line at the point *a* giving a single-phase short circuit, currents flow as shown by the arrows. The equations for this arrangement may be written as follows, reactance being expressed in ohms:

$$0.866\,E = i_1(x_1+x_2+3\,y_1+3\,y_2+y_3)+i_2(3\,y_2+y_3)+e$$

$$0.866\,E = i_2(x_3+x_4+3\,y_2+y_3+3\,y_4)+i_1(3\,y_2+y_3)+e$$

$$2[e-(i_1+i_2)z]=(i_1+i_2)\,(y_3+z)$$

from which may be found the equations

$$i_1=\frac{0.866\,E\times M}{(L+N)\,M+LN} \qquad (5)$$

$$i_2 = i_1 \frac{L}{M} \qquad (6)$$

in which

$$L = x_1 + x_2 + 3\ y_1$$
$$M = x_3 + x_4 + 3\ y_4$$
$$N = 3\ y_2 + \frac{3}{2} y_3 + \frac{3}{2} z$$

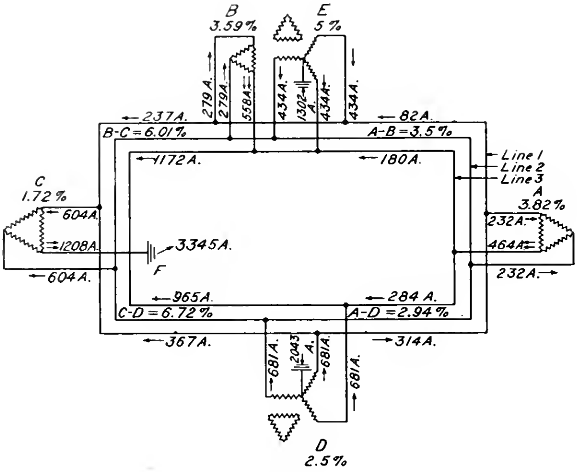

Fig. 5

Substituting for the letters the numerical values, and solving equations (5) and (6) we get

$$i_1 = 127.5 \text{ amps.}$$
$$i_2 = \ \ 75.5 \text{ amps.}$$

An equivalent circuit for Fig. 3 may be drawn as shown in Fig. 4, reactance here being expressed in per cent. This circuit may be solved as follows:

$$10+3.33+\ 4+\ 4=21.33.$$
$$12+4\ \ \ \ +10+10=36.$$
$$\frac{1}{\dfrac{1}{21.33}+\dfrac{1}{36}}=$$
$$\frac{1}{0.0469+0.0278}=\frac{1}{0.0747}=13.4$$
$$3+2+3+7=15.$$
$$13.4+15=28.4.$$
$$i_1+i_2=\frac{100}{28.4}\times I_{nor}$$
$$=3.52\times 57.7=203.$$
$$i_1=\frac{0.0469}{0.0747}\times 203$$
$$=0.628\times 203=127.5 \text{ amps.}$$
$$i_2=\frac{0.0278}{0.0747}\times 203=0.372\times 203=75.5 \text{ amps.}$$

Fig. 5 represents a network fed by three generating stations, *A*, *B*, and *C*. Transformers *D* and *E* with grounded neutrals are located as shown; *B* and *E* are in the same station; *D* and *E* have no generators on the delta side. The per cent reactance based on 3000 kv-a. and 44,000 volts is indicated for the various portions of the circuit. At *A*, *B*, and *C* the percentage given is that of the generators and transformers combined. For a ground at *F*, the equivalent circuit may be drawn as in Fig. 6. The solution of this gives the currents in the various portions of the circuit as indicated, and this in turn gives the currents shown in Fig. 5. The currents in lines 1 and 2 are of the same value and direction, but only those of line 1 are shown.

A problem which occasionally arises is the determination of the size and reactance of the transformer which is installed to provide a grounded neutral on an isolated system. When a ground occurs on the line, this transformer must allow sufficient current to flow to operate the relays, and also to react on the generator voltage so that there will be no danger of the voltage to ground of the ungrounded lines rising above normal. In order to accomplish this result, a current should probably flow through the generator of the magnitude of 75 to 100 per cent full load current.

In Fig. 7 *G* is a generator, T_1 a step up transformer and T_2 a Y-delta transformer with grounded neutral. The ohms reactance of generator and transformer T_1 combined is *x*;

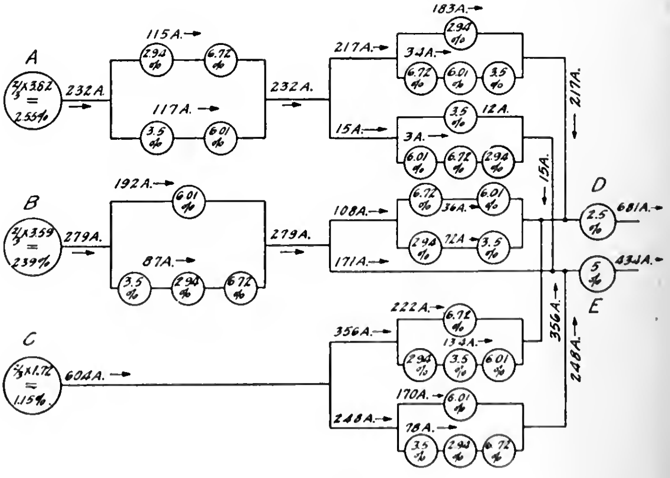

Fig. 6

the reactance of T_2 is z, and that of the lines, y_1 and y_2. Assume a ground on line at A, the following equations may be written:

$$0.866\ E = i(x + y_1 + 3\ y_2) + e$$
$$2(e - iz) = i(y_1 + 3\ y_2 + z)$$

from which we find

$$i = \frac{0.866\ E}{x + \frac{3}{2} y_1 + \frac{9}{2} y_2 + \frac{3}{2} z} \tag{7}$$

or

$$i = \frac{100\ I}{2/3\,\%\ Ix + \%\ Iy_1 + 3\,\%\ Iy_3 + \%\ I_3} \tag{8}$$

Suppose that when a ground occurs on the line it is necessary that at least 200 amperes flow in order to open the circuit breaker at B and to react on the generator voltage as previously explained. The minimum current will flow when the ground occurs at the end of the line C.

Then

$$3\,i = 200 \text{ and } i = 66.66.$$

Let

$Ix = 45$ per cent, $Iy_1 = 0$, $Iy_2 = 10$ per cent for the total length of line $B\ C$, all based on the normal three-phase current of 20,000 kv-a. at 100,000 volts, that is 115.5 amperes. It is required to find $\%\ Iz$. From equation (8)

$$\%\ Iz = \frac{100\ I}{i} - \frac{2}{3}\,\%\ Ix - \%\ Iy_1 - 3\ \%\ Iy_2$$
$$= \frac{100 \times 115.5}{66.66} - \frac{2}{3} \times 45 - 0 - 3 \times 10$$
$$= 113\% \text{ based on } 115.5 \text{ amperes.}$$

The maximum current will flow when the ground occurs at B. Then

$$i = \frac{100 \times 115.5}{2/3 \times 45 + 0 + 0 + 113} = 80.8 \text{ amperes.}$$

The momentary rating of the transformer would then be

Rating $= 3 \times 80.8 \times 57{,}700 \times 10^{-3} = 14{,}000$ kv-a. However, as it would only be necessary for the transformer to carry this current for a short time, that is, until the relays could operate, the actual or continuous rating of the transformer need only be a fraction of the momentary rating, or say 1000 kv-a. The reactance then, based on the rating of the transformer, would be

$$\frac{1000}{20{,}000} \times 113 = 5.65 \text{ per cent.}$$

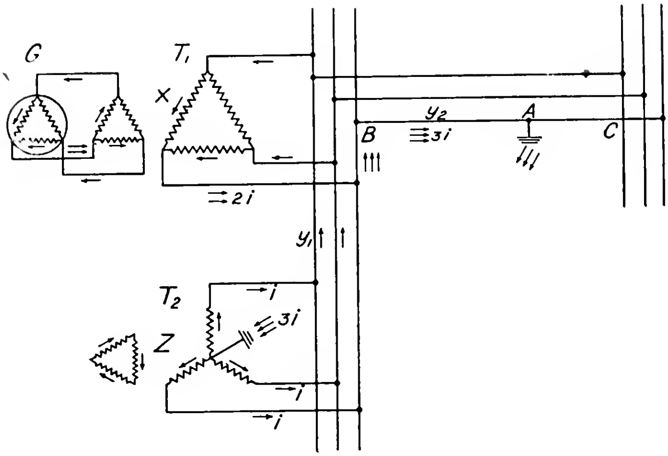

Fig. 7

A transformer used solely as a grounding transformer in this case would then have a rating of about 1000 kv-a. and a reactance based on its own rating of about 6 per cent.

In the foregoing the effect of resistance has been neglected, as this unduly complicates the calculations and is usually so small compared with the reactance that it may be neglected without serious error. Neither has capacitance been considered. In some cases this might need to be taken into account. For instance, if the circuit of Fig. 1 were a high-voltage system of large capacitance, charging currents of considerable magnitude might flow in the ungrounded phases, while at the same time the grounded phase carried short circuit current.

Acknowledgment is made to Messrs G. Faccioli and L. F. Blume of Pittsfield for valuable collaboration in formulating the theory on which this article is based.

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GENERAL ELECTRIC REVIEW

A MONTHLY MAGAZINE FOR ENGINEERS

Manager, M. P. RICE
Editor, JOHN R. HEWETT
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Subscription Rates: United States and Mexico, $2.00 per year; Canada, $2.25 per year; Foreign, $2.50 per year; payable in advance. Remit by post-office or express money orders, bank checks or drafts, made payable to the *General Electric Review*, Schenectady, N. Y.

Entered as second-class matter, March 26, 1912, at the post-office at Schenectady, N. Y., under the Act of March, 1879.

VOL. XX., No. 7

JULY, 1917

CONTENTS

E. W. RICE, JR.

President-elect American Institute of Electrical Engineers

GENERAL ELECTRIC REVIEW

THE LIBERTY LOAN

The Liberty Loan presents to all Americans an opportunity and an obligation.

An opportunity, because it offers a good return on the safest investment in the world. Of the Liberty Loan bonds, as an investment, Mr. Jacob H. Schiff says:

> "Here is a 3½ per cent, tax free bond of the government of the United States, which, if the war lasts a long time, may possibly, by reason of its convertibility into any higher rate bond that may be issued, become automatically a 4 or even a 4½ per cent bond. While, if the war should be a short one, which may be possible, and is to be hoped for, the further issue of government loans is likely to cease abruptly, in which event the Liberty Loan bonds are absolutely certain to go to a considerable premium.
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> "A 3½ per cent fifteen year bond on a 3 per cent basis is worth 106 per cent. And let it be remembered that 3 per cent United States bonds have sold at a premium no longer than a few weeks ago.

But it is of the Loan as an obligation that we wish chiefly to speak, for it is that aspect which is of most interest to all patriotic Americans.

The status of the great war calls imperatively for the immediate and utmost efforts of America. Russia is paying the price of her new freedom, in a disorganization, which, for the time at least, has paralyzed her activities, and may force her into a separate peace. Heroic France is threatened by the impending exhaustion of her man-power. England is harassed, and may be vitally menaced, by the submarine. Germany, on the other hand, by conquest and by reducing to vassalage her erst-while allies, has, since the war started, increased more than three-fold the number of men subject to the military despotism of Berlin.

In this crisis, the United States unfortunately is unprepared to give prompt and effective military aid. It will be many months before a large American army can relieve France of part of her crushing burden, or before new fleets of American merchantmen can loosen the strangle-hold of the submarine on England.

But financial aid can and must be given at once. America must immediately assume her share of the war expense, and every American must help. If industrial distress is to be avoided, the money must eventually come, not from past savings, which are already invested productively and constitute out nation's working capital, but from the immediate future. Nor will the savings of a few, however wealthy, suffice. All the people of America must help, even as they have in England, where 12 per cent of the total population subscribed to the last war loan. Banking houses and industrial corporations patriotically have gone to considerable expense to make it easy for everyone to invest his future savings in the Loan. A large subscription list will hearten our Allies and our own Administration, and will show Germany that America is in earnest, and thereby may even help to shorten the war.

Not everyone will be called to make the supreme sacrifice of enduring the hardships and dangers of service at the front, but everyone is now called, possibly at the minor sacrifice of some luxury or anticipated pleasure, to save, and to invest in the Liberty Loan, and thereby to do his bit in helping "to make the world safe for democracy."

THE LIBERTY LOAN, ITS ECONOMIC STATUS AND EFFECTS*

By Frank A. Vanderlip

President, The National City Bank of New York

For weeks, newspaper and magazine articles and posters have made appeal to the purchasing power of the United States to support the flotation of the Liberty Loan. In this article a different method of presenting the appeal is used—one in which all sensationalism, multi-colored inks, etc., have been replaced by facts and arguments expressed in such a simple and quietly forceful manner as to impress lasting conviction upon the reader.—Editor.

Magnitude of the Loan

We are a good deal dazed by the size of this loan; the authorization of a $7,000,000,000 credit is something of a shock to the country. Not many people have thought in billions of dollars. All the stocks listed on the Stock Exchange are less than twice that amount; all the stock of all the railroad companies in the country aggregate only $8,700,000,000; all the bonds of all the railroads in the country are little more than that figure. It is a huge total. And this amount must be raised this year. Don't think we are going to stop with $2,000,000,000. We are going to raise more. There will be other loans following this about as soon as this is out of the way; but while it is almost incomprehensively large, so is the country, so are our resources. There are 15¾ millions of depositors in the National banks alone in the United States. I should think it safe to say that there should be ten million subscribers to this loan if the people wake up to the need for the loan and the opportunity it offers. The last loan of Germany with her 65,000,000 inhabitants had nearly 6,000,000 subscribers. Surely we ought to have 10,000,000 subscribers in America if we would only wake up to it. The National Bank deposits have increased in 10 months $2,000,000,000—enough to take this part of the issue that is now being offered. The resources of the banks in America total $35,000,000,000. So you see, huge as this loan is—almost inconceivably large—it still is not so large when you measure it by some of the totals of the country. Our wealth is about $220,000,000,000. If the people subscribed to 5% of their wealth, they would over-subscribe this issue about six times. Back in the Civil War days with bank resources 1/20 of what they are now, we raised $3,000,000,000. So you see we are not facing an impossible proposition, but we are confronted by a serious proposition. I feel that people are not altogether awake to the seriousness of this war; not altogether comprehending that we are in war, that we are in a very serious war—war that might even come to our own shores. It is easy to think that Germany is 3000 miles away, surrounded by the greatest armies that were ever assembled; that the war is likely to be over before we can get any men into it; that we are like a manufacturer or merchant who is getting his customers to keep on buying at rather exorbitant prices, and that we are doing a good thing in loaning to the Allies, but that we are not in a very serious situation. As I conceive, it is much more serious than that.

European Contingencies

Now just let us take one or two contingencies that are perfectly possible. We have had a revolution in Russia. No man in America or Russia can tell what the future of that situation is. It is surely conceivable that Russia might make a separate peace. I do not believe she will, but it is conceivable. What would happen then? It is said that there are a million and a half prisoners in Russia. Suppose all the forces of the Central Powers on the eastern border might be withdrawn; suppose their forces were augmented by a million and a half returned prisoners; suppose Russia's food stores were opened for Germany, and all that happening very promptly, which is a conceivable thing. In that event could the armies of England and France on the western border withstand the onslaught? Is it not conceivable that, if some solution is not found for the submarine menace, England may be brought to the point of starvation? No matter what her wealth may be, starving men could not fight. I tell you it is within the possibilities that we may be raising not a Liberty Loan to pay for a war we hope successfully to wage, but a loan to pay the cost of a war Germany has been waging on civilization. This is no wild picture. I

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* Abstract of an address delivered at a meeting of the Fifth Group, New York Bankers' Association, Albany, N. Y., May, 1917.

certainly do not believe it is within the future of events but there is possibility enough in it to cause us to wake up as a nation, to make us recognize that we are in a great and uncertain war, and that we must support the military movement which this Government has got to make.

The Richness of America

We are a tremendously rich country. We must raise $2,000,000,000. Our wealth, as I have said, is about $220,000,000,000. Where is this wealth? It is in farms and railroads and factories and instruments of production. But you cannot subscribe a railroad to a loan; you cannot subscribe a factory. We must have fresh capital for this loan. Now remember that a war is the current effort of a nation; nothing that has been done in the past can fight it. It has got to be fought out of the current savings of the nation; all the savings of the past have been invested. The savings are now invested in fixed forms of capital; they are in the railroads and farms and factories, and the money that is going to be raised must come from the savings of the future, not the savings of the past. You may say, "I can purchase a bond with some money I have in the bank." Yes, you can, but this money you have in the bank is at work today; it is not idle. If you draw it out, somebody's loan must be called. This fund must be raised out of the savings from now on. The wealth you have accumulated is not in a liquid form. The past savings are invested and we want $2,000,000,000 right away—not some time in the future. These $2,000,000,000 will be spent before they are paid in, under the terms of the offer. You are going to raise this money by a creation of new credit now. You can get $50 subscriptions. Get every one you can. Get the whole ten million people to subscribe, but after you have all the success you can hope for with the $50 and $100 bonds, you will not have a very large total, measured by a two billion dollar loan. I am not in any measure discouraging these small subscriptions but the loan is going to be made up of much larger subscriptions. The men who will make these larger subscriptions are not going to make them from idle capital but from money which they will borrow.

Investment Motives

Now what are the motives to lead men to subscribe to the Government bonds? One is profit. The sense that it is a sound investment returning a good rate of interest. The other is patriotism. Let us take up the first set of reasons. Is this an attractive investment or are you facing calls to make financial sacrifices? I don't believe it is a sacrifice. You are being offered a bond for security which is beyond question the finest piece of paper in the world. The rate—3½%—looks low, but there are perquisites attached to that bond. Its income is free from taxation. You know what the minimum return is that goes into your pocket. You don't know what the maximum will be because the rate may be more. If this war goes on, and it looks as if it may for a good while, the chances are good that it will be more. You are not going to be penalized by being a subscriber to the first loan, that is certain. Whenever a subsequent loan comes out at a higher rate of interest, you are going to be in just as good condition as the tardy subscribers.

Now does anybody doubt that when the War is over and the pressure is off the market for Government loans there will be a rise in the value of Government bonds? I don't believe anybody would doubt that. Now remember the bonds you buy now bearing 3½% have a practical guarantee of parity, that is to say, if events go so that the Government cannot raise money at 3½%, your bonds will be convertible into the higher rate, and the minute the war is over, your bond at par will command a premium. I cannot think of a situation that will not find these bonds bearing a premium on their issue price after the war is over.

Patriotic Motives

Aside from the idea of profit or sacrifice, there are much nobler reasons why ten million people should subscribe to these bonds. Our belief in democracy, our belief in this Government, the foundations of our belief in freedom lie back of the motives that ought to move ten million to subscribe to this issue. Now we have got to be waked up as a nation to the fact that we are in war. I heard a newspaper editor say the other night that he had secret information that we were in war, but he had not been able to get it over to his readers yet. And there is a good deal of truth in that. We have not as yet recognized what an unsuccessful prosecution of war would mean. We want to wake up to some of the psychological effects of a very successful subscription to this issue. It would be pretty discouraging to Prussianism if this loan is subscribed twice over. It will be very encouraging to those men who are fighting under the flags of France and Great Britain on the Western front. It will unite this nation to a degree, I believe, to see that this issue is a tremendous success; that the whole people are back of the President, back of his declaration for liberty. The patriotic reasons seem to me so overwhelming that we hardly ought to think of that other side—whether this is an attractive investment—although it is an attractive investment. It is going to mean something besides patriotism in America; it is going to mean a new element in American life. It is going to mean an element of economy.

Domestic Influences

We have got to have this element of economy just as certainly as we have got to have this expansion of credit to make this loan a success, because the banks must be paid from future income and there must be economy to permit of that being done. We cannot give the Government seven billion dollars or any other number of billion dollars of purchasing power and expect to have just as much purchasing power ourselves. That would be a miracle of loaves and fishes that we cannot work out. We have got to economize. We have got to see that what we spend, we spend for necessities. You say "Yes, but what is going to become of business, it cannot go on as usual." We do not want business as usual. Our business is war. It is going to take the whole strength of this nation and it is going to discommode some people, probably discommode a good many people. You cannot have war without worries. You have got to remember that we cannot go on making unnecessary things, luxurious things, and make seven billion dollars worth of other things for war. Now you say, "Yes, but you have disorganized industry. You will make it necessary for producers to throw their employees out of work." Let me tell you there is going to be all the work that is possible to do for all the men and all the women that we have got to do it. There are two jobs waiting for every man there is to take hold, so we have got to have that kind of economy, the kind of economy that will make you weigh whether what you buy is absolutely necessary, for if you do buy something that is not necessary, you are competing for labor with the Government, which is engaged on works that are a national necessity. I think that is the test men must make of their purchases during this war. Are they competing with the Government for work that is unnecessary?

Objections to the Loan

Now I would like briefly to consider some of the objections to this loan—some that I have heard—and I hope later to hear some more and see whether we can sit down together and reason out answers for them. I say that men have got to borrow to invest. They have got to invest more capital than they have in immediate reach. There will be objection to that surely. The rich man or any man used to making investments may regard it as a very poor policy to go in debt. He has occupied the position of creditor, not debtor. But I believe when he sees the economics of the whole situation, when he sees the demands that are upon us, when he sees the resources that are available to meet that demand, he will see that borrowing is what he must do. The richer he is, the greater should be his borrowing.

I have heard some men say, "Well, I will wait, I will not invest in this loan now, the Government will need money on the third and fourth loan more than now." The rule of conduct that any man adopts may be measured by the results that would follow if all men adopted it. If you do not subscribe to the Liberty Loan now, there may be an indemnity loan later and you will subscribe to that. You had better all subscribe to this one and not have the Government lacking in the support that means military success.

You will find men who will say, "We will invest only our available cash; we don't borrow." But I beg of you to see this as I do and ask those men to borrow and invest all they hope to accumulate in the months to come.

You will find individuals who will tell you it is the Banks' affair. It isn't. It is less the Banks' affair than anybody's else in respect to the original subscriptions. It is not the function of a bank to tie up its deposits in a fifteen or thirty year investment, but it is the function of a bank to loan to an individual or corporation on a ninety day note, secured by the bond. That is the banks' function. Let the Banks aid the men who subscribe.

Bankers have got to increase credits. You cannot put the farm or the factory in;

you have to subscribe current bank credit and to do that we have got to have inflation, which is expansion. Do you fear inflation? I am not afraid of inflation that has its basis in Government bonds. There is back through this chain of operations a perfect check on it. The Federal Reserve Banks can loan and loan but there is a stop there. They can not loan after they get to a certain point in reference to their gold reserve. They are perfectly safe in inflating credit since the basis is Government bonds, and there is an ample basis of gold in the Federal Reserve banks. Let us not get alarmed. Let us take a little cheer that we are going to have this expansion and great growth in loans. I would almost be brave enough to say that we are going to have pretty easy money after this first loan. I think that it is improbable that we will have high money as a result of something over two billion dollars increase in deposits, which will be the effect of the operation according to my reasoning.

Conclusions

I think I can foresee some changes that we are going to get. It isn't all on the debit side as a result of this war. If we are going to loan three billion dollars to the Allies don't you think our international trade conditions are going to be improved by that? I do. Very greatly increased. And all the energies spent on the war are not going to be wasted. There will be new processes evolved, there will be new lessons learned in speeding up industry that will prove of great value. I remember that Huxley said that all of the costs of the Franco-Prussian War to France and the whole indemnity was paid up by the work of Louis Pasteur and its effect on the industries and life of France.

Now as to thrift. If we can get a considerable number of these ten million people that I want to subscribe to contract the habit of thrift, something of this habit that has made this marvelous effort of France possible, we will have made great progress. But the success of this loan, the successful prosecution of the War, the making of the sacrifice and the effort will bring to us a victory which will be greater than anything we can get from Germany—a moral victory within ourselves. We have grown luxurious and careless. We have needed this great moral awakening. I believe this meeting is just one of endless meetings that will make men soberly think of the moral gain that is to come out of this great war.

VIGOROUS AND CONCERTED EFFORT BY COAL MINERS NECESSARY TO PROVIDE WARTIME SUPPLY OF FUEL*

By Franklin K. Lane

Secretary of the Interior

As Mr. Lane points out, there are two ways of dealing with the exigencies of production and transportation in war time: one way is for the government to take over the mines, factories and railroads and operate them under compulsion; the other is by securing hearty co-operation between the men already directing these industries. That the former plan is made unnecessary in our country is obvious from Mr. Lane's statement: "I have been in receipt of letters from bankers, railroad men, mine owners, engineers, lawyers, men of the largest capacity and the largest income, tendering their services to the United States and offering to put not only their own services, but their own plants at the service of the government." In fact it seems that the big business men of the country have been first to realize the seriousness of the situation and the need for immediate and intense activity.—Editor.

One of the chief gratifications that I have had (and perhaps it is the greatest that I have had since the war began, or rather since we instituted the work of mobilizing the resources of the country), has been the cooperative spirit shown by the business men of the country.

Ever since this war started, I have been in receipt of letters from bankers, railroad men, mine owners, engineers, lawyers, men of the largest capacity and the largest income, tendering their services to the United States and offering to put not only their own services, but their own plants at the service of the Government. It would surprise the nations of Europe to know how intense is the spirit of loyalty on the part of our large business men and capitalists.

The idea that we are now working out is to get you people—and when I say "you" I mean not only the coal men of the United States, but those men who are large employers of labor, who are capitalists, in the sense that they use capital for the development of resources — to get you to work together in meeting the national need. I don't know to what extent you realize, but I presume you do realize as fully as myself, the greatness of this occasion. Not merely as a matter of producing men, and feeding men and getting them over to the other side, but producing also those things that the Allies need, and that we ourselves need.

There was a time—and it is only a century since—when practically the one thing needed by an army was food. When the lord on the hill wanted to fight his rival, to take a slice of his territory away, he had to concern himself with having a certain number of fighting men, and then with supplying them with food. War is now an industrial game; and the foundation of industry, as we know it now, is coal.

And so it is that you are at the very root and foundation of the great war industry. Unless we have an abundance, or at least a sufficiency of coal, war cannot be carried on.

Now there are two ways of dealing with a problem of this kind. One way is by the hearty cooperation of the men already engaged in the industry. The other way is by compulsion. My experience in the Interstate Commerce Commission led me to believe that the larger men in the railroad industry had quite as much vision as I had, and if I could show them the importance of an occasion they would try to meet it. So, instead of resorting to compulsion, instead of taking over mines and great operating plants, we are endeavoring to put you men to your best. This war is a challenge to us. It is a challenge to every miner and to every operator, to every railroad man and to every inventor as well as a challenge to every soldier. It is up to us to show what we can do; to prove to the men on the other side of the water that out of 150 years of freedom and the exercise of personal initiative and political independence we have developed a quality of genius that is superior to what they have been able to develop in the shorter period that they have enjoyed the benefit of free institutions. We have a reputation throughout the world as the world's greatest organizers. Let us prove that the reputation is deserved.

The problem that confronts us is not merely to meet our own demand, but a world demand when necessary. That is what this is. You know what coal is selling for in Italy, in Portugal, and in France. We do not know how much of that demand must be met from American mines. I think that by fall it will be up to us to contribute very largely to the support of the munition works and the other industries, as well as the domestic supply of those countries across the water.

Ours will be a problem of production and a problem of transportation to the seaboard; and then, somehow, out of the blue, must

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* Address before the organization of the Coal Production Committee of the Council of National Defense.

come some way of solving the problem of getting the coal across the water.

As I said at the beginning, a war cannot be carried on today without coal. So, in working for Uncle Sam, you are working for those on both sides of him and behind him; for the little powers that have been oppressed, and for the great powers struggling for their lives.

I regard this as one of the absolutely essential committees. The spirit you have shown in responding to the invitation of Mr. Peabody is one upon which I congratulate you. I know you will meet our national needs. How you can do that best must be worked out in detail by yourselves.

There are many men who believe that all of these problems can be solved by some wave of a magic wand. You who have dealt with men and with large problems, know that there is no such mysterious way of solving these great problems. They are largely problems of detail and of the management of men; of getting the machinery in motion; of getting the men to work together harmoniously. Of course your machine is not only the machine of the mines, but also of the railroads with which your committee must deal in the closest cooperation.

What do the railroads expect to do? They have gathered the executives of 250,000 miles of railroad, and have organized them practically as a single unit. They have brought them together upon the theory that the committee of five should handle them as one system, insofar as service is concerned.

England at the beginning of the war was prepared in one respect at least, that is, in respect to her railroads. The minute war began the government took over the railroads, upon an extremely simple plan; viz., that they should be paid the amount of net revenue per annum that they had received in 1913. Then the railroads were tied together. Unnecessary terminals and yards were eliminated. Things were so disposed as to unite all the railroads of England into a single system. I was surprised, in talking to Mr. Thomas, a member of the British War Delegation, a Member of Parliament, and president of the Railroad Men's Union over there (and that is an organization of 400,000 men), to learn what has resulted. Mr. Thomas told me that, notwithstanding the fact that the government pays nothing for the transportation of troops, munitions, or actual war material, business had so increased, and the economies created were so great, that after paying the 1913 revenue to the railroads, the Government was making money out of the operation of the roads.

The Railroad Committee will work with you in all earnestness. There should be no such thing as empty car movement; they should take off some passenger train locomotives to put into freight service; they should appeal to the patriotism of the public and cut down the demurrage time; and generally institute such reforms as to give the greatest possible service to the country.

The same spirit actuates you that actuates them. You must use much the same methods. You will have to do some things that, no doubt, some will object to. You will have to do some things that will upset, to some extent, I fear, previous longstanding conditions. I myself am not able to see why all the mines should compete with one another. It strikes me that the railroad men and yourselves can meet that situation. I can see where it may be necessary to have some change in the ordinances of some cities with respect to the character of coal used. All these things must be done tentatively, simply as a war or emergency measure.

The large problem is as to how to secure the greatest output of coal, and to get that output to the consumer. I need not emphasize that problem. Mr. Peabody has talked it over with me, and I can see that he has a larger grasp of that problem than I.

I hope you will go at this thing in true American fashion, with two fists; with the same determination to solve the difficulties that are besetting the industries of the United States today that the soldier will display when he goes across to the other side to meet the common enemy. You are doing soldier's work. It is not a thing of gratification that you have to be called here. It is, instead, a thing that should be regretted. But then the whole world-wide situation is one that must be regretted.

We are in this thing because we are determined to win, and we cannot win unless the industries that depend on you get from you the supply of fuel that is just as necessary to the continuance of their existence as are bread and meat to the continuance of the life of the soldier.

We want the big business men of the United States to feel that the burden of carrying on this war does not rest merely upon a few government employes, like myself, but rests, in no inconsiderable part, upon those who represent the genius of our economic and industrial life.

THE NEED FOR GREATER PUBLICITY ON MATTERS CONCERNING THE WAR

The Executive Committee of the National Chamber of Commerce has been very active in following the trend of the war and in keeping closely informed regarding conditions which arise therefrom. This committee recently drafted a set of resolutions for presentation to the entire membership of the National Chamber, the substance of which was as follows:

A thorough conviction by the Executive Committee of the vital necessity that the people of the country be authoritatively informed in regard to the actual situation of the war and the part that each citizen must play in cooperation with the government in order to bring the war to a successful conclusion.

That there exists today throughout the country a lamentable lack of information and understanding on these points; and

That no authoritative and distinct agency now exists for the purpose.

That the Executive Committee of the National Chamber, on its own responsibility and as far as its authority permitted, had endorsed and would undertake to advance a proposal about to be submitted to the President of the United States suggesting the creation of a definite branch of the government under the direction of the President to conduct a campaign of constructive education of the people as to the war and the important operations of the government regarding the war, so that the people may understand in advance the necessity for the various actions taken by the government in behalf of the people.

These resolutions were sent out to the membership under date of May 24th, and the situation was considered so acute that request was made for telegraphic approval of the Committee's action by the membership. This approval was granted, and on June 5th the resolution was presented to President Wilson, asking him to name the special Commission. It is understood that the President will act on this request and name a War Commission which will act entirely independent of all other bureaus. Furthermore, it is announced that the National Security League will send two thousand speakers throughout the country as soon as the new Commission can get underway.

Accompanying the letter of the Executive Committee to the membership was the following outline of facts bearing on the situation, which it will be to the personal interest of everybody to read carefully and thoughtfully.—EDITOR.

THE EXIGENCY AND THE PLAN

I

There is the strongest of reasons for believing that the United States will prove to be the decisive factor in the Great War. The best judges are of the opinion that the submarine will not end the war, that the food shortage will not end the war, that the present colossal conflict on the western front may not end the war. With France past her maximum of men, with England rapidly approaching her maximum and with Germany perhaps still some distance to go before her maximum is reached, it stands to reason that this country must prepare quickly to supply not only food, ships, and munitions and materials of war, but trained effectives in huge numbers, perhaps in millions.

Military men admit that until the United States entered the great conflict there was no decisive factor in sight.

How quickly, then, or how slowly, the United States meets these enormous obligations is the answer to the question of the war's length.

Aside from the question of shortening the war there are life-and-death reasons why the United States should speed preparations for the great conflict. There are possible and even probable contingencies which might cause the United States to bear the brunt of the fighting on her own shores.

If Russia should collapse
If the British fleet should be overcome
If the food situation should bring our allies to their knees
If great reversals should be met on the western front
If the submarine menace be not checked.

The impossible has happened so often in this war that any one of these contingencies is not impossible. The Germans *should have* gotten through at the Marne and captured Paris and Calais, and established control of the Channel. The English fleet *should have* annihilated the German fleet at Jutland. The Central Powers *should have* been starved before the last harvest.

The submarine campaign has resulted in the destruction of 1,500,000 tons of shipping during the months of February, March and April. Co-incident with this enormous decrease of the world's ocean-going mercantile marine have come increased demands upon shipping and the two combine to make this one of the most important and most threatening aspects of the war situation today.

The world-wide food shortage is making itself felt hardest upon Germany, next upon certain of the Entente countries and lastly upon the neutral countries, especially Scandanavia and Spain. The effèct of this shortage may soon be felt here.

This, then, makes it highly important that the United States quickly mobilize its entire forces in order to bring about a decision before the brunt of the fight will be shifted to America.

II

The main obstruction to speed is the failure of the people to appreciate the fact that we are at war. "The failure of the people to realize the gravity of the situation amazed me," said an English publicist, "until I remembered how slowly our own people came to this realization."

The same fallacies that beset England are to be overcome in the United States. England, too, thought it would be a short war, six months at most. England, too, though it would be a small job. England, too, thought that there wasn't anything special for the individual to do, that the government would do the work.

It is felt that an urgent need exists for precisely the same kind of campaign of national education and information as that conducted by the English government when it came to the realization of what the war really meant. That campaign was immensely successful in arousing the entire people of England to an understanding of the war and to the obligation of personal service which it placed upon each individual citizen.

III

Seven urgent matters must be made clear to the people if we are to get that unified action which is necessary to hasten our war activity:

1. That the banks cannot take care of the bonds. The bonds must be bought by individuals.

2. That conscription does not carry with it anything of disgrace. It is as patriotic and much more effective than the medieval system of volunteering.

3. That labor must be readjusted on a large scale. It must be made more productive, and its varied problems carefully considered.

4. That food administration will necessarily be repressive, but is in the interest of all.

5. That there is a false and a proper national economy. Business in war time is not "as usual."

6. That the intelligent cooperation of women in both direct and indirect branches of war effort is absolutely essential.

7. That there should be a centralized control for the systematic support of the familes of those who go to war. This should be through the intelligent cooperation of the government, local organizations and employers.

IV

Present conditions indicate clearly that a great crisis is approaching in the war situation and that it is probable the united efforts of America on a prodigious scale will be called for in the very near future. This means that the people must be stirred to a sense of their individual responsibilities in order that their whole-hearted cooperation may be secured. This spirit and this cooperation can be obtained simultaneously throughout the country by means of a properly directed national campaign of information under strong and intelligent headship.

The campaign should be considered as absolutely apart from routine, press publicity matter and the ordinary output from various department of the government meant for publication in newspapers and periodicals.

It should be a definite branch of the government, under the direction of the President, with a man at its head of broad practical experience in the use of the means of national education, with a capacity for organization, and possessing both energy and imagination.

The director, in consultation with those who are shaping the main war program, would map out such government campaigns as might be thought desirable and through various channels at his disposal would, by utilization of news and advertising columns, posters, etc., promulgate throughout every part of the country simultaneously the message which each campaign would be designed to impress upon the minds and the hearts of the people.

There could be utilized not only the machinery of the national political committees, but the machinery of the states committees as well, and, in addition, close working relations could be established with municipal administrative bodies and all sorts of patriotic societies throughout the country,—such societies as the National Security League, Chautauqua Societies, Boards of Trade and Chambers of Commerce, church and college societies, fraternal, labor and various social organizations, etc., etc.

If a campaign on such a matter, for instance, as the present War Loan were to be launched, advance notice would be given to all these affiliated societies and plans would be made to begin the campaign simultaneously in all parts of the country, the work to be prosecuted with the utmost vigor in all directions.

This work to be effective must be a branch of the government, backed by the government, controlled by the government, and financed by the government, and on this basis it would not fail to impress people much more strongly than would be the case if similar efforts were put forth entirely by private organizations. At least, that has been found to be so in England and there is little doubt that it would prove to be so here.

This same machinery would be used extensively for making the war situation clear in the minds of the people with a view to securing their full and genuine cooperation in the government's war program, thus avoiding the possibility of obstruction and friction and selfishness in various forms—all spelling delay.

This plan would serve to unify the nation quickly and make the people as a whole understand their individual responsibilities in the progressive phases of this country's participation in war on a big scale as they do not at all understand those responsibilities now.

We should move today as if we were to face Germany alone tomorrow.

The people should be given some idea of the magnitude of the fighting, for example, on the western front.

General Sir William Robertson, Chief of the Imperial Staff of the British Army headquarters, states that within six weeks the British alone have expended 200,000 tons of ammunition in France. He also stated that 50,000 tons of stone weekly were required to mend the roads behind the lines.

Perhaps his most significant statement, however, is this:

> The greatest peculiarity of this war is the colossal numbers engaged. It is not a war between enemies, but war between nations, and there is no man or woman in the Empire who is not today doing something, either to win or to lose the war.

Sir Arthur Henderson, a member of the British War Council, announced a few days ago that 7,000,000 men have been killed. The total casualties,—that is, the total number of killed, wounded and missing, among all the armies engaged,—reaches the amazing figure of 45,000,000—or half the population of the United States.

How war of this sort affects the life of a nation and may affect us—if quick steps are not taken to throw our strength into the balance—may be judged by a few of the recent developments in Great Britain.

The English army has been increased from 150,000 to 5,000,000 men.

Her navy has been increased from 150,000 to more than 500,000.

More than 100 great government plants have been built specially to cope with war requirements.

Working directly under the Ministry of Munitions are 2,500,000 men and nearly 1,000,000 women.

During the first two years of the war the British moved back and forth across the Channel over 8,000,000 men, over 40,000,000 tons of explosives, over 50,000,000 gallons of gasoline and over 1,000,000 sick and wounded, and all without any losses due to enemy attack.

Sir Robert Borden has just returned to Canada and his first message was that:

"The speed of the United States in sending ships, munitions and men will probably be the determining factor in the war.

"A great struggle still lies before us; at the commencement of this spring's campaign, Germany put into the field a million more men that she put into the field last spring."

And as mute evidence as to how serious Sir Robert considers the situation, he recommends an immediate measure for the compulsory military enlistment of Canadians, and in the face of the fact that Canada has already sent 400,000 men to the colors under the voluntary system.

Therefore, since the United States is the decisive factor in the great war, and speed alone will not only shorten the conflict but may forestall the burden of it being carried to our shores, and since the greatest obstacle to speed is the non-understanding of its gravity by the people, it seems imperative that a systematic campaign of education should be projected by the national government, which would clear away all doubts from the minds of the people as to what threatens them, as to what obligations rest upon them now and henceforth every day until the war is won.

ELECTRIC DRIVE FOR COTTON MILLS AND THE ADVANTAGES OF CENTRAL STATION SERVICE

By J. E. Mellett

Commercial Engineer, Georgia Railway and Power Co.

Present industrial activity and high prices for most commodities insure a sufficient margin of profit to the manufacturer to make strict economy unnecessary; but the turning point will come, when prices will recede, competition increase, and the problem of lowering manufacturing costs will be of prime importance. The cotton mill will be no exception to the rule. Mr. Mellett has made a thorough study of power equipment for cotton mills and his finding is that in practically every case the electric motor, when supplied with central station service, shows the lowest operating costs, highest quality of product, and greatest production. In this article he discusses the advantages in general of electric drive for cotton mills, and gives detailed consideration to the application of the electric motor to the various machines and operations involved.—Editor.

A splendid tribute has been paid the electric drive in the fact that thirteen years ago approximately 1,100 motors aggregating 65,000 horsepower were installed in textile mills, while from incomplete figures approximately 60,000 motors totaling 850,000 horsepower have been installed up to January, 1916.

The owners of the mechanically driven mill adopt the electric drive primarily because they are convinced that it is more economical and convenient than other types of power, and secondly, because the engine may have broken down or is overloaded; also additions may require more power and the first thought is to purchase central station power if it is available. The architect for a new mill being built today rarely ever thinks of any other than electric power, and if central station service is not available installs generating equipment for electric drive. He is also aware of the fact that thousands of dollars can be saved by the elimination of shafting, hangers, belting, etc., if electric drive is installed, and further if power is purchased from a central station the capital necessary for boilers, stacks and generating equipment can be invested in producing machinery, thereby increasing the output, decreasing the overhead charges on non-profit making machinery, and incidentally lowering the cost per unit of product. The reason why mills discard the steam engine or turbine, therefore, is that they obtain (and admit) a lower cost per pound of goods produced.

This fact is borne out by the following expression received by a central station from a cotton mill man using its service:

"About three years ago, after investigating electricity as a mechanical drive and having decided it was the only drive for a cotton mill, we made a contract with you and installed motors of the four frame drive type, and the only regrets that we have had since, is that we did not have the drive long before.

"We have observed the cost of the electric power very closely and have found that it is somewhat cheaper than we could furnish it for from our steam plant, and the upkeep of motors, etc., has been very little. We have found the electric drive a great convenience for running at night such machines as cannot take care of the run during the day. Our production has increased from 3 to 7 per cent over the steam drive, which is the result of doing away with so many belts, this giving us a steady drive and not so much slippage. Your service for the past two years has been

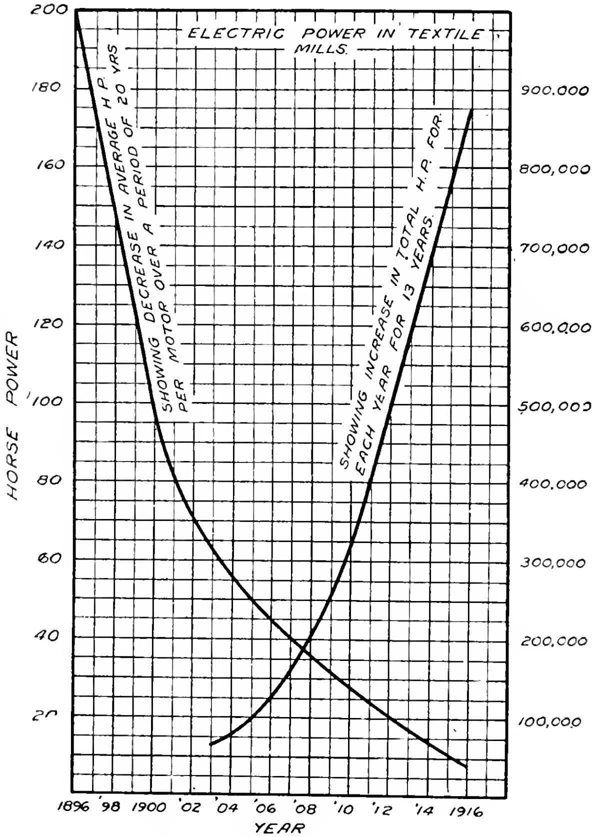

Fig. 1. A Comparative Chart of Electric Power in Textile Mills

very satisfactory; in fact it has been almost perfect.

"We will be glad to have anyone interested in the electric drive visit our plant and see for themselves that it is in the interest of all cotton mills to install electric power."

It is of interest to note that the average size motor installed in textile mills 20 years ago was over 200 horsepower and has been gradually decreasing, which is indicative that the mill man appreciates the advantages of placing the motor as close to the machines as possible in order to reduce the number of belts, slippage, irregular speed, inferior quality of goods and the consequent loss of production that is common with mechanical drive. Fig. 1 shows the decrease in the average horsepower per motor and the increase in horsepower installed in textile mills from 1896 to 1916.

We are living in an age of great accomplishments, and hear and read about so many big figures in the business world that the mere mention of a million or so is taken for granted and receives very little consideration; but if the owners, architect or engineer of the mechanically driven mill will stop to analyze the reason for this rapid increase in electrical horsepower applied to textile mills they will find that its growing popularity is based on that sound business principle—*economy.*

We are producing more and consuming more, but the present production does not meet the demand. We are floating along on an unprecedented wave of prosperity and have arrived at a point where the every day cost of living is rapidly mounting to dizzy heights, and the economic relief to soaring prices is increased production.

But when the turning point is reached prices are going to recede. Competition will be keener, and in order to sell goods at a profit the cost of manufacturing must be lowered.

A celebrated economist recently said: "With the prevailing high wage scale, European competition following the war and the awakening of our commercial rival beyond the Pacific, the industries of the United States will have to exert every effort toward economy and efficiency for increased production and lower manufacturing costs."

Increased Production

The cotton manufacturing industry has existed for a long time and from a crude beginning has reached a very high state of specialization; improvement upon improvement has been made, and at the present time the mill man cannot expect any radical change in textile machinery that will tend to materially cut the cost of manufacturing goods. Nevertheless, the problem must be solved in some manner if he expects to stay in the running. The average mechanically driven mill has an opportunity to decrease its manufacturing costs by adopting the electric drive and using central station service. Decrease in cost must come through an increase in production, while fixed charges remain practically the same. By the use of the electric drive the mill will secure an increase in production anywhere from 2 to 20 per cent, the ratio of percentage increase being dependent on the type of drive adopted and the type and condition of mill adopting it.

Increase in production by electric drive is secured through the maintenance of a more uniform speed on the producing machines or doing more work in a given time and staying on the job longer and better than the present mechanically operated machines. The mill man says he cannot run the machines any faster, or secure any closer speed regulation on the engine. Quite true, the engine may be regulating and maintaining a comparatively uniform speed, but after passing through the successive number of belts to the machine, the close speed regulation is lost. The electric motor maintains at the machine a speed regulation as close or closer than the engine itself, and of course can operate the machines faster if necessary because its speed is more uniform; but the increase in production is not secured so much by the higher speed as by the more uniform speed maintained. A serious item in spinning is the large number of breaks, which, to a certain extent, are due to the sudden start or jerk of the belt. When operated by the mechanical method the belt tries to take the entire load instantly. The motor, however, does not start with a jerk as its acceleration on starting covers a wider period of time; the speed gradually rises until it attains normal, thereby giving a smooth speed curve. The advantage of this method of starting the machinery over the old belt method is obvious, and is another instance where electric drive improves the quality of yarn.

The speed variation in connection with most operations in the manufacture of cotton goods is a source of loss that is apparent in decreased output, increased maintenance, depreciation, and poorer quality of the product. Thus speed variation is a vital problem with mechanical drive and one of the considerations responsible for the present wide use of electric drive and the purchase of power from the central station.

In order to bear out the argument regarding the difference in speed regulation of the engine as compared to the speed variation at the machine, Fig. 2 shows a tachograph record of engine and countershaft speed, the countershaft driving looms. Fig. 3 shows the speed variation of an engine-driven line shaft operating preparatory machinery compared with the speed regulation obtained by the adoption of electric motor drive.

Fig. 2 shows conclusively that there is a variation in speed between the engine crank shaft and the machines operated, and Fig. 3 illustrates the fact that a higher average speed is maintained by the electric motor, which must necessarily mean that more goods will be produced in a given time by this type of drive as compared with the old mechanical method. While the subject of production is a vital matter in all departments of the mill, the spinning and weaving generally receive the most consideration. Tests prove conclusively that in the average well-designed mechanically driven mills the speeds on spinning run from 3 to 15 per cent below normal where they are not carefully checked all the time. These conditions exist in the best operated mills and can be improved by giving careful attention to belts. This includes removing overloads, retightening, rearranging drive ratios and cleaning the belts twice a day. But with all this strict attention, the speed variation will still remain to some extent.

Fig. 4 is a speed record taken on a main line shaft operating the spinning of a cordage mill. Before this test was made the pulleys were overhauled and realigned, the belting was looked over carefully, all fly removed and the belts dressed. It is only natural that the superintendent of a mill would want to inspect the machinery before a test of this nature was made, but in a measure the fact that all machinery and belting are tuned up prior to a test is deceptive and does not give a true record of normal conditions under which the mill is operating daily. Nevertheless, after all the careful preparation the speed record told its own story.

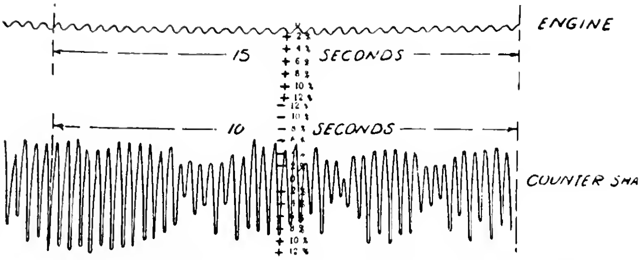

Fig. 2. Speed Curves, Variation 3 Per Cent and 20 Per Cent

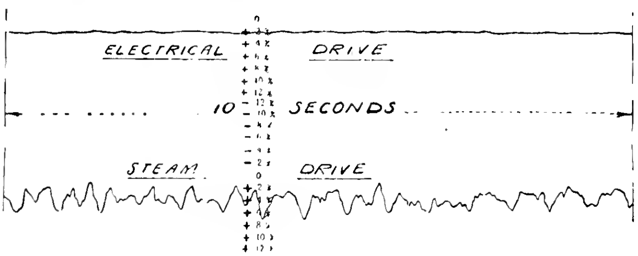

Fig. 3. Speed Variation, Steam 7 Per Cent, Electric ½ Per Cent

The average mill man is open to conviction and is willing to be shown and the speed record taken in the spinning room of the mill as shown, was responsible for the adoption of central station power. Anybody interested in the subject of speed variation would naturally be curious to know what sort of a speed record was secured on these spinning frames after central station service was adopted and if the statements of the central station representative with reference to more uniform speed and increased production finally proved correct. It will be of great interest therefore to observe Fig. 5 and note the uniform speed record after electric motors were installed.

While discussing the subject of more even speeds, increased production, etc., it will also be of interest to note the expression of complete satisfaction in electric drive and central station power by a man who has been in the cotton mill business for the past twenty years and who operates both steam and electrically driven mills:

"The principle advantage of the individual motor loom drive is increased production obtained. Incidental to this advantage is more uniform speed, and consequently more uniform quality of production, saving of wasted power, flexibility in arrangement of machinery and buildings, freedom from dust and fly, the ability to measure quickly and accurately the power consumption of any machine, the lessened liability of serious shutdowns, less maintenance expense of transmission equipment, better natural lighting and absence of oil drippings."

While this expression is more specific with reference to the weave room, it is also applicable to other departments using electric drive. For the benefit of the mill men who have in mind the electrification of their mills and those who are interested in the application of electric motors to cotton mills, it might be well to discuss briefly the power requirements and how the electric motors are applied.

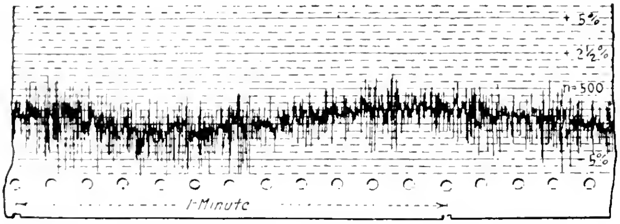

Fig. 4. Speed Variation on a Spinning Room Line Shaft

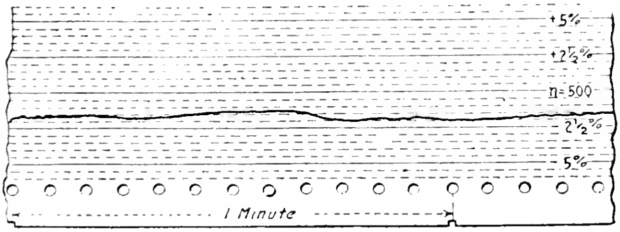

Fig. 5. The Speed Variation on the Same Shaft With Electric Drive

Power Requirements and Electrical Equipment

The power required to operate the various machines and departments in cotton mills is a subject that has received a great deal of attention and only since the advent of the electric motor have any data of real value been secured. The mechanically driven mill arrived at results by taking indicator cards on the engine driving groups or departments which necessitated shutting down, shifting of loads and a loss of production. This method would give the mill a general idea regarding the power required, but did not cover the inaccuracy of light load and varying friction conditions nor solve the power requirements of the many small pieces of machinery, which individually use a small amount of power. By the use of the electric motor, however, it is a comparatively simple matter to drive the various machines individually or in groups and take the necessary observations under varying load conditions without disturbing other machines or groups.

Cotton mills generally can be sub-divided into three classes, namely, coarse goods spinning up to 18's, medium goods 18's to 40's, and fine goods on the higher counts. The total power required to drive a mill is determined by the number of spindles, spindle speed, counts spun, class and grade of goods manufactured. The average finer counts require less power than the coarser yarns and from figures available at this time the average number of spindles per horse power runs about 27. This figure includes mills spinning both coarse and fine yarns and covers the total electric horse power installed for all departments.

If the average indicated horse power of the engine is used to determine the number of spindles per horse power in a specific instance, as compared with the result obtained by using the total connected electrical horse power, it will be found that the number of spindles per horse power in the latter case will be lower. This is due to the fact that the individual or group motors have each the proper horse power capacity to do its immediate work, while the engine gives only the average indicated horse power. However, if the average electric horse power is used on the same bases as the average indicated horsepower, it will show a greater number of spindles. The average percentage of the total power required for the various departments covering all classes of the mill may be divided approximately as follows:

Pickers	6.0%
Carding	16.0%
Spinning and spooling	50.0%
Weaving, warping and slashing	23.0%
Miscellaneous machinery	5.0%
Total	100.0%

The new mill adopting electric drive and the mechanically driven mill desirous of adopting it, have ample opportunity to select the proper electrical equipment, as the application of motors to cotton mills has received a great deal of attention, and within recent years has grown into a profession that is becoming highly specialized.

The Opener Room

The opener room machinery whether located in the main mill or detached can be driven by individual motors, or if desired the openers, waste machines, etc., may be driven in groups from one motor. The size motor required will vary from 5 to 15 horsepower, depending on local conditions.

The Picker Room

The pickers can be driven by individual motors mounted on the "A" frame and belted to the beater shaft. These motors will range from 5 to 10 horse power, depending on the beater speed and other conditions. If individual drive is not desired, the pickers may be operated by one or two groups, which will include fans and condenser equipment.

Carding Department

The general practice is to subdivide the carding department into small groups using from 20 to 50 h.p. motors. In this department individual motor drive can also be adopted by using chain drive for the drawing frames, slubbers, speeders and fine frames. Then, too, the roving frames may be driven by two or four frame slow speed motors from 5 to 15 horsepower, depending on conditions. The expression "two or four frame" means one motor to two or four frames, the motor being mounted on the ceiling directly over the frames and the motor shaft extended at one or both ends and equipped with two or four pulleys, which require only one belt for each frame.

The Spinning Room

There is probably no department in the mill where the variation in power requirements is so great. This is due not only to the quality of work, that is, whether fine or coarse numbers are spun, and whether it is warp or filling, but also to other factors, as speeds, atmospheric conditions, the attention given to cleanliness, banding and the many other details to be considered in connection with spinning. The spindles are driven by cotton bands which absorb moisture readily and shrink or slacken respectively, when the humidity in the room rises or falls. Therefore, as the band tension varies, the power required changes perceptibly. In most mills the bands are put on tight to prevent slippage and to secure a more even quality of yarn.

To show the power variation due to band tension, etc., it will be of interest to note the results obtained by actual tests on a frame of 256 spindles, 7 inch cylinder, ⅞ inch whorl, roll 120 r.p.m., cylinder 1250 r.p.m., spindles 9200 r.p.m., ring 1¾ inch, 5/0 traveler, medium gravity, No. 26 warp, No. 420 roving, 2 ends up.

Full frame, bobbins full, per cent of total power	100%
Ends down, per cent of total power	94%
Builders and roving off, per cent of total power	92%
Rolls off, per cent of total power	86%
Bobbins off, per cent of total power	68%
Bands off, per cent of total power	4%
New bands installed (throughout, per cent. total power	130%
After half hour run, per cent total power	87%

The new bands required 30 per cent more power to operate than the old bands, but after running for a half an hour required only 13 per cent more than the old bands under normal working conditions.

Another factor entering into the power consumption of the spinning frame is the spindle speed. Actual tests on ring spinning show that as the spindle speed increases the power required is greater. The power increase is not directly proportional to the increase in spindle speed, but is somewhat larger. These tests also show that with an increase of 10 per cent in spindle speed the power was increased 16 per cent. No set constant can be used for determining the power required for increased spindle speed, but through 7 to 70 per cent increase in spindle speed the ratio varies from 1.6 to 2.

In electrifying the spinning room the mill man can adopt about any type of drive his fancy calls for. 5 to 10 h.p., individual motors can be geared to spinning or twister frames. 10 to 30 h.p., two or four frame motors can be mounted on the ceiling and group drive may be adopted by mounting the motors on the ceiling, wall or floor. The type and horsepower of these motors depend on the specification of the frame, numbers of spindles, size of yarn spun and numbers of ply and whether run wet or dry on the twisters.

The Weaving Department

The quality of goods produced by the weaving department depends on a number of factors, one of the most important being the speed, which has a decided effect on the uniformity of the fabric, especially on open mesh. Up to the time of the introduction of electric drive the weaver was not able to obtain uniformity of speed, which is necessary for fine work. This has been due to variable belt traction, line shaft torsion and other causes.

The average mill man has been operating looms from three to six per cent below normal so long that it is only natural that he should be skeptical regarding an innovation that is proposed to remove "the slough of second nature or force of habit" he has grown into regarding speed variation. The individual motor with a close speed regulation has been on the market for some years and the mills which have adopted this drive have eliminated the speed variation in looms and removed the most troublesome factor in weaving. The application of individual or group drives for the loom shed should be given the most intelligent analysis in order that the proper drive may be adopted to produce the most uniform fabric.

Individual motors ranging from ⅓ to 2 horse power, geared to gear ring and keyed to the loose pulley of the loom, may be adopted. The operator can start these motors by friction as with the old belt method. Light or heavy group drive may also be installed in event the mill man does not think the additional production will warrant the extra investment for individual motors. The spoolers and warpers may also be driven by individual motors, from a small group or from a larger group driving some other department.

Cloth Room and Machine Shop

Finishing machines can be purchased with individual motors attached, but for the mechanically driven mill changing over to electric drive it has proven more economical and satisfactory to drive the various finishing machines in groups, using a 10 to 25 h.p. motor. The horse power required, however, depends on the capacity of the mill and type of goods manufactured.

In nearly all mechanically driven mills the machine shop is operated by a jack shaft from the main shaft, and when electrified is generally driven in a group by a 5 or 10 h.p. motor. The humidifier pump is driven by a 5 to 15 h.p. motor, depending on the size and number of heads.

Slashing and Sizing

This department is usually driven by one motor, the slashers and size kettles being grouped. The power required varies with the number of machines installed and actual tests show 3 to 7 beam slashers require from 2.75 to 5 h.p. each. Steam is used in nearly all cotton mills for some purpose and when the average mill man, who is using steam for slashing, is approached on the subject of electric power the first thought that comes to his mind is: "I use so much steam for slashing and heating that the central station cannot offer me a sufficiently attractive proposition on power which will compare favorably with my present power cost."

The average mill has not the metering or measuring equipment to determine accurately the steam requirements for each department and it is a difficult matter to apportion the proper amount chargeable to the various processes when steam is secured from a common source of supply.

It is quite true the slashing does require considerable steam, but it does not, in the average case, use 20 to 25 per cent of the total fuel required for power purposes, which is the opinion of the average mill man. Some mills require more steam for slashing than others and each case must be treated individually.

Tests have shown that in a mill operating condensing and using live steam for slashing with approximately 22,000 producing spindles, spinning 12's to 38's yarn, and slashing 15,000 to 20,000 lbs. per week, the quantity of steam used for the slashing represented 7 per cent of the total steam for power purposes. The estimates made on the amount of steam required for this purpose before the tests were made were from 18 to 20 per cent of the total fuel used.

It may be of interest to note that in another mill operating condensing and using live steam for slashing, the management estimated that the slashing required from 18 to 22 per cent of the total fuel. The mill in question has 11,900 producing spindles, spinning 13's to 18's yarns, weaving sheeting and slashing 15,000 to 17,000 lbs. per week, and tests made covering a period of one week showed the actual steam used for slashing represented 11 per cent of the total fuel used. In order to secure these results it was necessary to make complete evaporation and efficiency tests on the power plant and install steam flow meters in steam lines serving the various processes.

It is no doubt true that a few mills may use 20 per cent of the total fuel for slashing, but the usage depends on a number of conditions and especially on whether the mill is operating single or double shift and slashing single or double shift. It is obvious that if the mill is slashing only on single shift and operating the other departments double shift the percentage of steam required for slashing will be lowered proportionately. However, the average mill will find that after the proper tests are made, it can purchase central station power, buy coal for slashing and turn out its goods at a lower cost per unit than under the old steam plant regime. Electric power is now being utilized in about all the various departments of the cotton mill and at the present time some of the best electrical engineers are working on an electric boiler for slashing and it is possible that American genius will eventually produce an economical electric boiler that will invade the "sanctum-sanctorum" of the slasher room.

Underwriters Fire Pump

The various insurance companies have very strict rules and regulations with reference to the maintenance and operation of the fire pump, especially in cotton mills. This being an important factor it must receive proper consideration. A great deal has been said, pro and con, regarding the advisability of using the electric motor drive centrifugal fire pump as a substitute for the steam operated pump. The question of using either type depends on local conditions, capacity in gallons per minute required and a number of other factors. For instance, take the mechanically driven mill which has a steam driven fire pump installed and is contemplating the purchase of central station power. If this mill does no slashing or dyeing, steam will be required for heating purposes only and the mill management is uncertain as to whether the old steam driven fire pump should be retained and steam kept up during the months that steam is not required for heating, or to install an electric motor driven centrifugal pump in the event the mill is electrified. Upon investigation the mill will find that it will prove more economical to install the new motor-driven pump and use a small upright boiler for heating.

For the mill that requires steam for slashing as well as heating it is probably more economical to retain the steam driven unit. Nearly all the new mills being built at the present time are equipped throughout for electric drive and this equipment includes an electrically driven fire pump. The steam requirements covering heating, or both heating and slashing, are taken care of by the installation of a small boiler.

The electric motor driven fire pump is more compact, requires less space and has other advantages compared with the steam driven unit, and its all round economy and growing popularity especially in cotton mills is evidenced by the number being installed. Centrifugal units for 100 lbs. pressure, complete, with all underwriter fittings and electric motor direct connected to pump on common base, will cost from $1.30 per gpm., for the larger sizes to $2.50 per gpm. for the smaller sizes. The mill man has an opportunity of selecting a pump from a number of manufacturers, which means that prices will vary to some extent, but the average cost of these combined units at prevailing prices is approximately as follows:

G. P. M.	Total Weight	Total Price
500	5,000	$1,200
750	6,400	1,430
1000	7,100	1,600
1500	11,500	1,900

Conditioning Room

Very little can be said with reference to this department, as the features in connection with the conditioning of yarn vary with each mill and depend on local conditions. However, it is interesting to note that in addition to the electric power used for operating the pump and for lighting purposes, it is also being used in place of steam in the conditioning room by a number of mills to maintain the proper temperature. Up to the present time it has proven more economical to use electric power when the heating season is over.

To cite a specific case, a mill of 10,000 producing spindles spinning 8's to 30's hosiery yarns with a conditioning room 30 x 20 x 11, conditioning 25,000 to 30,000 lbs. of yarn per week and maintaining a temperature of 95 degrees F. has installed three 3000-watt 550-volt tubular type electric heaters, which operate from March to November, after which time steam heat is used. In circuit with the heaters, a thermostat and relay are used which automatically cuts in or out the proper number of heaters to maintain the necessary temperature.

Cost of Electrical Equipment

The investment necessary to properly equip a mill for electric drive is dependent on a number of factors. The practice used in new mills is to install individual motors for each machine or adopt the two or four frame drive for the spinning and lighter groups for the other departments. This method of drive is adopted in order to eliminate as far as possible all shafting, belting, etc. While this type of drive requires a greater investment for the electrical machinery than larger group drives the extra investment is offset by the larger investment for hangers, belting and shafting, and admits of a greater increase in production. The old mechanically driven mill has the opportunity of adopting the individual drive, but in equipping the mill properly one encounters a number of obstacles that the average mill man cannot easily overcome, consequently the use of the two and four frame drive and light or heavy group resorted to. In the latter method of drive the average horse power per motor is greater than under the first method, but the investment is less, which, in turn, will not give the same increase in production. The proper equipping of a mechanically driven mill requires the proper investigation with reference to type of goods manufactured, spinning speeds, loom speeds, etc., in order that conditions may be improved without disturbing the regular routine work. Therefore as the cost of electrification depends entirely on conditions existing in each mill, no definite amount can be used to determine the cost for any individual case.

Most all men operating mechanically driven mills are convinced that central station service is the power to adopt, but hesitate to make the change on account of the investment for electrical equipment. If the subject is thoroughly investigated, however, they will find that the additional profit obtained from the increase in production and the better quality of goods secured by more uniform speed, will pay a good return on the necessary investment.

Mill Lighting

It is a far cry from the tallow candle through the successive stages of the kerosene lamp, open flame gas burner and the carbon incandescent lamp to the efficient types of electric illuminants at the service of the industrial world today. Cotton mills have given very little attention to the subject of illumination, but with the development of highly efficient lamps the methods of artificial mill lighting have been revolutionized, and untold possibilities of efficiency and economy in mill operation introduced.

The lighting of cotton mills involves a variety of problems, beginning at the opener room through the numerous intermediate steps to the weave shed and finishing room. The quality, quantity and cost of the product depends on the amount of spoilage, the safety, willingness, and ability of the employees to furnish the best possible returns in labor. These results cannot be attained unless the management has given the proper attention to good lighting. Mill men are beginning to realize that proper illumination improves the efficiency of the operative, which in turn tends to eliminate "stoppages," "holdups," and time wasted in trying to do work under poor lighting conditions.

It is said that spoilage is directly due to fatigue during the latter part of the day when the operative is tired and more liable to be careless. At this time of the day, light fails him and good lighting is essential. Under artificial lighting and ordinary conditions the amount of actual work produced is between 10 and 20 per cent less than under daylight conditions. These facts mean a loss of production, which could be improved by better

TABLE I

ELECTRICAL INSTALLATION COSTS

Mill	Spindles	h.p. in. Motors Installed	Motors Cost Per h.p.	Wiring Erecting Cost Per h.p.	Total Cost Per h.p.	Cost per Spindle	Type of Motor Drive
A	8,500	520	$12.70	$3.85	$16.55	$1.01	Group.
B	14,000	600	12.85	4.35	17.20	.735	Group.
C	22,000	1,330	13.53	4.96	18.49	1.12	Two and four frame, group.
D	10,000	445	10.80	3.37	14.17	.63	Two and four frame, group.
E	11,850	665	15.80	4.96	20.76	1.16	Individual two and four frame, group.
F	40,000	1,900	9.22	4.73	13.95	.66	Two and four frame, group.
G	18,700	1,550	12.25	4.50	16.75	1.37	Individual two and four frame, group.
H	11,780	845	12.70	4.96	17.66	1.27	Individual two and four frame, group.
I	10,560	575	11.55	4.35	15.90	.98	Individual two and four frame, group.
Aver'ge	16,377	937	$12.38	$4.45	$16.83	$ .965	Four frame and group.

Table I gives the cost of electrifying nine mills from and including 1913 to July, 1016, and covers prices prevailing during that period. These figures do not include the cost of transformers or substations and are based on copper averaging approximately 23 cents per pound. Present prices are somewhat higher.

lighting. In the United States alone 500,000 avoidable accidents have occurred in one year and it is estimated that 25 per cent of these accidents were caused by indifferent illumination. Statistics show that the greatest number of accidents occur during the months of October, November, December, January and February. December being the shortest daylight month it has the largest number. It is therefore evident that one of the earliest "Safety First" movements would be to plan a campaign of education for better lighting especially for industrial plants.

In adopting central station power, the mechanically or electrically driven mill need not change its present wiring system, as a small transformer is used, stepping the current down to the proper mill lighting voltage, and connections are generally made to the present lighting switchboard, whether the current used in the mill is generated by a direct current unit or by a belted or turbine alternating current unit.

Mill Heating

The heating of a cotton mill must be given the proper consideration, but too much stress should not be laid to this item in figuring the amount chargeable to heating the mill in the event that the use of central station power is contemplated. If a greater quantity of fuel than necessary is apportioned to heating and other processes requiring steam, it is evident that on this basis the balance left chargeable to power purposes will show a very economical power plant, especially if the maximum indicator card on the engine is used for estimating the power cost. This method of estimating power cost is an excellent example of self deception and the man who adopts this system of power cost computation is merely standing in his own light. However, the up-to-date mill man realizes that the heating of his mill is relatively a small item as compared to other departmental costs, and is further cognizant that (if steam is used only for heating exclusive of power purposes) a small upright boiler can be installed which will furnish sufficient steam for heating on an economical basis. For the benefit of the heating skeptics, the mills contemplating the purchase of central station power and in doubt regarding the proper amount to charge up to heating the mill, and for the mills that hope to adopt electric drive at a future date, the data in Table 2 on actual heating costs secured from mills buying central station power will be of interest.

Efficiency of Electric Motors

Within recent years the efficiency of the electric motor has been gradually increasing, especially in the types used for individual drive in textile mills. These efficiencies run from 83 per cent in the fractional horse power to 93 per cent in the larger motors. Motor efficiencies for cotton mill work depend on local conditions and the type of drive. If a mill is equipped with individual drive throughout the motor efficiencies will range around 85 per cent. With individual, two and four frame drives, 88 per cent. If large units are used the efficiency will approximate 90 per cent. The overall efficiency including transformers, lines and motors for electrical installations can be summed up from actual data and past experience as follows:

Individual drive, Overall efficiency	82%
Individual, two and four frame, Overall efficiency	84%
Four frame and group, Overall efficiency	86%
All group, Overall efficiency	86%

The advantages to be derived from the various types of electric drive will be discussed later.

TABLE II

MILL HEATING COSTS

Mill	H.P. Motors	Producing Spindles	Contents mill cubic ft.	Sq. ft. Radiation	Cu. ft. per sq. ft. rad.	Cost per h.p. per yr. dollars	Cost per yr. dollars	Product
A	520	8,500	700,000	3,100	225	.60	312	Med. duck
B	600	14,000	790,000	3,000	260	.83	500	Hos. yarn
C	1,330	22,000	2,100,000	6,000	350	.75	1,000	Med. duck
D	445	9,800	320,000	1,610	200	.50	220	Hos. yarn
E	665	11,850	512,000	4,400	116	.75	500	Sheetings
F	650	12,700	....	.....	...	.49.5	315	Specialties
G	560	10,560	400,000	1,900	210	.61	340	Hos. yarn
Average	681	12,787	803,666	3,335	227	.67	456	

The average price of coal at these mills is approximately $2.60 per ton.

Mechanical Drive Friction Losses

The friction losses in mechanically driven cotton mills are very high and vary from 25 to 50 per cent, the losses for any one mill of course depending on the type and arrangement of drive. Some mills are fortunate in keeping the loss down to the minimum. It is very difficult to determine the actual friction loss, due to the fact that the friction at no load or light load is considerably less than under full load conditions. While the indicator card, taken with all the load off, in a measure gives a fair idea regarding the friction loss, it is not correct and does not give the true friction losses at full load. The friction losses in the average mill may be chargeable to the various sub-divisions of mechanical power transmission in consecutive order as follows: Engine, main belt or rope, head shaft, counter shaft and ultimate receiving shafts.

For the mill man who is not familiar with the various types of electric drive and the man who has decided to use it, but is undecided regarding the type to adopt, Table 3 gives the percentage of increase in production obtained and friction losses eliminated by the application of the various types under average conditions.

TABLE III

Electric drive type	Increase in production	Friction losses eliminated
Individual drive	10 to 20%	30 to 40%
Individual, two and four frame	8 to 15%	20 to 30%
Two, four frame and group	4 to 10%	10 to 20%
All group	2 to 8%	3 to 10%

Advantages of Central Station Service

The advantages of electric drive and central station service may be summarized as follows:

Increased Production.

Lower cost per pound of goods produced.

Reduction in capital expenditure or an equivalent increase in production with the same investment. More uniform speeds at all loads, as the prime movers of the central station are larger and operate at a more constant speed.

Power supply is more reliable, as the central station has auxiliary equipment and connections with other central stations.

Freedom from the necessity to watch the coal market, strikes, embargoes and other inconveniences.

Flexibility, freedom to make extensions or alterations and to operate overtime in any or all departments at a proportional or lower cost per power unit. The high cost of operating overtime in any one department of a mechanically driven mill avoided.

Investment made on electric motors having a high efficiency, which is maintained during the life of the motors; expenditure on steam plant is on non-profit machinery, which not only depreciates in value but decreases in efficiency.

More Economical Power.

The item of power cost was treated last, as the power costs in cotton mills are proportionately small compared to the total costs of production and of comparatively less importance than increased production. The central station can supply power cheaper, in most cases, than it can be furnished by the isolated steam plant, but the great advantage of increased output per machine and the lower cost of unit production outweighs the power cost.

The owners of mechanically driven mills will be interested in the statement of a man who is operating approximately 60,000 spindles and buying central station service.

"With reference to the subject of purchased power and electric drive for cotton mills, we wish to say that after a thorough investigation of our cost for operating condensing steam plant as compared to your proposal for electric power, we were fully convinced that central station power would be more economical.

"The installation of this electric drive has eliminated the main drive and a number of counter drives, and the consequent saving in belting and friction load.

"This power has been very satisfactory, giving us a uniform speed and increased production; the greatest advantage we have secured, however, is due to the fact that we operate any department overtime, or run such machinery as desired in all departments at night without increasing the power cost per pound of production, which is not possible with steam power.

"This power service is excellent, and there have been fewer interruptions and stoppages than with out steam plant."

PRACTICAL LIMITATIONS IN THE PROJECTION OF LIGHT

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A very simple and labor-saving method of considering the really important factors in light projection is presented by the author of the following article. After a brief comparison of the general merits of this method with those of the complex analytical methods, there follows a detailed and we believe an unusual treatise on the subject of brightness. In accordance with the tenets of the method outlined in the early part of the article is a discussion of the projection of light by mirrors, searchlights, lenses, post-card projectors, magic lanterns, and motion-picture machines.—Editor.

Preface

The art of lighting is divided into two sections, known as ordinary lighting and optical lighting. Most problems connected with the lighting of rooms and streets fall in the one section while all such things as searchlights, magic lanterns and moving picture machines belong to the other. Projection is a convenient term which is used to denote the latter division.

The distinguishing feature of ordinary lighting problems is that the lamps used can fairly be treated as point-sources (except in the matter of glare). Projection questions on the other hand will not admit of this kind of treatment, at least if quantitative results are required.

This distinction, coupled with the unequal commercial importance of the two branches of lighting, accounts for the lack of an elementary appreciation of projection among the many who are familiar with ordinary lighting technique.

Introduction

The accounts of the searchlight, etc., generally given in text-books on optics assume as a basis the use of a point-source of light. Now it may be asserted at once that the only sources of light which can be treated as point-sources in all practical circumstances are the stars. To assume off hand that any terrestrial source is a point-source or that its small dimensions will justify its treatment as such will often lead to the grossest errors.

It is true that the action of any source may be deduced by considering it as a group of infinitesimal elements and accounting for each one in turn. There is, however, another method which is far less involved and which can be followed by the general reader. While a complete treatment of projection problems employs both methods, the second is so simple and direct that it always affords a valuable check—as far as it goes—on the complex analytical method. In this respect there is an interesting analogy between questions of projection and questions of mechanism. The working of any piece of mechanism can always be examined in detail, taking account of forces and velocities in all parts; at the same time it is usually more profitable to consider in the first instance the conservation of energy in the system. It is often difficult and always laborious to find analytically the flaw in a perpetual motion invention. The existence of some flaw is self-evident, however, in the light of the conservation principle. So in projection problems, the method which is here described will often indicate at a glance that an analytical argument contains a flaw somewhere.

Brightness

We must first understand what is meant technically by brightness. Avoiding the popular senses which characterise a 100 c-p. lamp as ten times as bright as a 10 c-p. and a scarlet object as brighter than a gray we can arrive very quickly at the technical sense. The term is used of surfaces—not necessarily surfaces of imposing extent, for the finest wire is considered at times—and it is a matter of appearance as determined by the conditions of the moment. Thus white paper in a dark room has zero brightness; in average daylight the brightness would be of the order of 1/6 of a unit and in strong sunlight 15 units. Brightness may be due to self-luminosity as in the case of red-hot iron or phosphorescent paint in a dark room, or it may arise indirectly as in the case of all ordinary objects in a lighted room.

The origin of the brightness is of no significance as regards the effects which are produced. Neglecting color, which has no real bearing on the question, the degree of brightness is the only thing which counts.

Thus, the illumination values at various points due to a red-hot poker follow the same rule as do those due to a painted model of the poker illuminated in an appropriate fashion. Similarly, the illuminating effect of a d-c. carbon arc might be reproduced by a model having a crater represented in white paint. In both cases the sole difference would be one of the scale of values and would be explained entirely by the differing degrees of brightness.

Brightness does not depend at all on the distance of the observer and it is often nearly independent of the angle of viewing.*

An observer estimates his distance from any surface, such as a sheet of paper, by reference to the appearance of the boundary, and grain or surface markings. The same is true of his estimate of the angle of viewing, but if the paper be free from markings and the observer holds a card with a ¼ in. hole about a foot in front of the eye, the brightness of the paper will be the only thing he can judge by and this will give him no clue as to distance or angle.

There is now the question of a suitable unit in terms of which brightness may be expressed. The most convenient system is this: consider the illuminating value of one square inch of a surface relative to points lying on a perpendicular drawn from the center of that square inch.

Confining the attention for the moment to points which are a foot or more away from the surface it is found that the illumination varies with great exactness as the inverse square of the distance. A similar illumination might be obtained by placing a small lamp of suitable candle-power in place of the one square inch of surface. The candle-power of such a lamp is a measure of the brightness of the surface and we may say that the brightness is so many candle-power per square inch. It follows that the illumination at any point in such a case will be the same whether we have one square inch of surface at three feet, or 4 square inches at 6 feet, or 100 square inches at 30 feet. The appearance of the surface as viewed from the point is exactly the same in all of the cases, or stated more strictly, the solid angle subtended is the same. By extension we can say that if the view of a surface is limited entirely by an intervening frame or window, the solid angle subtended by the window and the degree of brightness of the surface together determine the illumination received. How far the surface is behind the window or what its inclination may be is of no consequence.

Considered in this way, illumination effects are very easy to understand; it is unfortunate that many people, owing to the influence of earlier training no doubt, will not leave well enough alone in these matters but must needs resort to point and ray methods which are full of pitfalls. It is worth while to labor this feature of the essential simplicity of brightness methods and a few examples will be inserted here to familiarize the reader with them.

No. 1. Suppose we have a perfectly even, clouded sky which has a brightness of 2 candle-power per square inch. A room with black walls is lighted solely by means of a hole in the roof, 10 square inches in area. The illumination at a point 6 feet directly below the hole will be $\frac{10\times 2}{6^2}$ ft. candles = 0.55 ft. candles. If the hole were 30 square inches in area then the illumination would of course be $\frac{30\times 2}{6^2}$ ft. candles = 1.65 ft. candles. However, at 10.4 feet below such a hole the illumination would be $\frac{30\times 2}{(10.4)^2} = 0.55$ ft. candles, the solid angle being exactly the same as that subtended by a 10-square-inch hole at 6 feet.

Next, consider a point which is not directly under the opening but off in a slanting direction—say 60 deg. with the vertical. The appearance of the hole from such a point will be very different. In fact a hole of 10 square inches will have an *apparent* area of 5 square inches. The illumination at such a point, then, if the distance from the hole is 6 feet, will be $\frac{5\times 2}{6^2} = 0.28$ ft. candles. If instead of using the sky we have a large white sheet stretched, say 10 feet above the hole, the illumination conditions in the room will be unchanged, provided the brightness of the under side of the sheet is the same as that of the sky. Even further, if a piece of paper or opal glass is fitted into the hole and the brightness of this is brought to the former sky brightness by proper external lighting, again the illumination conditions are unchanged.

The idea to be grasped is this. We can determine the illumination produced at any point by a bright object if we know exactly what is the appearance of that object as viewed by an eye placed at the point in question.

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* A surface which exhibits this latter effect perfectly is said to obey Lambert's Law.

The "appearance" includes two factors, brightness and *apparent* size; the latter is identical with the "solid angle" subtended.

No. 2. Metallic tungsten, like all other substances, becomes self-luminous when hotter than about 500 deg. C, and gains rapidly in brightness as the temperature is raised. At a temperature of 2000 deg. C, its brightness is some 740 candle-power per square inch. Suppose a lamp has a filament of tungsten operating at this temperature, which is to say, at this brightness. The illumination produced at any point can be deduced immediately if we know the apparent area which the filament presents towards that point and also the distance of separation. These two quantities together measure the solid angle subtended by the filament surface, but the solid angle is, after all, derivable directly from the appearance or "view" of the surface from the point in question.

The commonest type of tungsten lamp, viewed from the side, shows twelve straight pieces of wire in "full-face" view. Taking the lengths as 2 inches and the breadths as 0.002 inches, we have 12x2x0.002 square inches approximately as the total area presented to view. The candle-power of the lamp with respect to points opposite the side is therefore 12x2x0.002x740 (at 2000 deg. C). The further we go away from the side of the lamp, that is by moving around so as to face the tip, the smaller the apparent area of the tungsten becomes. It is halved by the time we reach 60 deg. away from the side, roughly speaking. The candle-power in that direction is correspondingly smaller. More exact information as to the value for any point could be obtained from a photograph of the lamp taken with the camera lens at that point.

No. 3. The d-c. carbon arc is effective by virtue of a very bright circular patch on the end of the positive electrode. This patch (or crater) is of even brightness and the "distribution curves" for such a lamp are determined solely by the apparent (or foreshortened) area of the crater as seen from different points. The peculiar form of those curves is entirely due to the limited view of the crater as seen from certain standpoints, the obstruction being obviously caused by one or other of the electrodes.

At this stage it is well to survey the possibilities of various light sources from the sole standpoint of surface brightness. The following Table gives the rough values assigned to familiar surfaces.

TABLE OF BRIGHTNESS VALUES IN CANDLE-POWER PER SQUARE INCH

White paper in bright sunlight	15
Coal gas flame	3
Kerosene flame	0.9
Acetylene flame	30–60
Welsbach mantle (mean)	30
Carbon filament	750
Tungsten filament (ordinary vacuum practice)	1,000
Tungsten filament (ordinary gas-filled practice)	2,000–7,000
Nernst lamp glower (max.)	3,000
Lime light	2,000
Tungsten filament (special practice)	24,000
D-c. carbon arc crater, from 3 amps upward	84,000
The sun at mid-day	600,000

Two things should be noticed, the enormous range of values as between different illuminants and the approximate constancy for any particular one irrespective of size of source and consumption.

Mirrors

We are now in a position to appreciate a very useful generalization relating to optical devices. This may be arrived at by strict geometry but, fortunately for our present purpose, the truth of it may be grasped by reference to matters of ordinary experience. The principle referred to is this: the appearance of any mirror, viewed from any point whatever, must always be what might be called a mosaic of surfaces exhibiting some or all of the brightness values of the surrounding objects.* It will be granted immediately that this holds in the case of plane mirrors, the "looking glasses" of every-day use. That it holds equally for all curved mirrors may be readily ascertained if a little attention be given to the polished† silverware of the table. Looking into the bowl of a spoon, there is usually no difficulty in identifying the brightness shown in the various parts with the brightness of the surrounding objects. Here there is a species of image effect which assists the recognition, but this is not always the case. The complicated and arbitrary curves of a tea-pot will always show perfectly definite areas endowed with the brightness of the sky; the identification of other areas with room objects is apt to be difficult owing to the diversity of the objects at hand.

Now a result of this kind, holding for the indefinite assortment of reflector curves occur-

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* For the moment, mirrors will be assumed to have 100 per cent reflectivity. The actual value for silver is 93 per cent and the difference may well be neglected temporarily.

† This applies only to articles which can be said to be "as new." The diffusion which occurs when the surfaces are scratched prevents their being considered as true mirror surfaces.

ring in table-ware, may well be expected to hold in the case of the few simple curves employed in optical mirrors. This is indeed so and as a result we know immediately the general possibilities of such mirrors.

The Searchlight

The searchlight is a familiar example. It is an instrument for producing illumination at great distances and it consists essentially of but two parts, a mirror and a light-source. The latter, as previously explained, is merely a bright *surface* of some size or other.

Suppose we consider the apparatus in use and station ourselves at the point to be illuminated. How may the illumination obtainable at that point be estimated? Why, the case is a simple parallel to those considered already and we shall observe the mirror to be sharply divided into areas *having the brightness values of the surrounding objects*. Here, however, there is the greatest disparity between those values; the carbon arc crater, assuming that to be used, will have a brightness of 84,000 candle-power per square inch while no other object adjacent is likely to have a brightness of more than 1/10 candle-power per square inch. The observer will notice only that area of the mirror which is as bright as the arc crater, all the rest will seem absolutely dark in comparison. The illumination obtained follows immediately, thus if the bright part of the mirror is apparently 20 square feet or 2880 square inches and the distance is 5,000 feet the illumination must be $\frac{2880 \times 84{,}000}{5000^2} = 9.6$ foot candles. We can also decide at once that if the *whole* apparent area of the mirror is 25 square feet = 3600 square inches, the maximum illumination possible with that mirror at 5000 feet (when any ordinary carbon arc is used) is $\frac{3600 \times 84{,}000}{5000^2} = 12$ foot candles. There is thus an evident limitation as regards the illumination attainable at any particular distance and there are two factors in this limitation, the apparent area of the mirror presented and the brightness of the source-surface.

Mirror size is limited by cost and unwieldiness, while source brightness is limited to the values characteristic of the types of illuminant available.

In all of this we have given no attention to the form (curve) of the mirror and the dimensions of the source-surface because these matters are not involved in the considerations given. Nevertheless, the form of the mirror is important because it determines how large an extent of source-surface will be needed in order that the mirror appearance from the point considered shall *all* be bright and hence maximum illumination be obtained. The extent of the source, beyond the degree involved in this last condition, is only significant as determining the lateral range of points enjoying such illumination, in other words the "size of the spot thrown."

It will be readily understood that the only difference between an ideal mirror surface reflecting 100 per cent and a practical one reflecting say 90 per cent is that the brightness values observed in the latter are reduced to 0.9 of their original values and consequently the illumination is 0.9 of its ideal value.

The special suitability of the parabolic mirror and the connection between source size and area of the illuminated "spot" are entirely matters of geometry which would be out of place here.

In passing it may be of interest to note that a polished spoon bowl (or better a round ladle bowl) will show roughly what the parabolic reflector exhibits in the highest attainable perfection, namely the conferring of brightness on a reflector by means of a relatively small surface of source. Hold the bowl of the spoon at arm's length (preferably so that a dark wall is behind the observer) and bring in front of it a scrap of white paper about ⅜ inch diameter. By moving the paper slowly toward the bowl a point will be found such that practically the whole bowl assumes the brightness of the paper. This arrangement is an exceedingly *crude* searchlight but a searchlight none the less.

Lenses and the like

The generalization which has been established for mirrors in the foregoing has its exact counterpart in connection with all transparent bodies having polished surfaces, that is excluding all diffusing (roughened, etched or frosted) surfaces. Most table glassware complies with this condition; on looking *through* any part of a water-bottle for example, we see within the outline of the bottle as a frame a mosaic of surfaces showing some or all of the brightness values of the surrounding objects—and no others.* The pattern may or may not be recognizable as a kind of image of the room, that depends on circumstances and is of no consequence.

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* Losses due to reflection and absorption are here neglected.

A complication may arise from the fact that each colored constituent of light is treated differently, and the mosaics for the different elementary colors are out of mesh, as in poorly printed maps. But if the observer were provided with deep blue or red spectacles he would discover that the reproduction of brightness values is true for each separate spectral color, a fact which is rather obscured if no such provision is used.

Once more we can argue that results which hold for the diverse, complicated and arbitrary shapes of tableware may be expected to hold for the simple forms used as *lenses* by the optician. This is so in fact and is capable of rigid proof from first principles.

The Post-card Projector

As an application of this result we may take the common post-card projector. The usual arrangement comprises a holder for the card, means of illuminating the card—that is to say of rendering the card bright—and a system of polished glass pieces known collectively as an objective.

We are not now concerned with the art involved in giving those glasses the precise curves which result in the post-card picture being reproduced faithfully on the screen or curtain.

The illumination at various points on the screen is what we are interested in and it is very easy to determine what the values will be. If we go close to the screen and look back at the objective, placing the eye well within a sky part of the picture, the whole opening of the objective will show a brightness identical with that of the white part of the card.* Why this should be is not perhaps self-evident but a little argument will make it clear.

That very property of the objective which leads to the faithful reproduction of the picture necessitates that a screen point, which is for example part of the pictured sky, shall derive light only from the corresponding part of the card. If the eye, looking back at the objective from that point could see any part of the objective endowed with the brightness of some separate part of the card (other than that under consideration) this condition would be violated.

Once more, then, we have a relation giving the illumination at any point on the screen. Suppose that from that point the apparent area of the objective opening is six square inches, the brightness of the opening (or the brightness of the corresponding part of the card) is 50 candle-power per sq. in. and the distance of the screen point from the objective is 8 feet, then the illumination is obviously $\frac{6\times 50}{8^2}$ foot-candles.

For any particular screen distance the illumination (and hence the brightness of the picture viewed) is determined by the brightness of the card and the effective area of the objective opening. Now in practice the real limit to the brightness of the card is set by the heating effect accompanying the powerful illumination which must be used. Not much improvement can be expected in the card itself; i.e. to get greater brightness while using the same illumination. Water cells can be used to reduce the heating effect accompanying the illumination but they are considered a nuisance and are rarely used with this apparatus.

Turning to the objective as the other limiting factor we encounter trouble with the lens maker when we attempt to go to larger openings. Not only is there difficulty and limitation in design in increasing the opening (camera buyers appreciate an exactly parallel difficulty) but the very size of the glasses required constitutes a manufacturing difficulty.

It is not necessary to discuss the method of illuminating the card; with either the arc or a suitable tungsten lamp as ultimate source the accompanying heating effect is the limitation at present in commercial apparatus.

The Magic Lantern

The magic lantern is related to the post-card projector but is an instrument with much greater possibilities. The difference is due primarily to the different kinds of pictures used; the post-card has the property of scattering light in all directions and consequently merely a fraction of this can reach the objective; expressed in other words, the brightness of any part of the card is very low relative to the intensity of illumination used. The post-card has the further disadvantage of absorbing the infra-red radiation (the so-called heat waves) almost entirely.

The slide used in magic lanterns is entirely different. It may scatter a little light but there is so much which is not scattered that

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* We are neglecting certain losses which occur in all lenses; viz., by reflection and by absorption. This applies also to the magic lantern and moving picture machine but in none of these cases is the effect very large. Furthermore, the corresponding factors are easily introduced by anyone who is interested in the matter.

a vastly better economy is possible as compared with the post-card. This in itself means a reduced heating effect, other things being equal, while there is yet another reason in the fact that in the clearer parts of the slide at least most of the infra-red is transmitted without absorption. The consequent subordination of the heating effect is such that the limiting feature in magic lanterns is not ordinarily the heating of the slides, although damage from this cause may occur.

An objective is used, just as in the case of the post-card projector. To consider a pictorial slide is apt to be confusing; a plain line drawing on clear glass offers no difficulties and all other slides will produce effects on the screen which are very simply related to that produced by the drawing. (The relation is the same as that of the densities which exist in the slides.) The line drawing on the glass stops the passage of light at certain points and at all other points the slide has no effect whatever.

Now there is a combination of lenses somewhat larger than the slide, just behind it. This is followed at an appropriate distance by a very bright source surface. Following the preceding line of argument and considering the appearance of the objective as viewed from the screen we find that some or all of the objective opening is as bright as the source while the rest has the negligible brightness of the other contents of the lamp housing. Usually the conspicuously bright area can be recognized as an image of the source, although it will show the color displacement previously referred to. The view from different points on the screen will show that the bright area of the objective is not the same for all, sometimes it lies in the center of the opening and sometimes it lies more or less to one side. But the *size* of the bright part is substantially constant for all viewpoints.

It is not necessary to repeat the expression for the illumination. The limitations are clearly the brightness of the source and the area of the objective opening *serving any one point.* The question of how much objective area can be provided for this service is an optical one similar to that of providing "working aperture" in a camera or a post-card projector.

It is interesting to note, however, that in the early days kerosene flames were used (9 c-p. per sq. in.). The brightness of this source is so low that large working aperture is essential in the objective to obtain reasonable illumination. Modern illuminants like the special tungsten lamps and the carbon arc have such a vastly greater brightness that the aperture requirement is not hard to meet unless the screen distance (and with it usually the size of the screen-picture) is inordinately great.

The Motion-Picture Machine

The motion-picture machine is a comparatively complicated piece of apparatus although it is closely related, optically, to the magic lantern. The lantern slide, which is about 3 inches long, is replaced by a similar picture, on celluloid, about 1 inch in length. In present practice the picture is held in place for a small fraction of a second, an opaque shutter then intervenes and cuts out the screen illumination entirely while the picture is being replaced by another, the shutter moves away and the projection of the second picture proceeds for a fraction of a second.* The apparent illumination on the screen is an average of the effects of this regular succession of exposures. The best result which is practicable is an average illumination of about 60 per cent of that attainable if these alternations did not occur.

Comparing the motion-picture machine with the magic lantern, the same kind of limitations are found to govern the illumination on the screen.

Again we have the working opening of the objective and the brightness of the source. However, if the screen distance and the size of the screen picture are the same in the two cases, the objectives required will be very different. Just as in the case of cameras, where a large plate means a long camera with a big lens and a small plate a short camera with a small lens (if the conditions are at all similar) so in the present case the large lantern slide can be provided with an objective proportionately larger than can be provided for the motion-picture film—equal quality of design being assumed.

As a consequence, the objective opening used in motion-picture work would be small as compared with that found in magic lanterns, and hence the screen illumination would be small, were it not for the fact that the lens makers have pushed the objective design further for the motion-picture outfit and thus reduced the disparity. To some extent this has involved a rather inferior sharpness in

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* Actual practice is more complicated, in order to prevent flicker.

the projected picture but to detect this requires a critical examination which motion-pictures do not receive, for obvious reasons.

The typical outfit of today, using the carbon arc as the source, is arranged in such a way that no part of the screen gets the benefit of the whole actual opening of the objective. It is possible by using different arrangements to secure that every part of the screen is served by the whole objective opening. The gain in working aperture is sufficient to offset the difference in brightness which exists between the arc crater and specially designed tungsten lamps. This means that in the great majority of cases it is possible to attain the present illumination values if we replace the present arc arrangement by a suitably arranged tungsten lamp and leave the objective as it is.

The injury to the sharpness of the picture which follows the increase of working aperture involved in this change is not such as would be noticed by the lay observer; even if it were so, the present objectives do not represent the limit of design and their cost is a minor item in the outlay which motion-pictures demand.

THE THEORY AND PRACTICAL USE OF PROJECTORS AND THEIR LATEST APPLICATION AS PORTABLE SIGNAL OUTFITS

By L. C. Porter

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National and private exigencies are now demanding that increased attention be given to the theory of the projection of light and to the design and manufacture of improved light projectors for signal and illumination purposes. In the following article, the author introduces his subject with explanations and diagrams of the effect of various factors on the projection of a beam of light and then describes experiments which were made with incandescent lamps and reflectors to demonstrate the theory as set forth. In the remainder of the article, he describes typical portable projection outfits which have been developed.—Editor.

Parallel light from an artificial light source has been, and probably will continue to be, an unrealized dream. Were it possible, a beam of such light would reach to infinity and, neglecting absorption, have the same intensity at any point along that rather lengthy path. If we could have light originating from an absolute point source, a very simple lens or a parabolic reflector could be utilized to collect and project the rays parallel, see Fig. 1. However, all practical light sources have physical size, and when used with a lens or reflector the rays of light emanating therefrom and striking any point of the lens or reflector form a cone, which, on reflection or refraction still remains a cone. See Fig. 2. The illumination, therefore, instead of remaining constant, varies inversely as the square of the distance from the light source to the point of measurement.

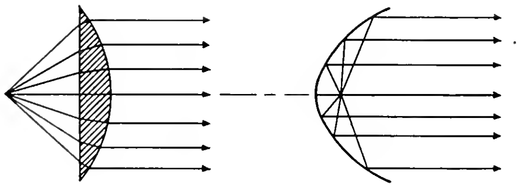

Fig. 1. Illustrating Theoretical Parallel Projection and Reflection of Light Rays from Point Source

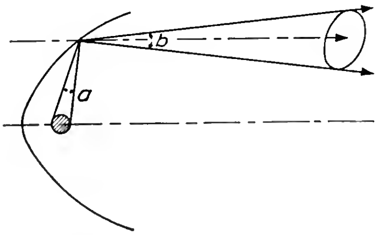

Fig. 2. Illustrating Practical Reflection of Light from a Source of Physical Size. Parallel Reflection of Rays is Impossible Here

As each point on the reflector emits a cone of light, the total projected beam must necessarily be a cone also. Now, the angle of the cone of light—or spread of beam, as it is more commonly called—projected by such equipment depends upon the size of the light source and also upon the focal length of the projector; the larger the light source the greater the spread of the beam, see Fig. 3, and the longer the focal length of the projector, the less the spread, see Fig. 4. We see, therefore, that if a light source of very small dimensions is used in a long focus projector, a narrow and, hence, powerful beam will result. If the intensity or intrinsic brilliancy of the light source is also high, we have a powerful projector, whose range is great.

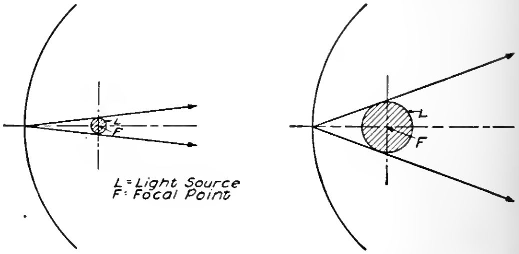

Fig. 3. Illustrating Influence of Size of Light Source on Spread of Beam

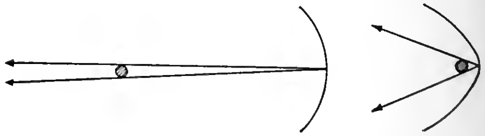

Fig. 4. Illustrating the Effect of Focal Length of Projector on Spread of Beam

The use of low-voltage Mazda lamps gives a very highly concentrated light source, which can be operated at a very high brilliancy—not so high as the crater of an arc, but possessing inherently superior control. See Fig. 5. In order to demonstrate strikingly the effect of the size of the light source upon the resultant beam, the writer had six Mazda lamps made, each operating at 100 spherical candlepower, i.e., emitting the same number of lumens or total amount of light, but having their filaments wound to occupy different volumes, as shown in Fig. 6. Each of these lamps, in turn, was carefully focused in the same reflector and distribution curves were made of the resultant beams. See Fig. 7. The results are given in the table below.

Fig. 5. Concentrated Filament Low-voltage Mazda Lamp for Projection

Equal amounts of light were projected in each case, but with a widely different spread. The lamp "A" of maximum filament concentration gave an exceedingly narrow beam and, therefore, a very powerful and far reaching one, all the light being confined in a small cross section; while the lamp "F" of little or no concentration gave such a wide spread to the light that it could hardly be said to form a beam at all. Its intensity and, consequently its range, were decreased correspondingly.

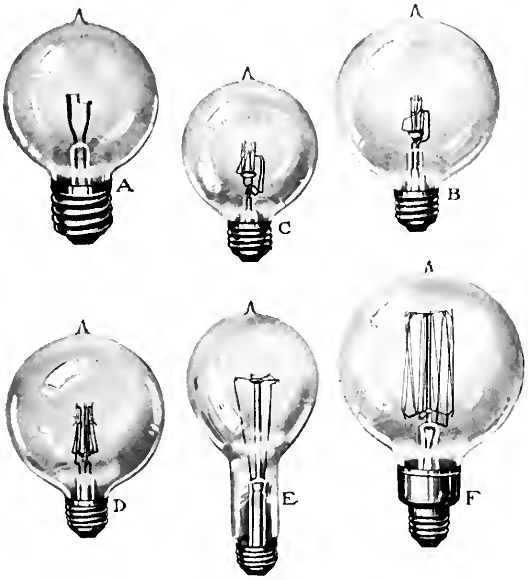

Fig. 6. 100 Candle-power (Spherical) Mazda Lamps having Filaments of Different Size for Testing Purposes

A highly concentrated light source located at other than the focal point of a lens or reflector may give results no better, or even worse, than would be obtained from a light source having little or no concentration. In order to illustrate this, the writer took a lamp having a filament similar to that of lamp "A" (see Fig. 6), but of still smaller dimensions and lower candlepower, and placed it accurately at the focal point of the reflector. From this point the light source was moved first forward and then backward along the axis of the reflector, one sixteenth of an inch at a time. The effect on the maximum candlepower of the resultant beam, as shown in Fig. 8, was as follows:

At focus..................	Beam c.p.	220,000
1/16″ back of focus.........	" "	70,000
2/16″ " " "	" "	40,000
3/16″ " " "	" "	18,000
4/16″ " " "	" "	8,000

Distribution curves were run across the beam with the light source at the focal point of the reflector, then one-quarter of an inch ahead of it, one-quarter of an inch back of it and one-quarter of an inch to one side of the

LIGHT SOURCE DIMENSIONS M.M.		Beam Candle-power	Lamp Used
Diameter	Length		
2.0	6.5	462,000	6 volt 108 watt G-30 bulb Mazda C headlight lamp.
5.0	5.0	223,000	32 volt 100 watt G-30 bulb Mazda C headlight lamp.
6.5	6.5	142,000	110 volt 100 watt G-25 bulb Mazda C stereopticon lamp.
8.0	8.0	32,600	110 volt 100 watt G-30 bulb Mazda B stereopticon lamp.
25.0	.5	12,700	110 volt 100 watt PS-25 bulb regular Mazda C lamp.
30.0	68.0	3,800	110 volt 100 watt G-35 bulb regular Mazda B lamp.

focal point. These curves are shown in Fig. 9. It will be noted that moving the light source away from the exact focal point, along the axis, spreads the beam and reduces its intensity very rapidly. If this is carried far enough, a dark spot appears in the centre of the beam. Moving the light source to the right of the focus throws the centre of the beam to the left, placing the source above the focal point lowers the beam, and vice versa, at the same time materially reducing the beam intensity.

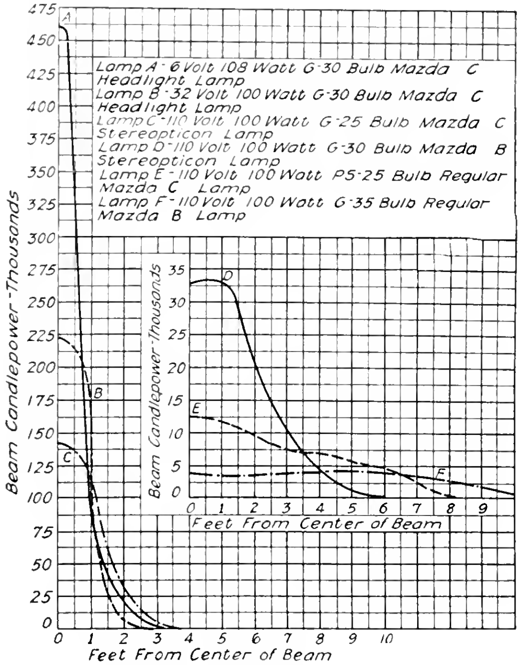

Fig. 7. Distribution Curves of Lamps Shown in Fig. 6.

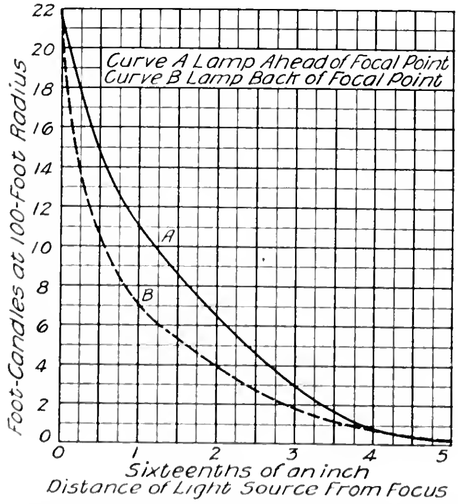

Fig. 8. Showing Influence of Filament Position on Candle-power of Reflected Beam for Parabolic Reflector

Therefore, in using any form of projector, be it stereopticon lantern, search light or signal projector, it is exceedingly important to see that the equipment is properly focused. Most projectors have some means of accomplishing this. It can best be done by training the beam of light onto a flat surface at some distance from, and preferably perpendicular to, the axis of the beam, and moving the light source about until the smallest spot of light is obtained; the light source will then be at the focal point. It should then be rigidly secured there. If no convenient surface is available, the beam may be directed up into the air and the light source adjusted until the edges of the beam become most nearly parallel.

Where incandescent lamps are used as light sources, a new lamp should always be focused upon installation, because it is not practicable to make lamps, even of the same kind, exactly true, and while a lamp may be in focus, it does not necessarily mean that the one replacing it will be. Other types of light sources need continual attention as to focus, due to the consumption of the light-giving element.

One of the latest applications of the above outlined theories of light projection is that of portable signal outfits. It is well known that even an ordinary oil lantern can be seen many miles, on a clear night. If the effective size and intensity of such a light is greatly increased, its visibility will be correspond-

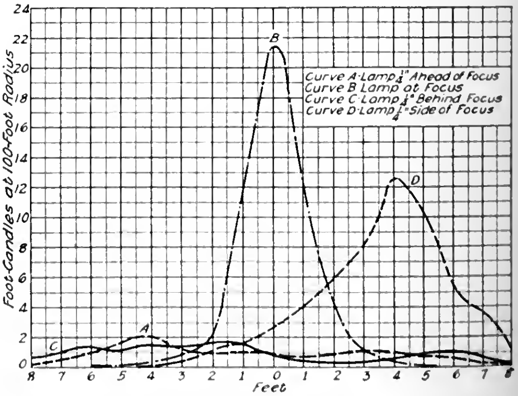

Fig. 9. Curves showing intensity of Light Across Beam for different positions of Light Source

ingly increased. This is what has been accomplished by placing an accurately ground and polished mirror back of the focus-type Mavda lamp. Tests were conducted some time ago, in which, by the use of a 12 candle-power Mazda lamp operated by four ordinary dry cells and backed by a 10-in. Mangin mirror, signals were transmitted a distance of 50 miles and read without the use of glasses. As a result of these tests, a portable signal projector has been developed, consisting of a 6 volt 1½ ampere 12 candle-power Edison Mazda C lamp, an 11-in. glass parabolic mirror and a container for the two, equipped with a telegraph key for making and breaking the circuit. Another form of this projector, see Fig. 10, has the battery and key in a separate casing.

This device has been adopted by the U. S. Coast Guard service. All their ships and stations are being equipped with them. The outfits weigh but a few pounds and can be set up and operated in the station, or a patrolman can take them out on the beach with him, to signal ships or other stations miles away.

These signals also have the advantage of being secret, as only those directly in the path of the beam can read their flashes at any appreciable distance.

The field for this device is large. There is no reason why every motorboat and other small craft, which are not at present equipped with any signalling apparatus, should not carry such a device. In time of war, this would be of great value. There are 30,000 boy scout troops in the country. Part of their training is signalling and this could be better practiced if each troop had at least one of these devices. The signal corps will probably use many of them, and undoubtedly they will be utilized in many other places, as on aeroplanes, for instance, or privately for amusement purposes.

Fig. 10. Portable Signal Projector, 11-in. Mirror, 6-volt 12-c.p. Mazda C Lamp

Fig. 11. Self-contained Coast Guard Signal Projector

A very simple signal projector having a range of some twenty-five miles could be easily made. It consists of a wooden box 12 in. long and 5 in. square, made of ¼-in. wood. This box contains a 5-in. Mangin mirror which could be obtained from Bausch & Lomb Company, Rochester, or from the Macbeth-Evans Glass Company, Pittsburgh, Pa.

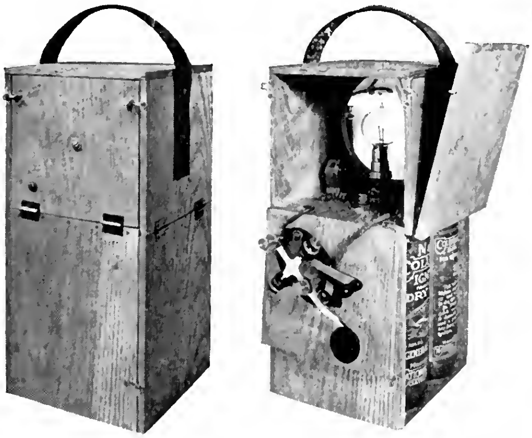

Fig. 12. Simple Signal Projector having a Range of 25 Miles. Fitted with 5-in. Mangan Mirror, 6-volt 12-c.p. Mazda C Lamp

At the focal point of this mirror is mounted a 6-volt, 1½-ampere Mazda C lamp, having a maximum concentration filament. (A 1½-ampere automobile lamp could be used, but the range will not be so great as with the maximum concentration filament lamp.) In the lower compartment of the box are four standard dry batteries connected in series and to the lamp through a standard telegraph key. Fig. 12 shows such a device.

VOLTAGE STANDARDIZATION

By M. D. Cooper

National Lamp Works of General Electric Company

Standardization is universally sought and requires no recommendation. Quite thorough standardization of our actions and the things with which we deal has been effected. The author of the following article shows how material benefit would result from a more rigid standardization of our distribution voltages, and, with regard to actual voltage values, reviews the influences of the past and shows the narrowing tendencies of to-day.—Editor.

One of the fundamental factors of our present-day civilization is standardization. In fact, we may say that our entire economic and commercial development has been brought about by standardization, or co-operation in the use of standardized measures of quantity and value, standardized methods of action, etc. Probably the first step that was made from savagery toward economic civilization was the standardization of values involved in the establishment of a monetary system. Standardization of money involved as the next step the standardization of units of weight and measure. Clothes have developed from the animal-skin coverings of our savage ancestors to their present forms by reason of standardization of materials, styles, and measurements. Consider the automobile; users of present-day machines can hardly imagine the chaos, inconvenience, delay, trouble, and increased expense that would exist if tires, wheel sizes, width of tread, engine ratings, sizes and forms of bolts and nuts, methods of control, traffic rules, and every other thing pertaining to an automobile were not very highly standardized.

Not only in the convenient use of any article, but also in its economy of use, standardization has played a major part. If shoes, for instance, were not of standard sizes and shapes, their cost would be multiplied many times over, for one would have the choice of sending his foot measurements to a factory and waiting for special lasts to be built or of hiring an itinerant cobbler to come to his house and laboriously fit the shoes to his feet.

The electrical industry in this country has grown to its present tremendous importance and high stage of development very largely by reason of the high degree to which electrical apparatus, appliances, material, and methods have been standardized. Probably no one industry ranks ahead of the electrical industry in thoroughness of standardization, yet there is one feature of the industry which still shows a considerable lack of standardization; viz., voltage of distribution. Of course, there is a standardization of ranges of voltage, such as 105 to 125, 220 to 250, etc., but in any one of these ranges there is no commonly accepted standardization upon certain definite values. If voltage standardization upon a very few values could be brought about, a very great benefit would accrue to the electrical industry. All apparatus which has to be closely selected for voltage, such as lamps, heating utensils, etc. could immediately be manufactured and distributed with less cost, and the saving would eventually react to the benefit of the ultimate consumer. Not only would the production and distribution be cheaper but it would be very much more rapid. Jobbers of electrical supplies could, for the same investment in stocks, carry more kinds and sizes of electrical apparatus, where now they have to carry lines of apparatus of slightly different voltage.

In connection with standardization of voltages, one is reminded of the standardization of lamp bases which was made some years ago. At an earlier period in the industry there was a multitude of forms and sizes of bases in use. It was agreed that standardization of bases would be very beneficial to the industry, but a means of accomplishing this standardization was not easy to find. It was manifestly well-nigh impossible to make an over-night change from one style of base to the proposed standard base, and some transitory means had to be devised. This means was found in the use of adapters for application to the variegated line of sockets then in use; and into these adapters the standard base lamp could be placed. New installations were then made entirely with the standard socket and replacements of the older sockets were made with the standard socket. In this manner standardization was brought about so that now-a-days there are but two styles of bases for commercial incandescent lighting: viz., the medium screw base and the mogul screw base.

A standardization of voltages would not require the transitory adapters that were necessary in the standardization of bases for it is a simple proposition to change the voltage of an central station, of a feeder, or of a isolated plant from its present value to some standard value.

Since the incandescent lamp requires the closest voltage selection of any piece of current-consuming apparatus, the conditions surrounding the manufacture of incandescent lamps have always had a very large part to play in the selection of operating voltages for lighting companies. At an earlier period in the industry, practically all central stations were operated at either 100, 104, or 110 volts. The carbon lamp at that time was the standard incandescent lamp. The manufacturers of lamps found that it was impossible to make all lamps exactly true to the predetermined voltage of design. There was, therefore, a considerable supply of lamps differing slightly in voltage from the standard figures; and in order that the lamp manufacturers might dispose of their entire product without waste, the lighting companies were urged to diversify their voltages throughout the range covered by the standard values. In time, the desire for a wider distribution and a more economical use of copper led the lighting companies to seek higher voltages than 110, with the result that ultimately the demand for lamps was spread over a range from 100 to 130 volts, although now the greater proportion of the demand lies between 110 and 125 volts.

Since the introduction of the tungsten filament lamp, and as the processes involved in the manufacture of this lamp have become perfected and developed, there has been a decreasing necessity for a widespread range of operating voltages because the lamp manufacturers have continuously been able to make their lamps closer and closer to the predetermined voltage of design. At the present time, the processes of manufacture

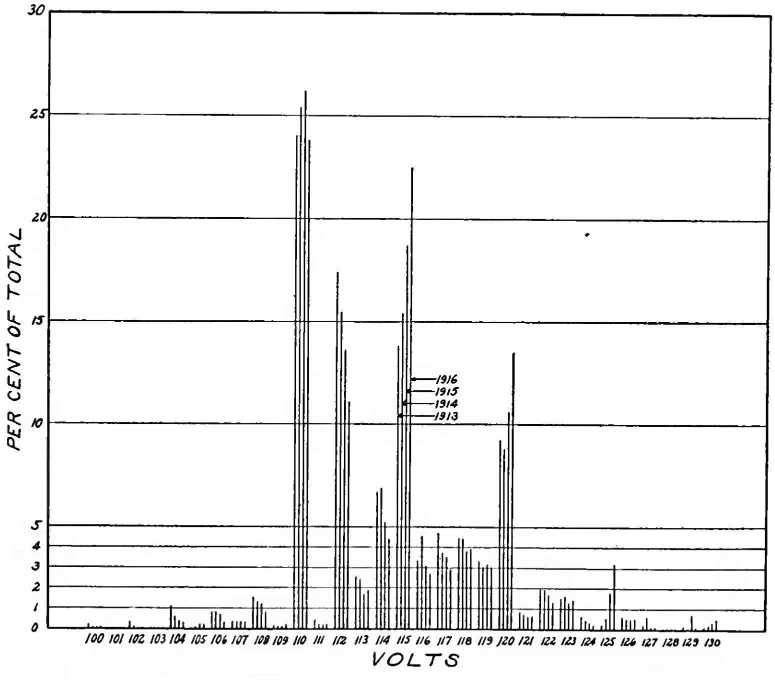

Fig. 1. Plot of Lamp Demand upon the General Electric Company showing the decided tendency toward standardization on 110, 115 and 120 volts

are so far developed that Mazda lamps can be made true to voltage within commercial limits.

As the influence of the manufacturers has been withdrawn from maintaining a diversity of demand for various voltages, the trade has shown an evident tendency towards standardization of certain voltages. Fig. 1 demonstrates the tendencies at the present time. This chart shows the percentage of total demand represented by each voltage over a period of years and it will be noted that 110, 112, 115, and 120 are at present the most prominent voltages. The tendency of 115 and 120 is strongly upward, while 110 shows no pronounced tendency either upward or downward and 112 evidences a very pronounced downward tendency.

This chart shows the fundamental basis of the movement now on foot tending toward universal standardization on 110, 115, and 120 volts.

THE ELECTRICAL RESISTIVITIES OF IRON ALLOYS

By T. S. Fuller

Research Laboratory, General Electric Company

Very often the engineer, engaged in the design of electrical machinery, requires alloys of widely differing electrical resistivities. Many times, however, he finds it difficult to select a particular alloy for his purpose because the available resistivity data for the various alloys are inadequate. To increase the scope of the existing knowledge on the subject, the author has investigated the electrical resistivities of some of the iron alloys and in the following records the results.—Editor.

Most of the alloys recorded in this article were melted either in an atmosphere of hydrogen or in vacuo. One-hundred-gram slugs were made in alumina crucibles, the melts being thoroughly stirred with a fused quartz rod. The component metals used were as follows: Swedish iron; Goldschmidt chromium and manganese; nickel from the International Nickel Company; and cobalt, 98 to 99 per cent pure, furnished by Eimer & Amend. The composition of the alloys and their corresponding resistivities are given in the various Tables. The added metals were carefully weighed and the slugs when cool were weighed again. No slug in melting lost over three or four per cent of the total weight. Portions of the one-hundred-gram melts were swaged and drawn down to wire having a diameter of 0.010 inch. All the alloys described in the following are therefore sufficiently ductile to be forged and drawn into small wire. The samples were annealed and the resistance measured at room temperature by means of a potentiometer, using the null method.

Alloys may be divided into three characteristic groups with respect to their electrical resistivity. In the first group are those whose resistivity can be calculated directly from the components, if the concentration by volume is known. If the resistivities of one of the binary systems of this group be plotted as a function of the volume concentrations, a straight line will result. Examples of this group are tin-zinc, tin-lead, tin-cadmium, lead-cadmium, etc.

The second group contains those alloys whose resistivity is much greater than that of either of the components. If the resistivities of one of the binary systems of this group be plotted as a function of its concentrations by volume, there results a curve which slopes off in both directions from a maximum to the resistivities of the components. Examples of this group are gold-silver, copper-nickel, iron-nickel, etc.

The component metals comprising an alloy of the first group are present as a mechanical mixture, and the components of the alloys in the second group are present in solid solution.

There is a third group of alloys whose component metals are present in a semimiscible state, that is, in which two series of solid solutions are separated by a gap. If the resistivities and volume concentrations of one of the binary systems of this group be plotted, the curve will rise rapidly from the values for each of the component metals to the values for the limits of the saturated solutions, but between these limits the variation will be linear. Examples of this group are copper-silver, copper-cobalt, etc.

All the systems considered in this article belong to the second group.

TABLE I

IRON-NICKEL ALLOYS

COMPOSITION		Electrical Resistivity Microhms per cm³.
Iron	Nickel	
100	0	12.0
83	17	38.2
71	29	79.5
70	30	83.3
66	34	86.3
19	81	23.9
10	90	19.4
7	93	18.1
2	98	11.9
0	100	11.8

Iron-nickel Alloys

The iron-nickel alloys, as shown by Table I, display a range in resistivity from the values for iron and for nickel up to a maximum of 86.3 microhms per cm³, which is fifty times the resistivity of copper. The alloys containing large amounts of iron are readily oxidized and therefore should not be used unprotected at temperatures above 400 to 500 deg. C.

TABLE II

IRON-CHROMIUM ALLOYS

COMPOSITION		Electrical Resistivity Microhms per cm³.
Iron	Chromium	
100	0	12.0
90	10	54.0
80	20	60.0
78	22	60.0
76	24	57.8
70	30	55.9

Iron-chromium Alloys

In the iron-chromium series, as presented by Table II, there appears only a small difference in resistivity for alloys containing ten, twenty, and thirty per cent chromium. However, the addition of ten per cent chromium to iron increases the resistivity five and one-half times, and gives a value 32 times the resistivity of copper. The more chromium present in the alloy, the greater the resistance to oxidation at high temperatures. Alloys containing twenty per cent or more of chromium may be safely used up to 800 deg. C.

TABLE III

IRON-COBALT ALLOYS

COMPOSITION		Electrical Resistivity Microhms per cm³.
Iron	Cobalt	
100	0	12.0
90	10	16.3
80	20	20.0
70	30	20.0
0	100	9.7

Iron-cobalt Alloys

Table III shows that the addition of thirty per cent of cobalt to iron about doubles the resistivity. Like the iron-nickel system, the iron-cobalt alloys are readily oxidized at high temperatures and should not be used above 400 to 500 deg. C.

TABLE IV

IRON-NICKEL-CHROMIUM ALLOYS

COMPOSITION			Electrical Resistivity Microhms per cm³.
Iron	Nickel	Chromium	
100	0	0	12.0
0	100	0	11.8
4	93	3	46.0
4	90	6	53.0
18	75	7	83.1
70	20	10	77.5
35	55	10	107.0
17	70	13	103.9
16	71	13	100.2
5	81	14	89.9
25	60	15	110.0
5	80	15	96.8
4	80	16	95.0
6	77	17	105.0
50	30	20	92.5
30	50	20	104.0
25	55	20	93.5
7	70	23	111.0
20	55	25	113.0
7	64	29	110.0
10	58	32	110.0
33	34	33	98.0
23	44	33	109.0
10	53	37	113.0

Iron-nickel-chromium Alloys

Data of the iron-nickel-chromium system is given in Table IV which shows resistivities ranging from 11.8 and 12 microhms per cm³ for nickel and iron to 113 microhms per cm³, the latter being 66 times the resistivity of copper. The only alloys of this group which are not highly resistant to high temperature oxidation are those containing large amounts of iron and less than twenty per cent of chromium. All others resist oxidation to a high degree. Those alloys containing large amounts of nickel and twenty per cent or more of chromium are the most resistant to oxidation, and may be used at temperatures up to 1000 deg. C. Alloys containing up to and including thirty-seven per cent of chromium were made. This marks the limit of forgeability. All melts containing more than this amount of chromium broke in forging.

TABLE V

IRON-NICKEL-MANGANESE ALLOYS

COMPOSITION			Electrical Resistivity Microhms per cm^3.
Iron	Nickel	Manganese	
100	0	0	12.0
0	100	0	11.8
33	65	2	54.1
80	17	3	54.0
51	45	4	93.5
55	41	4	93.5
50	44	6	87.0
69	25	6	87.0
77	17	6	75.0
34	59	7	85.5
55	36	9	103.0
80	10	10	78.0
53	36	11	103.0
60	20	20	94.5

Iron-nickel-manganese Alloys

The iron-nickel-manganese alloys, as shown in Table V, have resistivities up to 103 microhms per cm^3. These alloys are readily oxidized at high temperatures and should not be used above red heat.

TABLE VI

IRON-NICKEL-CHROMIUM-MANGANESE ALLOYS

COMPOSITION				Electrical Resistivity Microhms per cm^3.
Iron	Nickel	Chromium	Manganese	
100	0	0	0	12.0
70	2	25	3	86.5
70	2	23	5	86.8
81	10	3	6	69.0
69	15	10	6	79.6
64	15	15	6	78.6
61	16	21	2	81.0
59	16	23	2	85.7
57	16	26	1	83.5
63	17	17	3	82.8
63	17	18	2	82.1
64	18	15	3	84.2
64	19	13	4	83.0
64	20	10	6	81.7
71	22	4	3	75.1
64	22	11	3	83.4
59	25	10	6	88.0
64	26	8	2	84.5
65	29	4	2	83.0
54	30	10	6	85.0
49	35	10	6	99.0
42	39	16	3	111.0
47	40	10	3	106.0
44	40	10	6	96.0
35	49	10	6	111.0
35	50	10	5	107.0
34	50	10	6	111.0
35	52	10	3	110.0
19	56	19	6	110.0
24	60	10	6	91.0
10	66	19	5	105.0
0	100	0	0	11.8

Iron-nickel-chromium-manganese Alloys

What has been said of the iron-nickel-chromium system applies equally well to the iron-nickel-chromium-manganese alloys. Those having a high nickel and chromium content are resistant to oxidation at high temperatures and may be safely used up to 1000 deg. C. Data on this system appear in Table VI.

PERMANENT MAGNETS

By F. C. Kelley

Research Laboratory, General Electric Company

Permanent magnets find some very useful applications in the electrical industry and as very few contributions to the literature are now found in the technical press this resume of the work of the principal investigators is both interesting and instructive. The effect of chemical composition, shape and dimensions, heat treatment and usage on the strength and permanence of magnets as determined by the different experimenters is reviewed in detail.—Editor.

The application of permanent magnets in the electrical industry is an important one, but the amount of work which has been given to this subject is comparatively small. The literature has been abstracted very well by Professor Silvanus P. Thompson in the Journal of the Institution of Electrical Engineers, Vol. 50, pp-80-142, and in the German by Dr. Ing. G. Eger, International Zeitschrift für Metalography. Messrs. C. F. Burgess and James Aston, of the University of Wisconsin, have done some very good work on this subject, which is reported in the Metallurgical and Chemical Engineering Journal, Vol. 8, pp-673-676, 1910.

The following is an outline of the literature on permanent magnets according to Professor S. P. Thompson:

1. Quality of Steel: Carbon Steels; Alloy Steels.
2. Shape and Dimensions: Short and long bars, curved shapes.
3. Heat Treatment: Normalizing, Quenching, Tempering.
4. Magnetizing: Methods; Appropriate intensity of field.
5. Maturing: By Ageing, by Mechanical Shock, by Reheating, by Partially Demagnetizing.
6. Conserving: Safeguards for Conservation.

Carbon Steels

By means of the hysteresis loop we are able to determine the two most important facts that we ought to know about steel for permanent magnets, namely, the remanent magnetism and coercive force; the height of the point where the curve cuts the vertical axis, and the breadth of the loop on either side of the zero point. The coercive force is the most important. The author quotes Professor J. O. Arnold as authority for the statement, that though the magnetic permeability of a specimen is inversely proportional to its carbon content, the amount of permanent magnetism retained is directly proportional to the carbon content. Arnold claims that the amount of hardenite, a sub-carbide of iron ($Fe_{24}C$), present determines the permanentness of a magnet. That is, the coercive force depends upon the carbon content, but not the remanence. He shows a curve by Dr. Carl Benedicks in which the coercive force is plotted against the carbon content. The coercive force increases between 0.5 per cent and 1 per cent and at 1.5 per cent carbon reaches a value of about $H_c = 50$.

Alloy Steels

Certain alloy steels containing other constituents beside carbon possess magnetic hardness and magnetic fixidity. Mushet's steel is an example of this class which remains hard when very hot;, and when forged it is self-hardening without having to be quenched. This steel contains 7 to 12 per cent of tungsten, besides having 1½ to 2 per cent of carbon. Other metals, such as Mo, Cr, Mn and V, are used to give hardness to magnet steel. Manganese steel containing 12 per cent Mn and 1¼ per cent C is very hard, but curiously is almost non-magnetizable. Allevard steel is a very good magnetic steel and contains 5½ per cent of W and about 0.59 per cent C.

Microscopic Examination

Probably no advance in recent times has had an importance comparable with that connected with the application of the microscope to the study of metallic structures.

As the result of microscopic researches steels are known to contain certain structural constituents known as ferrite, cementite, pearlite, martensite, hardenite, austenite, etc., which can be recognized under the microscope. The amount of each one of these may be controlled by the temperature at which the steel is annealed, quenched or tempered. Then by this microscopic examination of different carbon and alloy steels, we have learned the effect which each temperature treatment has upon the structure of the steel under examination. The hard constituent called hardenite, which may be a solid solution of carbon in iron, or possibly a subcarbide of iron is of the same percentage as pearlite, and is formed during any cooling that is so rapid that the particular pearlite structure has no time to form. This constituent appears to be the most important in magnets.

Diagrams of the equilibrium states of different carbon steels at temperatures varying from 500° to the melting point of pure iron have been made possible by the use of the microscope. From such diagrams it is possible to pick out the composition of the steel which is best suited for various uses.

Effect of Shape and Dimensions Upon Magnetic Properties

The shape and dimensions of a magnet have a great effect upon its retentivity, due to the fact that the poles of every magnet exercise a self-demagnetizing influence on the body of the magnet. The self-demagnetizing coefficient in the case of cylindrical bar-magnets depends on the ratio of the length to the diameter, and this ratio has a great effect upon the qualities of the magnet. The shorter the bar, the nearer together are its poles, and the greater the demagnetizing action.

The demagnetizing effect in case of slit rings has been shown by H. Lehmann & H. DuBois to be nearly proportional to width of the slit, or gap in the magnetic circuit. It would be exactly proportional if there were no magnetic leakage, and if the gap itself were small compared with the radius of the ring. If the ring is provided with large pole pieces and the gap is narrow, the demagnetizing coefficient may be greatly reduced. Professor Thomas Gray found that the amount of remanent magnetism increased regularly with the dimension-ratio, that is, the ratio of the length to the diameter of the bars. Mme. Curie has also found this to be the case.

A laminated magnet has been found to be no more powerful than a solid magnet of equal weight and length.

Heat Treatment of Magnetic Material

In the heat treatment of magnetic alloys it has been discovered that when any specimen has cooled down through the recalescence stage it is capable of being magnetized. Since the coercive force of magnets depend upon the way they are hardened, it is essential for magnets which are to have the greatest coercive force that they be quenched at a temperature above that at which they recalesce, and quenched quickly. This has been shown by Mme. Curie, who magnetized an annealed bar and tested it. Then it was heated just below the point of recalescence, quenched in water, magnetized and tested. Next it was heated above the point of recalescence, quenched in water, magnetized and tested. The magnet improved each time it was tested, but the improvement was greatest in the latter case.

Magnetic material which has had previous working should be annealed slowly, and then quenched just a little above the point of recalescence. Mme. Curie tried experiments on the effect of quenching carbon steels of 0.06–1.20 per cent C and found that 770°C. was the best temperature for quenching. If quenched at 975°C. the remanence and coercive force both fell in value. She also found that the best magnet material, after hardening, if it be reheated to 905°, degenerated. By quenching first a little above and then a little below the point of recalescence, and going through this cycle several times, she found that the material could be improved and that the material which had become poor by over-heating could be repaired.

Barus and Strouhal tried some experiments on the effect of annealing on the magnetic qualities of permanent magnet steel, and found that annealing at a temperature which gave a blue tint produced the best results. They also found that for short bars a glass hard state, produced by heating to a bright red, and quenching in cold water, gave the best results.

Mme. Curie has investigated also the effect of heat treatment on the alloy steels. Her two best carbon steels containing 0.84 and 1.2 per cent C are as good as can be found for any carbon steel, giving a remanence of 670 and 645, and a coercive force of 58 and 53 respectively. They were made in the form of rings. She found that Allevard steel (5.5 per cent W and 0.59 per cent C) not quenched, gave a remanence of 900 and coercive forc of 26, but when quenched at 770°C. it gave a remanence of 850, and a coercive force of 26. Another tungsten steel ring (2.7 per cent W and 0.76 C) gave a remanence of 800, and 69 as the coercive force. A bar of the same material 20 diameters long gave 500 and 68 as corresponding values. Styrian steel containing 7.7 per cent W and 1.96 per cent C quenched at 800°C. gave corresponding values 370 and 85. This is considered a very good steel for short magnets. She also obtained very good magnet steels with the respective compositions $3\frac{1}{2}$ and 4 per cent Mo, 1.25 and 1.72 per cent C.

The statement is made that the tungsten steels which have proved best for magnets fall in two groups: (1) Those containing 5 to 7 or 8 per cent W with about 0.5 per cent C, and (2) Those containing 2½ to 3½ per cent W with 1 per cent C.

Professor W. Brown examined chromium steels containing from 0.75 to 9.5 per cent of chromium. They have high coercive forces; but there seems to be little advantage in adding more than 2½ or 3 per cent Cr.

Campbell and Pierce have both shown that cast iron would make good magnets. Campbell, by quenching at 1000°, found values of remanence from 200 to 229, and coercive forces from 48.9 to 52.8.

Methods of Magnetizing

The method of magnetizing bar magnets is to put them inside a long magnetizing coil about twice as long as themselves. Short bar magnets may be put between the poles of an electromagnet, as may horse-shoe magnets. The field to which they are subjected should not be less than $H=250$. Little depends upon the duration of the operation. There is a slight advantage in repeating the magnetization a few times by turning on and off the current. A slight advantage is gained by mechanical agitation while magnetizing and by not turning off the current too suddenly.

Ageing

Permanent magnets age with time, or lose part of their magnetism. Professor Thompson says that the most harmful thing that can happen to a permenent magnet is to slam on the keeper. Causes for the decay of magnetism of magnets are mechanical shock, changes of temperature, contact with magnets or iron, and exposure to demagnetizing forces. The lapse of time also apparently effects a deterioration. But in all magnets there seems to be a limit to this decay. The magnetism of a newly made magnet seems to be made up of two parts, a removable or sub-permanent magnetism, which slowly decays, and a really permanent part. Mechanical shocks and change of temperature help to get rid of the removable part. The time taken to get down to constancy varies with the quality of the steel and the dimension ratio.

Methods of Maturing

Permanent magnets are matured by repeated gentle heating and cooling, protracted gentle heating, repeated subjection to mechanical shock, and partial demagnetization.

Barns and Strouhal found that by heating a glass-hard magnet in steam for 60 hours, then remagnetizing, and steaming again, its remanence was reduced to a constant value. After this treatment it was dropped from a height of 1.5 to 0.5 meter on a wooden block and it did not change over 0.54 per cent.

Mme. Curie found that heating magnets in steam caused a reduction of both coercive force and remanence, and that reheating to 200°C. was disastrous, for about 50 per cent of the original total magnetism was lost.

W. Brown found that glass-hard magnets resist shocks much better than others, and that those of higher dimension ratio were superior to those of a lower ratio. He also found that by prolonged reheating at 60° a constant state was reached with a reduction of from 1 to 3 per cent in best steels.

Mme. Curie found that an Allevard bar was rendered constant by shocks after it had been reduced 6 per cent, while carbon steel 0.5 per cent had to be reduced 40 per cent before it was constant.

Klemencic investigated the influence of allowing time to elapse between hardening and magnetizing. He found that the regular fall in their strengths was practically independent of the time when they were magnetized, and depended only on the time that had elapsed sinced they were hardened. This proves that there is sort of a self-annealing going on in the newly hardened steel, and that the molecular settling down of the material is scarcely influenced by the process of magnetizing. This settling down is hastened by boiling at 100°.

Krüse found that materials having the greatest coercive force had the least percentage loss from shock. He also found that drawing a magnet over the face of an iron plate had a reduction effect of 20 per cent.

Safeguards of Conservation

It is essential if a magnet is to retain its magnetism, that the keeper is not slammed on. A magnet should not be drawn over the surfaces of iron or steel and should not be subjected to the demagnetizing influence of other magnets. Care should be taken that a magnet is not subjected to constantly changing temperatures.

Summary of Literature According to Professor Thompson

These results may be summed up as follows: To produce permanent magnets which are both constant and powerful, a tungsten steel should be used, having from 5 to 8 per cent of tungsten and from 0.4 to 6 per cent carbon. Chromium up to 2 or 2.5 per cent may be present, but the presence of manganese, titanium, copper, sulphur, and phosphorus should be avoided. For bar magnets the dimension ratio should be as large as possible. For horse-shoe magnets the gap between the poles should be short as possible, and the polar areas as large as possible.

The forging of magnet material should be done with as little working of the material as possible, and with as low a temperature as possible. After forging it should be normalized by raising to 900°C. lowered to 750° for a time, and then cooled off. To harden the magnets, they should be heated to 950°C. for 5 minutes only, then lowered to 700°, and quenched in brine or oil at 20°C. Some tungsten steels are better if quenched between 770 and 850°C.

There is no advantage in tempering tungsten steel. Magnets of carbon steel of 20 diameters may be tempered to a straw tint, and those of 40 diameters to a blue tint. Any letting down below a straw tint impairs their power to resist decay and usage.

Magnets should be matured by boiling or steaming for 10-12 hrs. or by heating them to 60°C. for 20 or more hours. There is some advantage in letting them cool several times during the process.

The magnet should be magnetized by an electromagnet, or, if a bar magnet, by a magnetizing coil, using the highest degree of magnetization possible. There is some advantage in reversing the magnetism a few times, but in the final magnetization the current should be turned off slowly to zero. There is an advantage in giving them a slight mechanical shock. Some magnets which are to have extreme constancy are subjected to demagnetizing forces.

WORK OF BURGESS AND ASHTON

Method of Testing

C. F. Burgess and James Ashton in their article published in Metallurgical and Chemical Engineering, Vol. 8, p-673-676, 1910, describe their method of testing as follows: They used an Easterline permeameter for their work. The bar was inserted in the permeameter, the magnetizing force H was raised to the maximum 200, and the density B (max.) was recorded. H was decreased to zero, and the retentivity B (Ret.) noted. Next the coercive force H_c necessary to reduce the retentivity to zero was determined. Similar readings were taken for the reverse magnetizing forces, and the average of these positive and negative readings B (max.), B (Ret.) and H_c for each bar was recorded for comparison.

Heat Treatment

All of their samples were heated in a $BaCl_2$ bath to 1000°C. and quenched. The authors recognize that 1000°C. might not have been the best temperature at which to quench, but on account of the impossibility of obtaining the critical points for so many samples in the time allowed they quenched all at 1000°C.

Methods of Maturing

Samples which showed a great retentivity and a coercive force of 30 were tested for stability. The bar was subjected to a maximum magnetizing force of $H_c=200$ and the retentivity noted when the magnetizing force was reduced to zero. The bar was then rapped, jarred or boiled. When boiled, the sample was enclosed in an iron pipe to shield it from magnetic fields, and the boiling was kept up for three hours. The authors claim but one vigorous rapping is necessary. The samples were tested as forged, and after quenching.

Alloy Steels Tested

Chromium up to 16.65 per cent did not give high coercive forces, and these samples of high percent Cr were no better than those of low percent Cr. This agrees with the findings of Prof. Brown previously recorded. The best alloys had a Cr content of 5 or 6 per cent, plus .75—1 per cent Si or 0.3 per cent to 0.5 per cent of carbon. Cr in pure iron does not make a good magnet material. Vanadium increased the hardness.

Manganese with pure iron does not make a good magnetic material, because the retentivity is too low.

Molybdenum alloys with vanadium added showed no such hardness as in the case of Cr. Only one alloy showed up well in the forged condition, 8 Mo, .3 V, .6 C. It had a retentivity of 9200 and a coercive force of 39.

In the binary alloys of Ni-Fe, an increase of Ni causes a decrease of retentivity and increase of coercive force. An alloy of 26 per cent Ni-Fe is non-magnetic. Alloys of higher per cent Ni are magnetic. Vanadium increased the magnetic hardness. Ni alloys are not regarded as a good magnetic material.

Binary alloys of W-Fe are not good for permanent magnets. The addition of vanadium may be beneficial, and the addition of carbon certainly is. The author's mention that all of the satisfactory alloys of this series except one contain carbon.

Summary

In summarizing, the authors say that Cr, Mn, Mo, and W are important additions in the manufacture of steels for permanent magnets, but that the presence of a third element is necessary. While carbon is beneficial, highly satisfactory results are to be obtained with Si and vanadium, especially vanadium.

The following tables represent the best alloys obtained for permanent magnets. The first table represents results obtained before rapping or ageing; the second after rapping.

Some very good results were given in Professor Thompson's article on Remy steel, but I have not been able to find the composition of it.

WORK OF J. A. MATTHEWS

Mr. J. A. Mathews of the Halcomb Steel Company presented a paper at the annual meeting (1914) of the American Society for Testing Materials, which brings out some very interesting points. The paper appears in the Proceedings of the American Society for Testing Materials Vol. 15, 1914, pp-50-66.

New Factor to Judge Magnetic Quality

He devotes one section of his paper to the definition of the different magnetic units, and proposed a new unit to represent the factor Br/H_c which he uses to judge the magnetic quality of steels. He goes on to state that the coercive force alone is not a sufficient measure of permanence and that just as we use μ to denote permeability, in other words, the average number of lines of induced magnetism for each unit of magnetizing, H, so the factor Br/H_c indicates the average number of lines of residual induction removed

Bar	Composition	B (Ret)	H_c
TABLE I			
.WIC	(6 W+C)	13,450	30. as forged
156 E	8 Mo, 0.3 V, 0.6 C.	11,750	53.7 quenched
155 X	5 W, 0.5 C	11,700	59. quenched
136 M	5 Cr, 3 Mn, 4 Mo, 1 Si	11,350	55.8 as forged
160 P	4 W, 0.4 V	11,300	43.8 quenched
163 J	4 W, 0.4 V, 0.5 C	11,050	38.0 forged
155 P	1 Mn, 10 Mo, 0.5 C	10,750	58.4 quenched
155 K	10 Cr, 2 Si, 0.3 V, 0.6 C	10,700	32.9 as forged
163 P	4 W, 0.4 V, 0.6 C	10,650	35.5 as forged
150 C	2 Cr, 10 Mo, 0.5 C, 0.3 V	10,500	78. quenched
156 A	1 Mn, 2 Mo.	10,500	39.6 quenched
163 E	7 W, 0.3 V. 0.6 C	10,450	39.4 as forged
160 E	4 Mo. 0.6 V	10,400	35.0 quenched
160 C	10 Mo, 0.3 V, 0.4 C	10,350	59.8 quenched
155 Y	10 Ni, 5 W	10,300	35.2 quenched
136 V	10 Ni, 5 Mo.	10,150	36.7 as forged
141 F	10 Mo, 1.2 C	10,000	37.4 quenched
TABLE II			
150 C	2 Cr, 10 Mo, 0.3 V, 0.5 C	6,300	77.2 quenched
163 E	7 W, 0.3 V, 0.6 C	5,600	81.0 quenched
156 C	2 Mn, 5 Mo, 0.6 C	5,500	57.2 as forged
155 P	1 Mn, 10 Mo, 0.5 C	5,400	57.5 quenched
136 M	5 Cr, 3 Mn, 4 Mo, 1 Si	5,300	64.7 as forged
155 X	5 W, 0.5 C	5,200	52.5 quenched
133 K	6 Cr, 0.84 Si	5,200	52.3 quenched
150 D	2 Cr, 16 W, 5 Mo, 0.3 V, 0.5 C	5,000	63.5 quenched
163 H	10 Mo, 1 V, 0.4 C	5,000	53.5 quenched
156 E	8 Mo, 0.3 V, 0.6 C	5,000	52.2 quenched

by one demagnetizing unit of coersive H. The smaller the numerical value of this quotient, the greater the absolute permanence of the residual magnetism. The ratio of Br H_c becomes almost constant above $H = 200$ and therefore permits of comparing tests made at different values of H. The instrument used for testing was the Esterline permeameter.

Influence of Carbon upon Magnetic and Physical Hardness

In trying to establish a relationship between physical and magnetic hardness, it was discovered that for some heat treatments of an ascending carbon series when Hc was plotted against the Brinell number a straight line relationship was found showing the influence of carbon on both properties. In other conditions of heat treatment no semblance of a curve could be plotted.

Effect of Size upon Magnetic Properties

The work which was done to prove the effect of size upon magnetic properties is very interesting. Two different heat treatments were given steel of the following composition: C, 0.65 per cent; W, 5.22 per cent; Mn, 0.33 per cent. The material for these experiments was rolled down from the same ingot, the diameter of the magnets was varied, and the length was kept in the same proportion to the diameter. By quenching in cold water from 900°C. (1650°C) the induction B, and residual induction Br, increased as the size decreased, while Br/H_c showed the largest section to be most permanent. This is contrary to the experience in making horseshoe magnets, but it must be recalled that ordinarily for any given purpose, only the cross-section in them is changed, while the length and air-gap remain constant. Hence the rule applying to bar magnets applies to some extent to them, and as the ratio of section to length increases, the demagnetizing effect of poles increases, and a weaker finished magnet results from the use of large sections.

Effect of Quenching upon Magnets of Different Sizes

By quenching in lard oil from 875°C. (1600°F) the opposite result was found, namely, the smallest section gave the best test, and in only the very smallest bars was the rate of quenching in oil fast enough to develop high permanence. These differences are explained by reactions in quenching.

These results may be contrasted with experiments of another steel of the following composition. C, 0.61 per cent; Si, 0.54 per cent; Mn, 0.82 per cent; Cr, 0.80 per cent. In these experiments the large samples, when quenched both in water and in oil, showed the best test for permanence. Judging either by the coercive force, Hc, or by Br/Hc, the larger section is best for permanence.

Facts Contrary to the General Idea about Magnets

The general idea about permanent magnet material is that the harder it can be made the greater its permanence. Comparative tests on materials quenched in water or brine would be expected to show that the harder the piece, the less permeable, the lower its residual induction, and the higher its coercive force, but it is only true with certain steels under restricted conditions.

It is well known that the hardening capacity of steel decreases as its mass increases, yet it has been pointed out previously that the larger mass, and hence the softer piece, is magnetically most permanent.

It is well known, too, that the rate of cooling in oil is slower than water, and does not give as great hardness. Yet previously referred to experiments on steel, which was quenched both in water and in oil, show the relatively soft oil-hardened pieces when compared with the water-hardened pieces of the same size to have lower induction, lower residual and higher coercive force than the much harder water-quenched pieces, and the factor Br/Hc shows superior permanence of the oil quenched steel very clearly.

Hardening of Magnet Steel in Oil and Water

Experiments on the hardening of magnet steel in oil and water (cold and boiling) are very interesting.

The table of results is given below:

Charge No.	Sclerescope Number	Brinell Number	B	Br	Hc	Br/Hc
1	73.5	594	16700	11415	44.66	256.0
2	63.0	534	14330	9040	52.40	172.5
3	70.0	548	15500	10285	50.00	205.7

Analysis, C, 0.50%; Si, 0.51%; Mn, 0.79%; Cr, 0.73%.

Treatment

1. Average quenching temperature of six bars, 815°C. (1500°F) in cold water.
2. Average quenching temperature of six bars, 843°C. (1550°F) in oil.
3. Average quenching temperature of two bars, 843°C. (1550°F) in boiling water.

The above results were verified in three separate series of tests on variable carbon ingots of the same type of steel, whose analysis is given above.

In the above table it will be noticed that No. 3 in all its properties lies between Nos. 1 and 2. This is not a peculiarity of this particular type of steel. It seems to be generally true of the great class of structural alloy steels, such as are covered in automobile-steel specifications. It holds good for chrome-nickel 3.5 per cent of Ni, and nickel-vanadium steels of various carbon contact. It does not hold good for two types of steel most used for permanent magnets, namely, common open-hearth magnet, of the type represented by C, 0.60 per cent; Mn, 0.75 per cent; 1.00 per cent; and high grade tungsten magnet steel of the type, C. 0.60 per cent and W, 5.00 per cent.

Effects of Drawing the Temper upon Magnetic and Physical Properties

Drawing temper of steel has a very marked effect on the magnetic properties. Hardness may be relieved by drawing the temper, but this gives results directly contrary to those due to retarded quenching rates. That is, the maximum induction and residual magnetism are increased, and the coercive force lowered. This is true whether the steel owes its original hardness to oil or water hardening, and it is also true that the effect of tempering is more marked on oil-hardened than on water-hardened pieces. That is, the augmented permanence in these alloy steels, due to oil hardening, is unstable, and this fact limits the possible commercial application of oil-hardening of magnets in manufacture.

Boiling in water has only a slight effect upon the magnetic tests, while drawing the temper at 205°C. (400°F), seriously impairs the magnetic permanence. This is true of both the structural alloys and the commercial magnet alloys. At a drawing temperature of 315°C. (600°F) the difference between oil and water-tempering is wholly wiped out, and nearly identical tests result. Experiments on drawing to 315°C. softened the oil-hardened pieces physically to a less degree than the water-hardened piece. On the contrary, the greatest magnetic changes are in oil-hardened steels.

While drawing to 315°C. lowered the Brinell hardness 101 points in the water-hardened pieces, it lowered the oil-hardened pieces but 36 points; on the other hand, the change in B, Br and Hc is much greater in oil-hardened bars than in water-hardened ones, yet the total change brought both physical and magnetic properties approximately to a level, and wiped out the marked differences in the original properties due to oil and water-hardening.

Summary

Mr. Mathews has shown results which seem to be out of the ordinary in that they are many times just the opposite of what one would expect. The fact that at present we are not able to explain these results shows the need of further investigation in this field. There is need of more information in order that we may have a better conception of the relationship between physical properties and magnetic properties, and that we may discover the laws governing these properties.

An extended bibliography of this subject, is given by Prof. Silvanus P. Thompson, in his paper referred to at the beginning of this article.

THE SPRING LAKE MARINE RAILWAY

By Jacob A. Harman

Chief Engineer, Elliott & Harman Engineering Co., Peoria, Ill.

Electricity operates the Spring Lake Marine Railway which is a mechanism designed and constructed to serve the same purpose as a marine lock, but to cost less and to be maintained at a lower expenditure. Mr. Harman gives the reasons as to why the Marine Railway came to be built, fixes its location, and then proceeds into a very interesting and full description of its construction, it equipment, and its operation.—Editor.

The Spring Lake Marine Railway, located in the Illinois River valley about 30 miles below Peoria, Illinois, has finally become a reality after several years of discussion, litigation, and negotiations. It was built by the Spring Lake Drainage and Levee District, organized under the Laws of Illinois for the purpose of reclaiming about 14,000 acres of land that was subject to overflow by the Illinois River. The District, as organized, included a body of water known as "Spring Lake," which was shut off from communication with the Illinois River by the levee constructed by the Drainage District. The Attorney General of Illinois took the position that Spring Lake is a navigable body of water and as such should not be closed to the public. Extended litigation and negotiations resulted in an agreement and a Decree of the Court providing that the Drainage District should construct and forever maintain for the use of the public certain levees and other works which hold the water at a fixed level within the lake, and the marine railway herein described for the purpose of transferring across the levee the boats and barges that navigate the Illinois River.

It was at first contemplated that a lock should be constructed for the purpose of communication between the river and the lake, but the cost of the construction and maintenance thereof would have been so burdensome upon the Drainage District that the matter was referred to the Rivers and Lakes Commission of Illinois, and approval was obtained for the construction of the marine railway as being adequate to serve the needs of the public for navigation. This marine railway has now been constructed, and a satisfactory test was conducted by the Engineers of the Drainage District in the presence of the Rivers and Lakes Commission in October, 1916. The electric power for operating the mechanism is supplied from the power plant of the Canton Gas & Electric Company at Canton, Illinois. The transmission line, about 20 miles long, is a 13,000-volt line, and also supplies electric current for the Banner and the Spring Lake Drainage Districts pumping plants. The Spring Lake Marine Railway, the Spring Lake Pumping Plant and the Banner Pumping Plant were designed by and constructed under the supervision of the Elliott & Harmon Engineering Co., Consulting Engineers of Peoria, Illinois, who also conducted the negotiations leading to the change in plan from the concrete lock to the marine railway.

In general, the marine railway consists of an incline track leading up each slope of the levee to a turn-table located on the summit of the levee. A cradle, or boat carriage, is mounted on wheels so that it can be lowered on these inclines into the water to receive the boats, raised to the turn-table, rotated thereon, and lowered to the water again on the opposite side of the levee, keeping the boat in its natural position throughout all of this operation. An electric hoisting engine for hoisting and lowering the boat carriage, and an electric swinging engine for rotating the turn-table are housed in a reinforced concrete building alongside the turn-table.

The marine railway mechanism is designed on the basis of handling as a maximum load a flat-bottom barge, or power boat, 24 feet wide, 120 feet long and having a draft of 3 feet 6 inches; the cradle, however, as designed is sufficiently wide to accommodate shorter boats of a maximum width of 28 feet. Smaller boats, barges, and launches can also be handled. Each incline consists of two standard gauge railroad tracks, laid parallel and spaced 50 feet center to center, the gradient of the tracts being 10 per cent. These tracks extend from the turn-table down into the water on each side of the levee to a depth sufficient to have 4 feet of water over the floor beams of the boat carriage at the low-water stage. The rails used for all tracks are 120-pound standard T-rail sections and are laid on creosoted ties 6 in. by 8 in. by 10 ft. 0 in., spaced 16 in. on centers.

These ties are firmly compacted in place in a bed of sand, at least 12 inches deep below the bottom of the ties in all places. The turn-table at the summit of the levee is in effect an extension of one of the inclines and is mounted on a steel structure provided with wheels on which the structure may be rotated about a fixed pivot on circular tracks. The circular rails on which the turn-table moves are mounted in a concrete pit, 115 feet in diameter, upon a heavily reinforced concrete foundation of the slab type.

The cradle, or boat carriage, is a fabricated steel structure mounted on wheels. The main structural members consist of two trusses on each side of the cradle connected by a system of fixed floor beams. The trusses are 80 feet long and 10 feet high with a clear opening between them of 30 feet. The fixed floor beams are arranged in pairs, and between each pair is mounted a heavy movable beam which can be adjusted to fit up snugly against the bottom of the barge or boat in its natural position. These movable floor beams are hung on heavy threaded rods which extend upward through the upper chord of the truss, at which point the rod is suspended from the top of the truss by means of a split nut with four handles resting on a short coil spring. There is also provided a winch adjustment for each of these rods for raising the beams rapidly to position, after which the split nut is closed and the beam is brought up close by the use

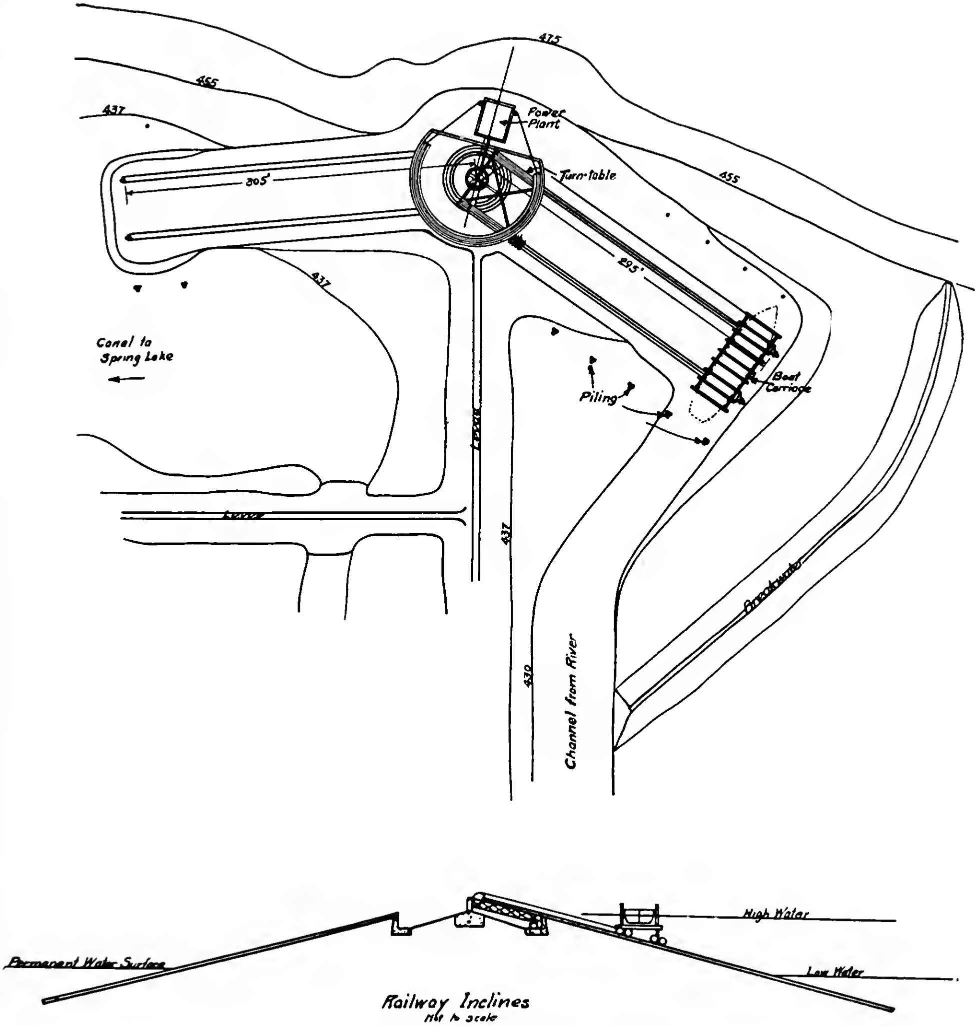

Fig. 1. Map and Elevation showing Layout of Marine Railway

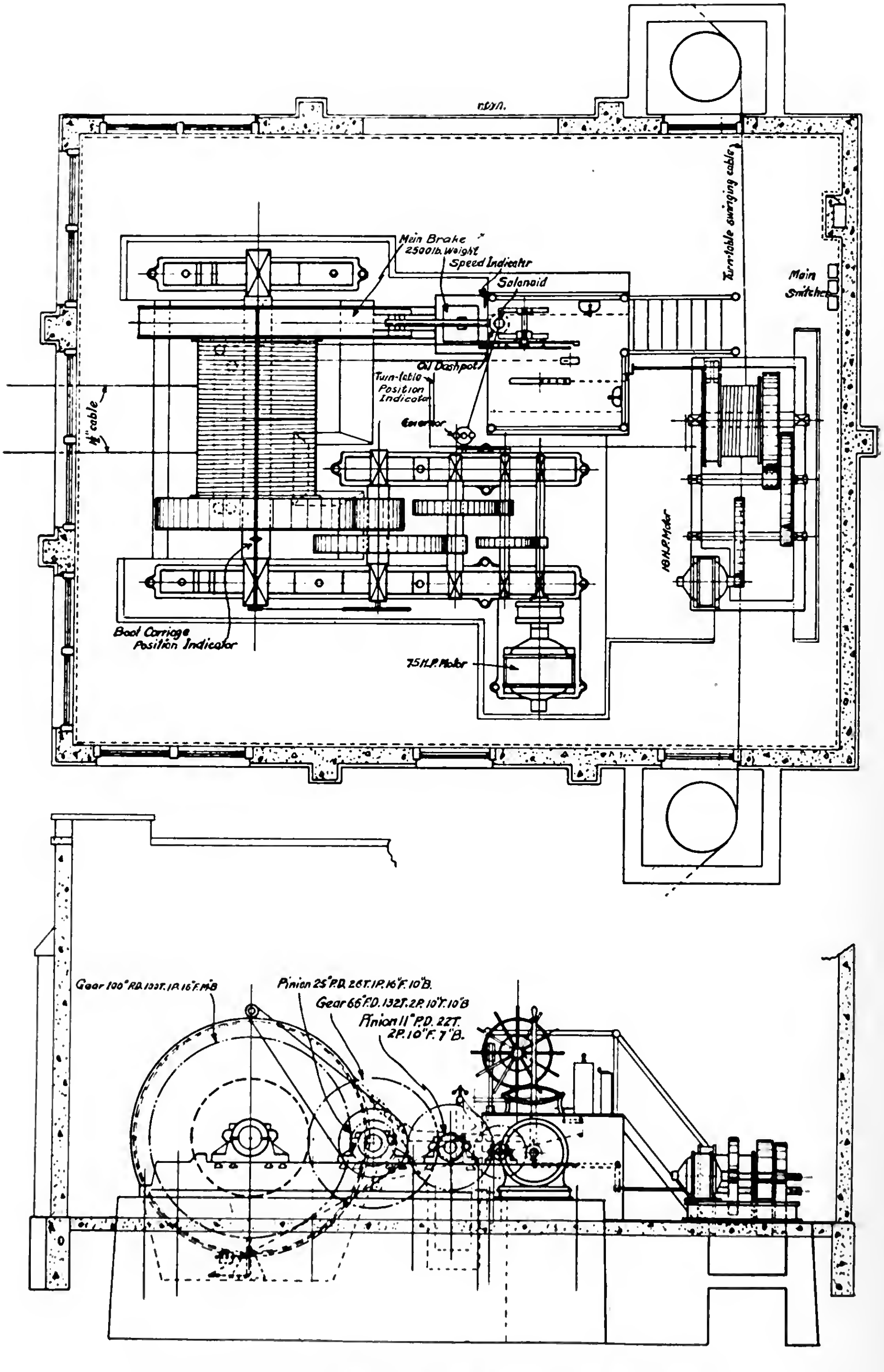

Fig. 2. Equipment for Hauling Boat Carriage and Operating Turntable

Fig. 3. Boat Carriage in Canal Leading to Spring Lake

Fig. 4. Boat Carriage in Water at River end of Marine Railway

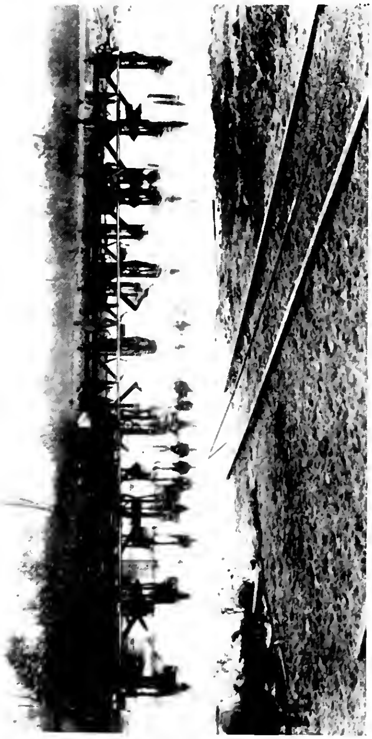

Fig. 5. Boat Carriage in Water at River end of Marine Railway

Fig. 6. Boat Carriage going up the Incline on the River Side of the Levee

Fig. 7. Turntable, Spring Lake Marine Railway

Fig. 8. Boat Carriage on Turntable at Top of Levee

Fig. 9. Turning the Boat Carriage Around on the Turntable

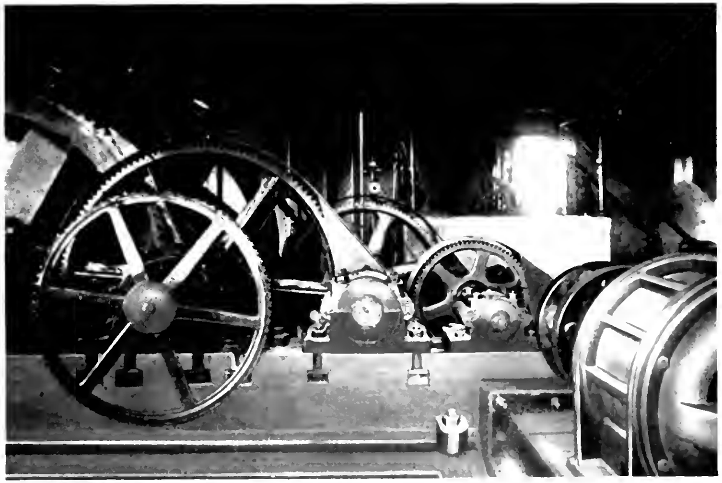

Fig. 10. A 75-h p., 440-volt, 3-phase, 60-cycle, 600-r.p.m., slip-ring type Induction Motor driving a hoist having a maximum cable pull of 100,000 pounds and a cable travel of 16 ft. per minute; and a 18-h.p., 440-volt, 3-phase, 60-cycle, 600-r.p.m., slip-ring type Induction Motor driving swinging cable drum, cable pull 10,000 pounds.
Spring Lake Marine Railway

of the nut. In order to facilitate the raising of these beams, they are constructed in the form of a box girder closed at the ends and are made water-tight so that they have considerable buoyancy when under water. Counterweights are also provided on the winches, so that the weight of these movable floor beams is so nearly counter-balanced as to require a very slight lifting effort to bring the beams to their proper position. This boat carriage is supported on two specially constructed 8-wheel trucks of a heavy type, the mounting being arranged so that the floor of the boat carriage is always in a horizontal position. Each of these trucks is provided with special draw bars to which are attached the steel haulage cables used for raising and lowering the boat carriage on the inclines. Each truck is also provided with a system of brakes which may be set by hand and which are so constructed as to be set automatically by a coil spring whenever the tension of the haulage cables is released.

The power and hoist equipment consists of two electrically driven hoisting drums, one for raising and lowering the boat carriage on the inclines and the other for rotating the turn-table. The main hoist drum is 60 inches in diameter, carrying two 1½-inch steel cables each having a maximum working load capacity of 50,000 pounds. From the drum these cables pass to the center of the turn-table and then separate, running over a system of 60-inch sheaves, leaving the turn-table on the center lines of the two incline tracks, and connecting to the two draw bars of the boat carriage. Means at this point is provided for adjusting and equalizing the tension in the two cables. This main hoist drum is driven through a train of spur gears by a 75-h.p. (intermittent rating), 600-r.p.m., 440-volt, 3-phase, 60-cycle, slip-ring type induction motor with a reversible drum type controller mounted on the operating platform. The gear ratios are such that the main haulage drum makes approximately one revolution per minute, and the traveling speed of the main haulage cables is approximately 16 feet per minute. All of the shaft bearings are mounted on heavy cast-iron sole plates of the box type, grouted in and securely fastened to a massive concrete foundation by heavy foundation bolts. The drum is of heavy cast-iron construction, with the main driving gear at one end and the main brake spider at the other. The brake drum is 10 feet in diameter with a 14½-inch face. This brake is applied by means of a system of heavy weights and levers, and is released by raising the weights with a drum and wheel hoist mounted on the operating platform. A pawl and ratchet device on this hoist keeps the brake mechanism in the released position after the weights have been lifted by the hoist. This pawl and ratchet device may be released, thus applying the brake on the main drum by four independent agencies: (1) by means of a foot trip, mounted on the operating platform; (2) by means of a ratchet device, which engages the teeth of the large gear when the cable starts to unwind, thus automatically setting the brake; (3) by a centrifugal governor, which automatically sets the brakes should the speed of the boat carriage exceed the predetermined speed of 16 feet per minute; and (4) by an electric solenoid device, which automatically sets the brake in case the supply of electric current should be interrupted. Device No. 2, which automatically sets the brake when the cable starts to unwind, is made inoperative when lowering the boat carriage by means of a foot pedal on the operating platform. Device No. 3, the centrifugal governor, is also provided with a speed indicator mounted in front of the hoist operator, showing when dangerous speeds are approached. In order to prevent the brake being applied too suddenly when the weight is released, an oil dash-pot is provided to regulate the speed of application.

The turn-table swinging engine consists of a 36-inch drum driven by an 18-h.p. (intermittent rating), 600-r.p.m., 440-volt, 3-phase, 60-cycle, slip-ring type induction motor with a reversible drum type controller mounted on the operating platform. The brake on this engine is operated by a hand lever mounted on the operating platform, and the traveling speed of the cable, which is hitched to the outer trucks of the turn-table, is 20 feet per minute.

The complete list of the safety devices follows:

1. An automatic brake on the boat carriage trucks, which is applied by a heavy coil spring whenever the tension on the main haulage cables is released, whether by design or by accident.
2. An automatic device for setting the brake on the main hoisting drum when the cable starts to unwind, whether by design or by accident.
3. An automatic device for setting the brake on the main hoisting drum when the speed on the boat carriage, either coming up or going down the incline, shall exceed 16 feet per minute.

4. An automatic device for setting the brake on the main hoisting drum in case the power should fail, due to an interruption of the supply of electric current.

In addition to these safety devices, there are three special indicators to aid in the operation of the apparatus.

1. A speed indicator, heretofore mentioned in connection with the centrifugal governor.
2. A circular indicator, 4 feet in diameter, mounted in front of the operating platform indicating at all times the position of the turntable relative to the inclined tracks.
3. A horizontal indicator, 12 feet long, mounted just above the main drum in front of the operating platform, which indicates continuously the position of the boat carriage on the inclines.

The operating platform is lifted above the floor level so that it is possible to see, through the windows of the building, the general position of the boat carriage and turntable most of the time, but the view is at times somewhat obscured and the indicating devices are of great assistance in operating the mechanism.

In conclusion, the following data concerning the marine railway will be of interest:

Maximum Lift of Railway.......... 27 feet Vertical.

Estimated Maximum Weight of Boat Carriage and Boat............ 800,000 pounds.

Largest Boat that it is Calculated to Carry.... Length 120 feet, width 24 feet, draught 3½ feet.

Distance Between Centers of Incline Tracks.. ...... 50 feet.

Slope of Tracks........One foot in ten.

Estimated Maximum Pull on Haulage Cables.. ...... 100,000 pounds.

Speed of Boat Carriage........16 feet per minute

DISCHARGE ALARMS FOR LIGHTNING ARRESTERS

By C. E. Green

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Closely allied with the following article is another, entitled "The Development of the Coherer and Some Theories of Coherer Action," by the same author, General Electric Review, May, 1917. In the earlier article appeared a complete description of the development, construction and characteristics of the coherer which is the "brains" of the coherer type of alarm devices. Both the coherer type and the spark-tube type of discharge alarms and discharge recorders and described in great detail below, as are also the coherer high-frequency alarm and the high-frequency recorder.—Editor.

For some time there has been a constantly growing demand for some device that will give reliable information as to the behavior of lightning arresters.

Various kinds of discharge recording devices have been tried out but none of them met with a very great degree of success. In many cases the records were very hard to read, and even where clearly legible there was the lack of a warning signal given simultaneously with the discharges.

An ideal discharge recording device should keep an accurate record of the number of discharges over the arrester gaps and at the same time give some kind of a signal at a place where it can be observed by the station attendant or operator. Two pieces of apparatus fulfilling the above requirements have been developed. One is known as the Coherer Discharge Alarm; the other as the Spark-Tube Discharge Alarm.

These discharge alarms are devices for giving an alarm, by sounding a gong, and making a permanent record, by operating a counter, every time a discharge occurs over the gaps, or any one gap, of the lightning arrester.

Coherer Discharge Alarm

The coherer discharge alarm consists of two parts, the coherer panel, shown in Fig. 1, and the counter-gong relay, shown in Fig. 2.

The coherer panel supports a coherer, a small relay in series with the coherer, and a solenoid for producing de-coherence; while, as the name indicates, the counter-gong relay consists of a counter, a gong, and a relay all in one piece of apparatus.

The operation of this alarm may be briefly described as follows: When a discharge occurs over any or all three phases of the lightning arrester gaps, Fig. 3, there is sufficient voltage impressed on the suspension insulators, which act as condensers, to spark over gap 1, pass through the coherer, and spark over gap 2 to ground. This causes the granules in the coherer, that were previously non-conducting, to act as good conductors, and allow current to flow from the four dry cells through 3, the relay coil, the coherer, and back through 4 to the other side of the dry cells. The relay armature is now pulled down, closing its contact. Current flows from the control circuit through 7, the relay contact, through 5, and the coil of the counter-gong relay, to the other side of the control circuit. This causes the counter-gong relay to operate and sound the gong, operate the counter, and close its contact. Current now flows from the control circuit through 7, the resistance, the de-coherer solenoid, and 6, across the contact on the counter-gong relay to the other side of the circuit. A strong magnetic field is now set up about the coherer, which lifts the magnetic granules away from the electrodes that are sealed into the bottom of the pant's legs of the coherer tube. This movement breaks the circuit from the dry cells through the relay, so that its armature is released, opening its contact and breaking the circuit through the counter-gong relay coil. Its armature now drops out, opening its contact, breaking the circuit through the de-coherer solenoid, and the granules drop back in a non-conducting condition. Nothing more happens until another discharge occurs, when this same operation is repeated. When the arrester discharges continuously, the discharge alarm operates at the rate of about three or four times a second. For a single discharge only one operation is made.

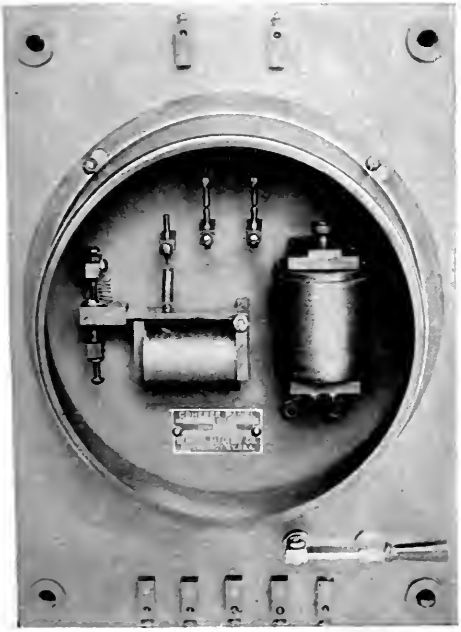

Fig. 1. Coherer Panel for Coherer Discharge Alarm

When this alarm is used with arresters that do not require charging, it may be connected as shown in Fig. 4 for line voltages as low as 11,000. This is permissible because the alarm is not called upon to operate at normal line voltage and normal frequency. However, this connection should not be made from the neutral of arresters which require charging, if the line voltage is below 30,000.

Fig. 2. Counter-Gong Relay for Coherer Discharge Alarm

The coherer discharge alarm can also be used to detect the presence of high frequency on a transmission line or bus, even through the voltage does not rise above normal. This is due to the fact that the critical voltage of a coherer is a function of frequency; an increase in frequency causing a great decrease in the voltage necessary to produce coherence.

When this device is so used, it is called a Coherer High-Frequency Alarm. All connections of the mechanism remain the same as in the discharge alarm, Fig. 5, with the exception that the spark gaps are short-circuited, the ground connection removed, and the voltage that produces coherence is secured by tapping off from the top and bottom of an insulator *B* which is at the bottom of a string of insulators *A* suspended from the transmission line or bus. At normal or even double voltage when the

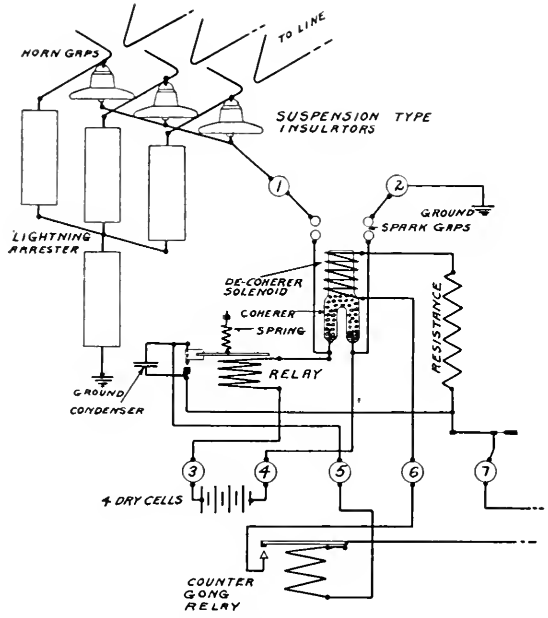

Fig. 3. Wiring Diagram for Coherer Discharge Alarm

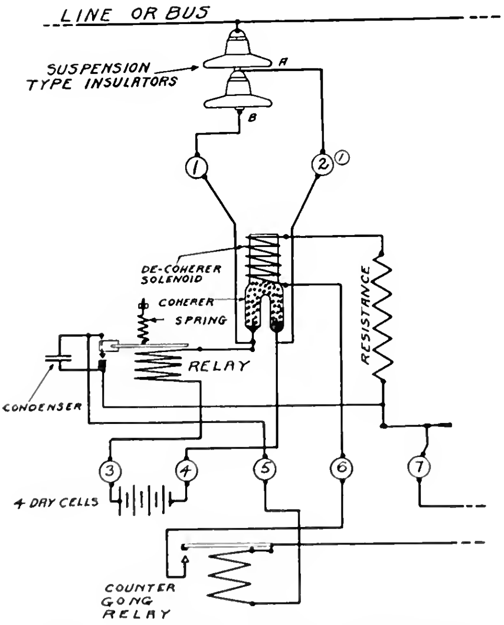

Fig. 4. Wiring Diagram for Coherer Discharge Alarm

frequency is normal the alarm does not operate; but when high frequency occurs even at reduced voltage an alarm will be given and a record made.

After coherence takes place, the operation of this device is the same as that previously described.

By using a coherer high-frequency alarm and a coherer discharge alarm on the same line, selective operation may be obtained. The former will operate only when high frequency is present, whether at increased or reduced line voltage, and the latter will operate only when surges are of a sufficient value to arc over a sphere gap or the gaps of the lightning arrester. For example, if transformers or generators break down while the high-frequency alarm is operating and the discharge alarm is not operating, it would indicate the trouble was due to high frequency at a voltage lower than that required to arc across the arrester gaps; while if both operated, it would indicate a high-frequency surge at a higher value of voltage than that for which the gaps were set; while if only the discharge alarm operated it would show the surge was not accompanied by high frequency and was merely high-voltage at a moderate or normal frequency.

These discharge alarms may be used on either alternating or direct-current control circuits.

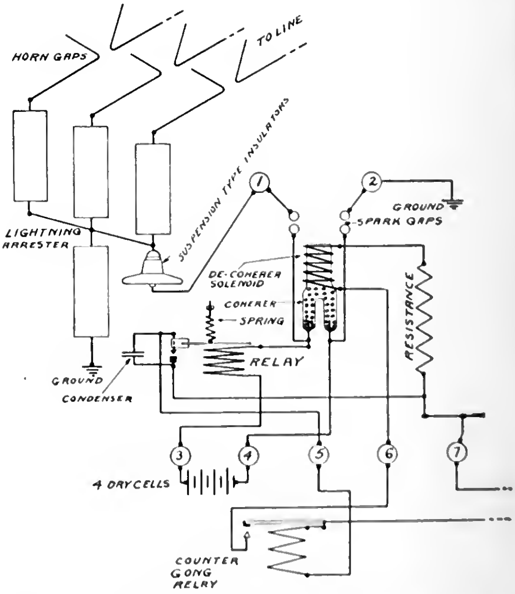

Fig. 5. Wiring Diagram for Coherer High-Frequency Alarm

When the devices are used in connection with the multi-recorder, the counter-gong relay is replaced by a coherer actuated relay which is mounted on the same panel with the coherer and connected as shown in Fig. 6. This relay has two auxiliary contacts and a common connection, or neutral, from which connections are made to the multi-recorder. A photograph of this panel is shown in Fig. 7. This apparatus is known as the coherer discharge recorder, and when used to detect high frequency as shown in Fig. 8 it is called a coherer high-frequency recorder.

Both these devices are for use only on direct-current control circuits, due to a necessary inherent time element that is required in the drop-out of the armature of the coherer actuated relay.

The operation of this coherer recorder is practically the same as that of the coherer alarm, the only difference being that the coherer actuated relay holds its armature in the closed position during the entire discharge, or high-frequency surge, letting it drop back to the open position when such a discharge, or surge, has ceased; while the counter-gong relay operates continuously. This continuous operation in connection with the multi-recorder is not desirable, because if a surge lasted for some time a great number of useless records would be made for the multi-recorder would print at the rate of about four operations a second. As designed, this device allows only two records to be made for a continuous surge regardless of its duration, one at the beginning, giving the day, hour, minute, and second, and the other at the end, giving a like record.

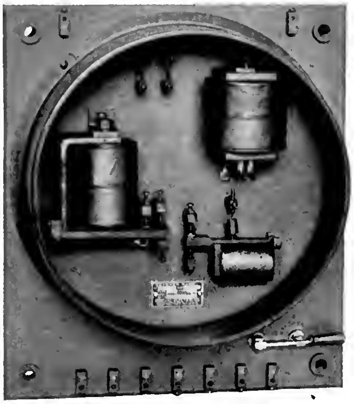

Fig. 7. Coherer Discharge Panel for use with the Multi-Recorder

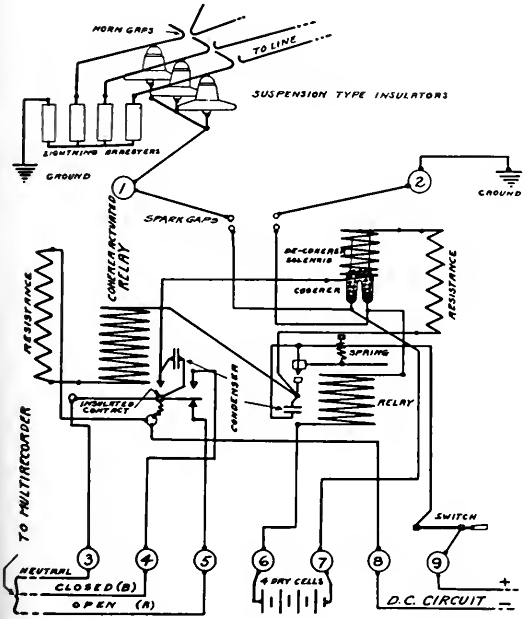

Fig. 6. Wiring Diagram for Coherer Discharge Recorder

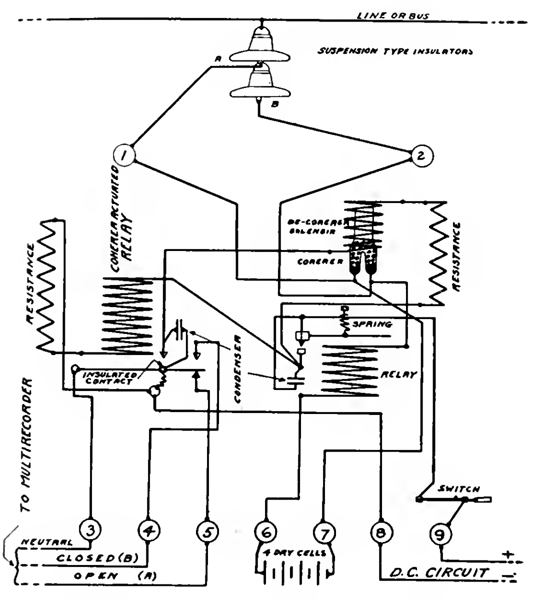

Fig. 8. Wiring Diagram for Coherer High-frequency Recorder

Spark-Tube Discharge Alarm

The spark-tube discharge alarm and spark-tube discharge recorder perform the same functions as already described for the coherer discharge alarm and recorder. While the coherer alarms may be used on any control voltage alternating-current or direct-current or even a 12-volt battery, the spark-tube alarms require a minimum of 225 volts direct current for their control and are not adaptable for alternating-current control.

Fig. 9. Spark Tube Panel for Spark-tube Discharge Alarm

The spark-tube discharge alarm consists of two parts: the spark-tube panel shown in Fig. 9, and the counter-gong relay shown in Fig. 10.

The operation of this apparatus is as follows: When a discharge occurs over any or all three phases of the arrester gaps, Fig. 11, there is voltage impressed on the top of the suspension insulator, or insulators, which act as a condenser and this impresses sufficient voltage on the spark-gap to spark it over and the spark-tube then sparks over to ground through the condenser. The reactance of the relay being on the high side of the spark-tube causes the static to spark over the tube as an easier path to ground. When this static spark passes from the large electrode to the smaller one, it carries a very minute stream of conducting ions across the gap. This completes the path for the direct-current control circuit.

The operation is now as follows: When the tube sparks over, as just described, current flows from the negative lead, through the relay, the spark-tube, and back to the positive lead. This causes the relay to pick up and in doing so it operates a counter, sounds the gong, and breaks its circuit by opening a contact in series with its coil. This contact, in opening, stops the direct-current arc in the spark-tube and the relay drops back into position, closing its contact. When the contact is again closed direct-current voltage is again impressed on both sides of the spark-tube, so when its gap sparks over the direct current will follow and cause another alarm and operation of the counter.

The dashpot on this relay limits the action to about two or three complete operations a second.

In cases where the gaps of the arrester arc over continuously, the gong and counter will operate continuously at intervals of about ½ to ⅓ second. For single discharges the gong will sound once and the counter will increase its number by one.

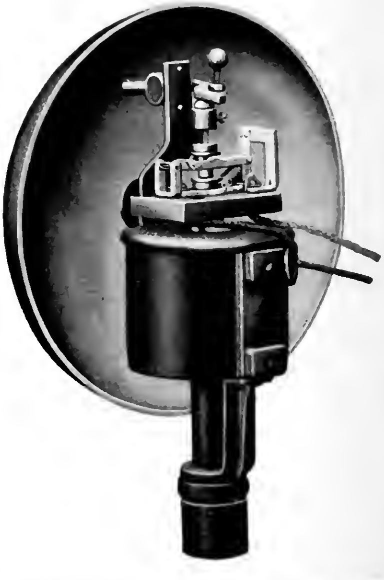

Fig. 10. Counter-Gong Relay for Spark-tube Discharge Alarm

This apparatus may also be used to detect high-voltage on a line or bus, above any predetermined value—say 150 or 200 per cent normal—by setting a sphere-gap to spark over at that value, as shown in Fig. 12.

When this spark-tube device is used in connection with the multi-recorder, it is connected as shown in Fig. 13, the relay taking the place of the counter-gong relay. This relay has an oil dashpot that prevents it from closing the *open* contact to the multi-recorder until the surge has ceased, thereby also giving only two records for a surge on the line regardless of its duration.

These discharge alarms have a great advantage over various other types in that only the coherer panel, Fig. 1, or spark-tube panel Fig. 9, need be installed near the arrester to which it is attached through insulators, while the counter-gong relay, Fig. 10, may be placed at the distance most convenient for the operator or station attendant to take counter readings and observe the alarm given by the gong. For instance, a bank of arresters may be located some distance from the operating station so the operator is not aware of their action. In this case an alarm would be given near him, simultaneously with a counter record for every discharge, and he would thereby be kept thoroughly informed as to the presence of high-voltage disturbances on the transmission system.

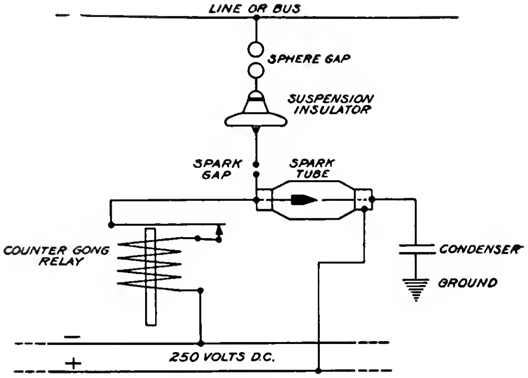

Fig. 12. Wiring Diagram for Spark-tube Surge Recorder

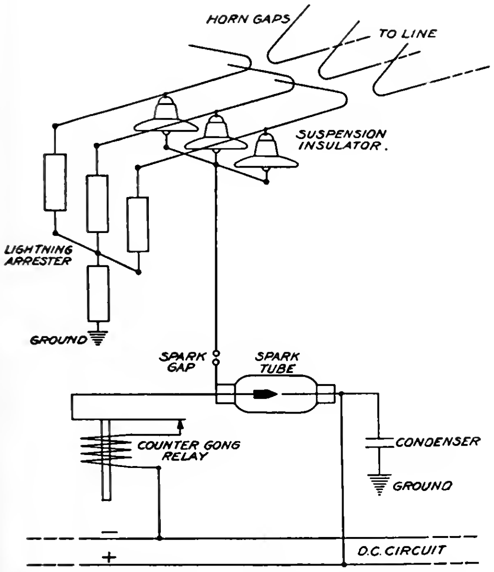

Fig. 11. Wiring Diagram for Spark-tube Discharge Alarm

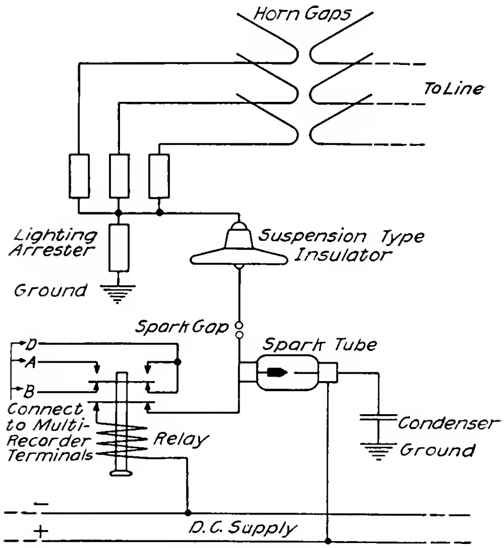

Fig. 13. Wiring Diagram for Spark-tube Discharge Recorder

THE COMMERCIAL DEVELOPMENT OF TECHNICAL BUSINESSES*

By Geo. H. Gibson

Consulting Engineer, New York City

In order for manufacturers, and especially manufacturers of engineering appliances, to prosper it is necessary for them to work incessantly for new products and for improvements in the old. As the author observes, the greatest success in engineering businesses have come to men who possess the threefold ability to foresee the need or opportunity, develop the solution, and focus the attention of the public upon the result. With large businesses it is impossible for one man to frame the general policy of the concern, and at the same time perform the research or inventive work and the designing; therefore these functions are divided between different lots of men, and the degree of success achieved by the organization is dependent upon the fitness of each. The prejudice to new and useful things that is often manifested by the public can be quickly overcome by judicious advertising, and the period of profit-making thus increased during the seventeen years monopoly conferred by patent.—Editor.

The application of science proceeds at an accelerated pace. The days have about gone by when one good idea would keep a family in business for several generations. No one dare rest content, for as Solomon remarks: "Yet a little sleep, a little slumber, a little folding of the hands to sleep, so shall thy poverty come." Every manufacturer, and particularly manufacturers of engineering appliances and products, must maintain a constant output of improvements and new developments in order to protect his investment in plant, organization, and good will—and indeed, to stay in business. As has justly been said, the invention of a new machine or process (by some one else) may be as disastrous as a fire, and far more likely to occur.

Moreover, the more progressive and the more advanced a concern is, the greater will be its volume of new developments and improvements. Inventions breed inventions.

At the same time, the investment of time and money in research and development is a capital risk, that is, the preliminary investigation upon which the design of improved apparatus is based and the provision of manufacturing equipment and organization for turning it out must largely be paid for before the market for it can be developed. It is only by the prompt enlightenment of the prospective consumer, in other words, by educational advertising regarding the applications and advantages of the new article, that the loss of time and the waste which always intervene between the perfection of a device or process and its general use can be reduced.

The introduction of new things is a speculative venture which bars the timid, but for that very reason is highly profitable. Patents more or less effectively insure to the originator a safety zone, protecting him from competition for a limited period that he may have the opportunity to recover his great initial outlay. Advertising, however, is equally useful, since it can shorten the period of loss, conserving for profit-making a greater portion of the 17 years' monopoly confered by the patent and increasing the volume of profit. Advertising itself exerts an accelerating influence on technical development, for before advertising one should have something worth advertising. Much of the strategy in the competitive selling of engineering appliances consists in originating better methods or designs, or new and improved products.

Good business has been defined as the art of selecting probabilities, and it is certainly true that the greatest successes in the engineering businesses have come to men who have the ability to do the following things.:

1. Foresee the need or opportunity.
2. Develop the solution, and
3. Focus the attention of the public upon the problem and its solution.

As examples might be mentioned: Edison with the incandescent lamp, Westinghouse with the air brake and alternating current transmission, Hunt with rope transmission, Sturtevant with fans and blowers, De Laval, Curtis, and Parsons with the steam turbine, Babcock and Neier with the water-tube boiler, Diesel with the oil engine, the Wheelers with surface condensers, Hill with technical journalism, Thurston with technical schools, Patterson with the cash register, Herschel with water meters, Kent with his handbook, and many others.

The inertia and prejudice which must be overcome in the introduction of a new device may be illustrated by the experience of Corliss with his variable cut-off four-valve steam engine. After he had perfected and demonstrated the remarkable savings of his engine as compared with the engines then common in this country, he was still compelled to give the engines away and to take his payment in the fuel saved during the first year's operation, in order to make headway.

Many people have the idea that the invention is the important thing. Very few engineering businesses, however, are founded altogether on exclusive and basic patents. They are based rather on a combination of

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* From an address delivered before the Technical Publicity Association.

scientific knowledge and business sagacity, with the help of such protection, monopoly, or trading advantage as can be obtained from the detail patents which it may be possible to secure as the development of the art unfolds itself. A man may have the germ of a good idea for a successful business, but still nothing that can be protected by a patent, even though patentable improvements will doubtless be discovered upon developing the idea. Nevertheless, the essential factor is the broad judgement or foresight which leads him to take up certain matters at a particular juncture, and not the specific mechanical contrivances by which he may carry out his ideas. In such cases, the best protection to the idea is advertising by means of which he can promptly get the full benefit of the potential demand for his product before competitors have had time to imitate and develop. Once he has his organization and business well under way, competition will be at a disadvantage.

For businesses up to a certain size, there is nothing that will beat one-man efficiency. The man who can see a need or an opportunity for a need and act accordingly is fit to be the head of a business, if he is also an administrator. However, the organization of modern industrial enterprises branches out into a great multiplicity of specialized details, and we cannot always get in one man all those qualities of genius that are necessary in the inventor, in the captain of industry, and in the promotion expert. We therefore have performing these functions a number of men who may be described as follows:

First, there is the general strategist, who may have the title of president, general manager, chief engineer, and not infrequently sales manager, since the study of how to sell a product as already built leads almost invariably to the discovery of improvements whereby it can more easily be sold in larger volume and at a greater profit. It is the disposition and function of this Head never to be satisfied with things as they are. He is continually studying the trend of engineering, scientific and business developments with a view to visualizing their probable future course. His policy is to build a monopoly of information and brains and then to serve the public with little or no competition by having the best solution for each new problem as it arises.

A good example of the necessity of appreciating research on the part of the directors of industrial enterprises is supplied by the editor of London *Engineering*, who relates that the firm of Simpson, Maule & Nicholson, in their day leading manufacturing chemists in England, became millionaires largely through the fact that Nicholson was a very able chemist. When he retired, the firm ceased to develop. His successors employed several very able chemists, but these had no control over the business policy and the end was disaster. At one time their leading chemist was the late Prof. Meldola. When he invented his blue, however, the firm refused to take it up, and he accordingly published an account of his discovery with the result that it founded the fortune of a leading German firm. The successor of Meldola was Prof. Green, who invented primulin, a dye of an entirely new type. This the firm refused to patent, and within a few weeks it was in consequence made in Germany, the whole advantage being lost to England.

Again, some fifty years ago an ingenious engineer invented the duplex steam pump, standardized the type and in time built up an able and aggressive engineering, manufacturing, and sales organization. Its success having been demonstrated, this type of pump was taken up by numerous competitors, each of whom developed a complete line. A comparison of the bulky and closely printed catalogues with page after page of tabulations of sizes and models of duplex pumps issued by the dozen or so builders will indicate the immense amount of money invested in drawings, patterns, and manufacturing equipment, not to mention catalogues and advertising. Partly because of pressure of competition, seven or eight of the largest of these concerns went into a merger and eventually into the hands of a receiver. All of their pumps, regarded as assets upon which to base a growing business, have now become practically obsolete, or at least greatly depreciated in value by the perfection of the more compact, simple, reliable, and efficient steam-turbine-driven centrifugal pump as used in all services from boiler feeding to city water works supply.

The steam-turbine-driven centrifugal pump requires precise, scientific design, and accurate manufacturing methods, in order to secure both efficiency and reliability; but if some of the original pump builders had devoted a modest fraction of the time and money spent in copying other reciprocating pump builders, to intelligently directed research and commercial development work, they might while continuing to supply the demand for reciprocating pumps then existing have created a new and exclusive market for themselves. It, however, remained for entire outsiders, steam turbine builders, to perfect and introduce the steam-turbine-driven centrifugal pump.

Second, we have, or should have, the inventor or research man. His endeavor specifically is to put the existing business out of business by bringing out something better. He must be an independent thinker, and his department is primarily a thinking and scientific intelligence department, largely free from dictation and direction by minds engaged in the routine of the business. (The business man is generally about as good an inventor or research man as the inventor is a business man.)

The research man is herein differentiated from the designer, as it is not so necessary that the research inventor should design as it is that he should be able to see things from both the maker's and the user's points of view, should have a wide play of fancy, and should have the power to co-relate facts. He reads everything. He may even at times take delight in considering the improbable or the unlikely from a spirit of mere novelty and adventure. The man who makes radical inventions is a man of vision, and perhaps of visions, he must penetrate the curtain of convention and habit. Certainly, he must not be overburdened with routine, must not travel in a rut, and must never entertain the idea that anything has reached finality, or that he has done his utmost. He can quite properly be stimulated to venture freely in the quest for good ideas by some kind of contingent reward, something that will make the work interesting. He should not be discouraged by indefinite, intangible promises, or by the offer of a mere fixed salary that may stop at any time.

A few concerns have grasped the value of always pushing forward; it is said, for example, that one automobile builder spends $500,000 per year in research and development. A great number, however, hardly do more than trust for their progress to the inconstant and flickering light of chance ideas.

The third member of our ideal technical business organization is the designer, the man who works ideas into shape for the shop and the user. While upon his sagacity and skill depend tremendous economies in manufacture, as well as satisfactory performance of the finished article, he is essentially conservative, a "stand-patter," having a keen realization of the fact that every scratch of a draftsman's pencil costs money in the pattern shop, foundry, and machine shop. The attempt to conduct research in the production department usually demoralizes the latter while rendering the research impotent.

The advertising manager of a technical business should seek to grasp new ideas in their full import and in all their implications, and should endeavor to estimate and appreciate their possible and probable effects on existing practice and business. He works in close co-operation with the administrative, research, and engineering departments, in order that he may understand what they have done and seek to do, and that he may formulate and popularize those ideas which will stimulate and guide customers' demands in conformity with their plans. It is his problem to tell the public how to use the product and why to use it, to make the product more thought of and better thought of, since the value which people will place upon the product naturally depends upon what they know and think about it. He endeavors to bring the user and producer closer together and seeks effective and economical ways for educating the user.

His problem is a little different from that of the general advertiser. He must co-ordinate facts of physics, chemistry, engineering, and commerce and infuse into them the spirit and purpose of a business. Exacting demands are made upon his breadth of view and industry, but at the same time his work is facilitated because of the interest which naturally attaches to new things. There is nothing of human use to which interest does not attach, and anything that men have to do with can be made to interest them in some way. Engineers are naturally interested in new forms of construction, new theories, and tests and descriptions of installations, and it is the advertising man's part to add pithy, succinct, and forcible presentation.

In advertising to managers of enterprises, consulting engineers and others who purchase engineering appliances, he can to advantage appeal to their desire for further knowledge, and to the sentiments, beliefs and ideas of wideawake, self-reliant men, who probably have a large store of systematically organized knowledge which they will bring to bear upon the statements made to them. He must therefore argue logically and with a full command of the facts.

Engineering products are purchased almost solely for their utilitarian value. Their usefulness can be weighed, measured or computed in some way; and they are usually purchased with much deliberation, for the reasoning faculties of the people who buy them have been emphasized by technical and business training.

The advertising should arise from and carry forward the general ideas and beliefs of the guiding mind of the business. It finds inspiration in new products and the exploitation of new fields. As compared with this broad purpose, the means and methods discussed in books on advertising, such as typography and display, color of ink, quality of paper, etc., are to a degree only incidental—all that is asked of them is that they should do their part in transferring ideas efficiently and not get in the way of the main motive, which is the making use of the spectacular qualities of advancement and improvement and the doing or saying of things interestingly.

The world is run largely on ideas and the dissemination of ideas is the business of the advertising engineer.

DEVELOPMENTS IN SWITCHBOARD APPARATUS

Improvements in the Design of Benchboards

In connection with the manufacture of switchboard equipments for some of the large power plants during the last few years, various improvements in benchboard have occurred to the designing engineers, or have been suggested by the customer. It was, therefore, decided to redesign the several types of benchboards already on the market, to incorporate these improvements and at the same time to standardize, as far as possible, the design so that a fewer number of parts are required, or that common parts can be used for different types of benchboards. This will enable the factory to take the benchboard material from a not too cumbersome stock, and greatly shortens the time of assembly, as long as the customer confines himself to standard design.

Designs have now been completed, and the following types of benchboard can be ordered from standard drawings:

1. Open type board (see Fig. 1).
2. Closed type board, with back panels in two or three sections.
3. Closed type board, without back panels, installed near wall.
4. Control bench, for installing in front of instrument and meter panels.

The standardization width of sections for all types of benchboard are 16, 20, 24 and 28 in. All types of board are designed so as to make future extension possible at either end: in fact, with this design a benchboard can be extended just as easily as a vertical switchboard.

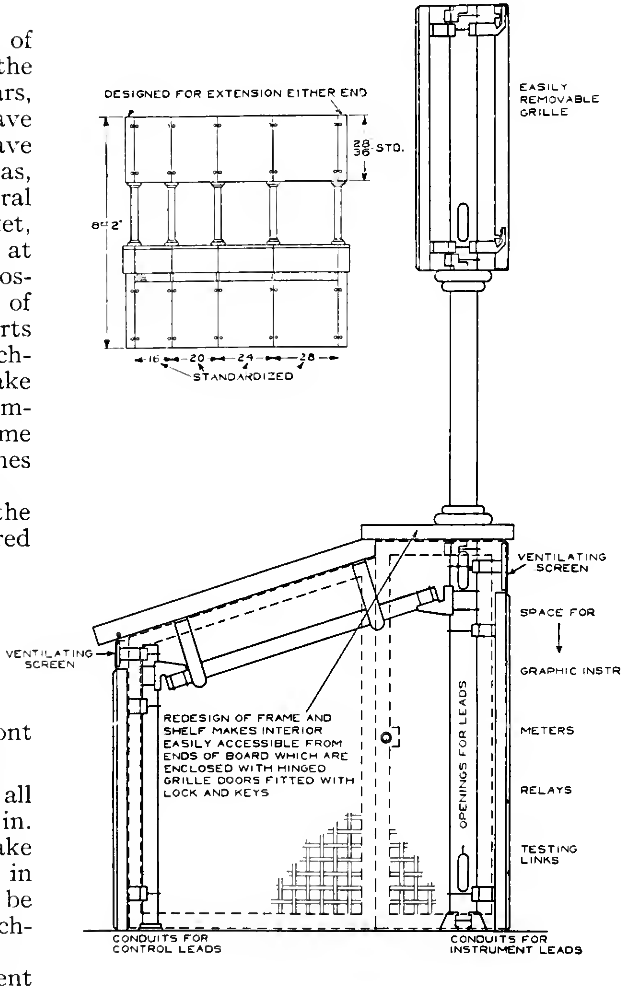

Fig. 1. Standard Open Type Benchboard

The grille panels back of the instrument sections are easily removable without the use of wrench or screwdriver. Instead of grille work back of the bench, panels are used which provide a convenient place for mounting graphic instruments, meters, relays, testing links, etc. This enables the customer to test these devices without interfering with the operator in front of the bench. Furthermore with this arrangement of apparatus, all instrument leads can be brought up from the floor in almost a straight line to the instrument section without passing under the control bench, which is usually crowded. The control leads can then be distributed neatly back of the sub-base, where they leave the conduits, and up to the control apparatus. This condition of wiring not only gives a neat arrangement of wiring, but, in case of trouble, the whole system is exposed at once.

Redesign of the bench frame and increasing somewhat the dimensions of the bench structure makes the interior easily accessible from the ends of the bench, which are enclosed with hinged grille doors equipped with lock and key.

Ventilating screens are provided on the front and back, running the entire length of the bench, thus preventing excessive heating from lamps and resistances. Further improvements include the use of welded instead of pivoted joints, which makes a better job and also gives a more pleasing appearance.

Special Disconnecting Switch for Restricted Quarters

The ordinary high-voltage knife-blade disconnecting switch is operated by a hook on the end of a long rod. This necessitates an amount of space for the operator directly below the switch and perpendicular to its base, depending both upon the length of the blade and of the rod used to open and close it.

The switch shown in Fig. 2 is operated from directly below by a disconnecting switch hook. There is not needed the room which would otherwise be necessary for the operator to use the switch hook at the considerable angle required.

The construction of the disconnecting switch is made clear from the illustration.

The insulators, insulator caps, and terminals are standard. The blade is a copper rod with a cast eye fastened on one end and a readily renewable sold brass contact tip on the other. The stationary contacts are the same as those used on H type oil circuit breakers.

When the switch is opened a flange near the tip of the blade prevents the blade from dropping below the upper part of the lower stationary contact. A wide flare on the lower end of the upper contact leads the blade into place when the switch is being closed.

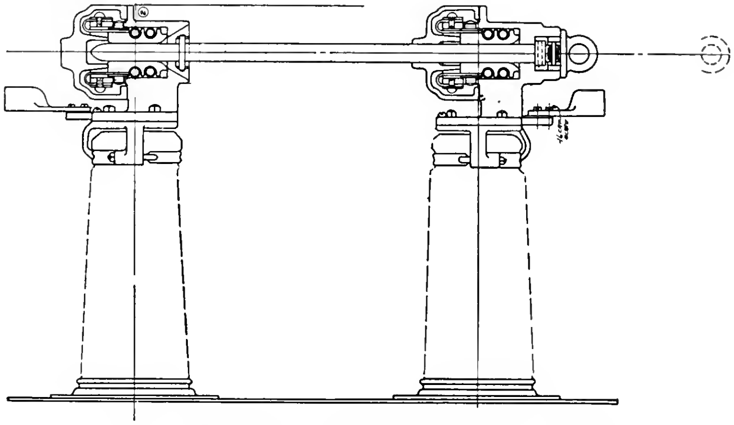

Fig. 2. Special Disconnecting Switch for Restricted Quarters

After the blade is closed a slight turn to the right or left by the operating rod locks the blade in position and prevents it from opening except when desired.

Dead Front Plug Switches for Series Lighting Circuits

The predominant characteristics of the "stab" or plug switch are: a simple inexpensive appliance which can be used to make and break small currents at comparatively high voltage with safety. These features have made this type of switch particularly suitable for use on both primary and secondary sides of constant current transformers in connection with series arc and incandescent lighting.

They are used also occasionally on small capacity feeder circuits up to 2500 volts.

Plug switches are either single- or double-break and as made today possess certain improvements as contrasted with older designs which give better protection to the operator.

In the older types the line ran to the receptacle at its inner end and the parts protruding through the panel were always alive. Now, because of general changes in design the current leads are attached to the outer ends of the receptacle and the parts accessible from the front of the panel are dead when the plug is not in place.

The single plug switch has been provided with greater insulation and a larger handle. The new plug itself is much safer than the older type but in conjunction with the new method of making connections it is extremely satisfactory from the viewpoint of safety.

The double plug switch follows the design of the single-pole element in the use of tube insulation; porcelain and brass supports, etc., but each complete switch consists of two tubular receptacles and a two-plug double-break switch per pole.

Until the switch has opened sufficiently to break the circuit there is slight chance of touching the live parts of the switch.

The entrance bushings for receptacles are of moulded material and extra large in size. The two-plug switches have thick, wide cross bars which constitute a guard and an additional protection. Receptacles and plugs are identical for both open and short circuiting, but the arrangement of receptacles is such that there can be no confusion in operation.

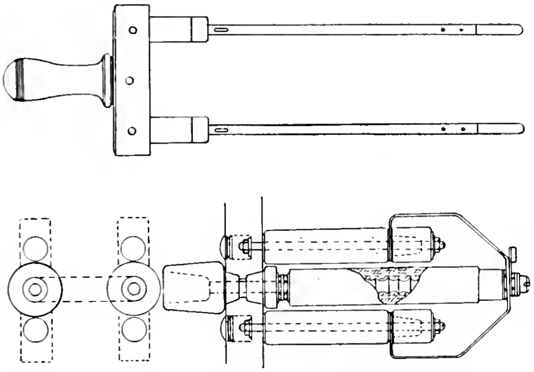

Fig. 3. Dead Front Plug Switch for Series Lighting Circuits

PRACTICAL EXPERIENCE IN THE OPERATION OF ELECTRICAL MACHINERY

PART XXII (NOS. 84 TO 87)

BY E. C. PARHAM

CONSTRUCTION DEPARTMENT, GENERAL ELECTRIC COMPANY

(84) VOLTMETER CONNECTION INCORRECT

Switchboard instruments of the astatic type have one coil which provides the controlling field and another coil which constitutes the deflecting member. Therein they are somewhat like instruments of the permanent-magnet type, in that the controlling field is maintained practically constant irrespectively of the field strength of the deflecting coil. The astatic meters have the advantage, however, that they are comparatively immune from the effects of stray fields and that their controlling fields are not permanently weakened by the demagnetizing effects of line short-circuits. (Astatic meters, therefore, are well adapted for use on railway switchboards since these are often subjected to the effects of external short-circuits.) A characteristic of the permanent-magnet type meter is that the strength of the deflecting coil field depends only on the impressed voltage; therefore, if the voltage is of the wrong polarity, the meter needle will be deflected in the wrong direction, or of the scale. Meters of the astatic type will not act in this manner because any reversal of the polarity of the line will reverse the polarity of both coils, and the direction of the deflection will thereby be maintained the same.

In a certain installation there was reason to believe that the insulation of a railway generator (which operated alone) was defective. An insulation test was made by means of the voltage of the machine itself and a permanent-magnet voltmeter. In the course of the test it developed that the polarity of the generator was reversed: instead of the trolley wire being positive, which is the standard polarity for ground-return systems, it was negative. This condition of course had not affected the operation of the railway and had not been noticed because the switchboard meters were of the two-coil type which indicate in the same direction for both line polarities.

As there was no means available for the "flashing" of the generator field in order to give it an initial charge in the correct direction, the polarity of the line was corrected by reversing the generator terminals at the switchboard.

(85) POLARITY REVERSED

Astatic types of voltmeters and ammeters include two coils, a field coil and a deflecting coil. The field coil generally is permanently connected to the busbars and the field provided by it corresponds to the field that is provided by the permanent magnet in the permanent-magnet types of instruments. The deflecting coil is connected across the circuit of which the voltage is to be indicated. The magnetic circuit of the field coil is operated at such a high magnetic density that even appreciable variations in the exciting voltage that is applied to the field coil do not materially affect the strength of the field and, therefore, do not appreciably affect the indications of the instrument. In other words, the iron of the field magnetic circuit is so highly saturated that a considerable change in the exciting voltage is required to materially affect the constancy of the field strength. Therefore, in the case of a voltmeter, the deflection will be directly proportional to the voltage that is applied to the deflecting coil. That there is a limit to this proportionality of deflection, however, is illustrated by the following instance.

The engineer of a summer hotel complained that the indications of his voltmeter were not correct, that although the brilliancy of the lamps and the speed of the elevator indicated that the voltage must be about normal the voltmeter needle "wasn't more than half-way up the scale." Investigation disclosed that the voltmeter was being used in connection with a three-wire generator, that the voltage between the outside wires was 240 and was used for the elevator, and that the voltage to neutral was 110 and was used for lighting.

By means of a double-throw switch, the deflecting coil could be applied to indicate either voltage (this arrangement is perfectly permissible.) The trouble was due to the fact that the field coil was permanently connected to the 110-volt busbars while it was designed for 220-volt excitation. The error was, however, in the safe direction, for had the field been intended for 110-volt excitation and it has been permanently connected to the 220-volt bus the coil probably would have been burned out.

After changing the field coil to the 220-volt busbars, the voltmeter indications became normal.

(86) WRONG TAP SPACING ON CONVERTER

The voltage ratio between the continuous-current end and the alternating-current end of a plain shunt-wound synchronous converter is practically fixed, excepting insofar as the voltage of the continuous-current end may be slightly changed (without changing the voltage of the alternating-current end), by shifting the brushes. The extent to which the brushes may be shifted without producing bad results is limited by the machine's commutation characteristics. The changing of the field excitation has no appreciable effect on the voltage ratio, because such a change affects the power-factor and the resulting reaction of the displaced current on the magnetism of the pole-pieces tends to restore the magnetic conditions that existed before the field change was made. Indeed, unadvised changes in field current are to be avoided. Where such a converter supplies a constant load, the proper method of securing correct voltage at the commutator end is to supply the necessary voltage to the collector end. If the secondary voltage of the supply transformers is too high and the transformers have no taps, the same results may be obtained by connecting reactances between the secondary of the transformers and the collector rings.

A three-phase 240-volt converter was the subject of a complaint on account of sparking. Investigation disclosed that the alternating voltage was too high and that, due to an attempt to lower the continuous voltage by shifting the brushes on the commutator, the brushes had been moved to a position where they sparked. As a movement of the brushes back to the non-sparking point raised the continuous voltage, still higher, the operator was compelled to use reactances for the transformers had no lower taps. The reactances permitted non-sparking operation at approximately the desired continuous voltage, but the converter heated excessively. Furthermore, it was noticed that the heating was practically the same at light loads as at heavier ones. Considerable time was spent in trying to locate the trouble by testing, but this was unproductive. Finally, it was learned that the armature had been repaired at an earlier date. In checking the repair work, it was discovered that when the taps from the rings to the continuous-current winding were replaced, the taps had been spaced incorrectly. Most of the trouble had been due to the cross currents incident to the wrong tap spacing and to the fact that the wrong spacing gave more impedance drop between one phase than between the others.

In this instance, the trouble seekers were called to remedy a minor trouble and they located a major one after considerable delay. If they had known that the armature had been to a repair shop, much time would have been saved.

(87) WORN CENTRIFUGAL SWITCH

The following letter was received from a large operator of sewing machines that are motor-driven:

"Dear Sir:

"I have so many machines to watch; these machines are run by single-phase motors which they don't give ever much trouble, but still these motors give some small troubles which don't amount to much. I watch my motors very close; most of them do fine but three of them don't; they spark much when they work also they get hotter as the other motors. I open one motor inside I find one arm burnt; but not the other arm burnt. I take the burnt arm off and motor now run first rate. Other waist makers might have trouble the same like this.

Signed Max........"

The motors referred to were single-phase motors made to start by means of an internal starting switch which automatically operates to cut the starting winding in and out at the proper time. Fig. 4 indicates the connections. Here *d* and *e* are brass rings which are mounted on the shaft and which turn with it. A small carbon brush *c* bears sidewise upon *d* and two brass contact fingers or arms *a* and *b*, connected in parallel, are spring-pressed on ring *e* as long as the armature speed is below a certain value. Above this speed, centrifugal force throws *a* and *b* outward, thereby opening the starting winding. The operator's trouble was due to the fact that the weight and tension of one finger were such that the lever would throw outward just far enough to hold an arc. The removal of the faulty finger of course eliminated the trouble.

SUBSCRIPTION TO THE LIBERTY LOAN BY GENERAL ELECTRIC COMPANY EMPLOYEES

The official announcement of the amount of the subscription to the Liberty Loan has not been made public as we go to press with this issue of the Review, but preliminary estimates show that the Loan has been over-subscribed by about a billion dollars.

As soon as plans had been formulated for a nation-wide campaign to insure the success of the Loan, the General Electric Company announced that it would purchase $5,000,000 of bonds, and would also purchase for its employees as many bonds as they would subscribe for, to be paid for in approximately one year by weekly or monthly deduction from wages. This is broadly the plan that has been followed throughout the country by corporations, banks, and merchants for their employees. Subscribers to the Loan by this method commit themselves to compulsory saving, and this feature no doubt is partly accountable for the splendid response by the country's workingmen—by which we mean that large army of men and women who are dependent upon their daily wages for a livelihood.

At the Schenectady Works of the General Electric Company June 6th was appointed "Liberty Loan Day." Six hundred bond salesmen from among the employees made a thorough canvass of the office and factory, and when their returns were compiled the subscriptions showed a grand total of $1,057,200. There are about 22,000 employees at the Schenectady Works, of whom 13,234 purchased Liberty Bonds.

The other plants of the Company made equally good showings and the total of subscriptions from all works and offices to June 15th amounts to $3,000,300.

	Number of Subscribers	Total Subscriptions
Schenectady Works including General Offices	13,234	$1,057,200
Lynn Works	8,782	563,300
Pittsfield Works	4,021	280,250
Erie Works	2,445	177,300
Edison Lamp Works	3,118	202,150
Fort Wayne Works	2,125	151,550
Sprague Works	809	57,850
National Lamp Works		278,200
District Sales Offices	1,683	205,750
General Office Depts., elsewhere than Schenectady	226	26,750
Grand total		$3,000,300

GENERAL ELECTRIC REVIEW

A MONTHLY MAGAZINE FOR ENGINEERS

Manager, M. P. RICE
Editor, JOHN R. HEWETT
Associate Editor, B. M. EOFF
Assistant Editor, E. C. SANDERS

Subscription Rates: United States and Mexico, $2.00 per year; Canada, $2.25 per year; Foreign, $2.50 per year; payable in advance. Remit by post-office or express money orders, bank checks or drafts, made payable to the *General Electric Review*, Schenectady, N. Y.

Entered as second-class matter, March 26, 1912, at the post office at Schenectady, N. Y., under the Act of March, 1879.

VOL. XX., NO. 8

AUGUST, 1917

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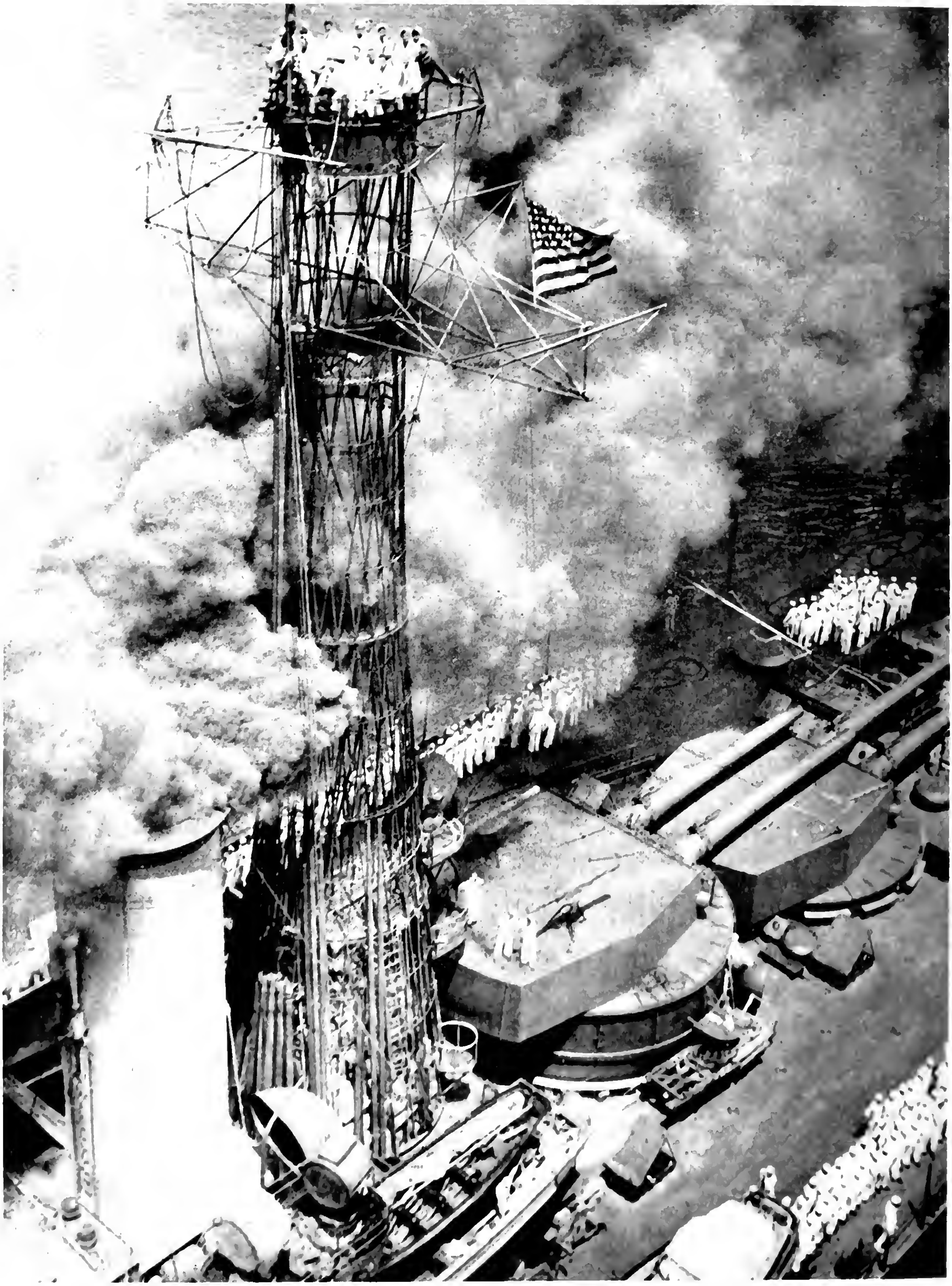

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Engraving by Courtesy of Sea Power

A glimpse of the U. S. S. Wyoming, one of our first line sea fighters, as she passed under the Manhattan Bridge, New York. The cage mast is used only in our navy, and experiments have proved that it can be considerably damaged by gunfire without falling.

GENERAL ELECTRIC REVIEW

THE FUEL PROBLEM

"Not only food but fuel is a vital need of this country and of our allies—coal to run the ships and railroads, to feed the iron furnaces, and furnish steam for all the manufacturing plants, coal in greater quantities than have ever been mined in the United States, or in any part of the world; and this is being met in truly American fashion by the operators and owners of the mines and by the diggers of the coal."—*Secretary of the Interior, Franklin K. Lane.*

A new record was set for the first six months of this year; 270 million tons of bituminous coal were mined. This is 20 million tons more than in the first six months of 1916, and if maintained during the summer (when the mines usually shut down for a time) will produce 540 million tons for the year, as against 442 millions for 1915.

Continuing, Secretary Lane says: "The difficulty of distribution now so great will be intensified, however, in the coming winter months. Just as consumers of foodstuffs are being urged to eliminate all waste and to practice sensible economy, so the consumers of coal must do their share in working out the coal problem by unloading every car as fast as it is received, and in improving their plants so as to utilize to the fullest the heat value of the coal that reaches their bins. In stopping the coal panic and in expediting a condition of fuel sufficiency, every consumer can do his bit."

In this and subsequent issues we will call attention to ways in which the consumer in the electrical and allied industries can help by adopting methods for more efficient utilization of our fuel resources. Such methods include: (1) More extensive development of water power; (2) Utilization of the less concentrated sources of kinetic energy, such as tides, waves, wind, solar heat, and terrestrial heat, (although these cannot be utilized on a large scale during the present emergency); (3) Utilization of by-product fuels, such as coal-mine waste, coke-oven and blast-furnace gas, and wood waste; (4) Utilization of local resources of low-grade fuel in territory now dependent upon transportation of high-grade coal from distant sources; (5) More efficient means of utilizing the latent energy in fuel for generating heat and power; (6) Concentration of the production of power from fuel in central stations where the most economical methods may be utilized, and its distribution electrically to consumers; (7) The use of electric vehicles, charged by central-station power, to help relieve the great demand for gasolene for urban transportation.

Owing to the war and the high cost of materials and shortage of labor, there has been little done recently in the way of initiating new enterprises for the transmission of power from hydro-electric plants, and from steam power-plants located at coal mines. At the same time there has been a steady increase in the demand for power and for fuel.

With the present limited development of our water powers and of our deposits of low-grade fuel, the country is largely dependent upon localized mining activity in the regions where deposits of high-grade coal and oil are found. Large sections of the country receive their fuel supplies by long rail or water routes. They are often subject to delays from shortage of cars, locomotives, or shipping; from congestion of traffic or from transportation or miner's strikes. The cost of freight prohibits the transportation of any but the highest grades of coal for distant consumption. In such parts of the country there are undeveloped deposits of low-grade fuel which can be used locally, by several available methods, in connection with existing equipment.

POSITION OF THE ENGINEER IN NATIONAL AFFAIRS*

By H. W. Buck

PRESIDENT AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS

The prestige that is being attained by the engineer in national affairs is a source of much satisfaction to the engineering fraternity, and Mr. Buck's address will be read with interest by all its members. Not so long ago the engineer lived in a little sphere all his own, with its restricted outlook on the world's affairs, intently bent on the study of some scientific phenomena or technical problem, and having little care for and no voice in political and sociological matters. But the accomplishments of the engineer in the last few decades have worked such sweeping reforms in our business structure and methods of living that he has been carried forward by the tide of his own creations into the front rank of prominent and influential citizens. The prestige of the engineer in both technical and civil affairs has promise of being further strengthened by the activities of the Engineering Council, a recently formed body representing some thirty thousand engineers.—Editor.

There has been much discussion concerning the position of the engineer in modern times, but conditions are changing so rapidly and points of view are undergoing such a fundamental evolution that it is well from time to time to review the relations of the engineer to his surroundings and to secure if possible the proper orientation.

The Accomplishments of the Engineer

The change and improvement in the engineer's position in the world in recent years have been so rapid as to surprise even those who were the optimists in the underdog days of the engineering profession. In the middle of the last century, when the engineering and technical schools began to be formed in this country by men of far-seeing vision, the classical scholars looked on askance and took pains to differentiate these upstart institutions from their own traditional schools of learning and to ostracize those who pursued the new courses by classifying the professions as "learned" and technical.

Times fortunately have changed. The engineering profession is coming into its own. Today the engineer is being swept along by a tide which he himself has created with an irresistible force, and it is well therefore for the engineer to take his eyes off his work occasionally and to observe his constantly changing surroundings. A flood of scientific and technical accomplishments has swept over the face of the earth, revolutionizing life, commerce, and international destinies. Even the turmoil in which the world now finds itself can probably in the last analysis be traced to the over-acceleration of world affairs resulting from the work of the scientist and engineer.

In all this development period of the engineering profession during the last century the engineer has worked his way along alone and in silence, so to speak, seeking his reward rather in the joy of accomplishment and in the realization of his dreams than in worldly recognition and accumulation. The very inherent greatness of the pioneers who have laid the foundations upon which we now build prevented them in a way from acquiring a more worldly position in affairs. This tradition, however, is not a virtue beyond a certain point, and the engineer by nature is too willing to give way to others. The time has come when he should take a more worldly position in the world which he himself has created.

In our general relations to intellectual development we may consider that we are just emerging from a classical period where tradition, custom, prejudice, ignorance, and dogmatic religion were the controlling forces. Movements which took place in world affairs were largely political, following the paths best suited to the advantage of the ruling classes. There was little real progress, because there was no development of scientific knowledge and its application in engineering. Scientific truth held no standing. The worship of tradition caused a powerful reaction against any scientific discovery which might necessitate a readjustment of established habits of thought and life.

For centuries before the dawn of the scientific and engineering era great changes took place throughout the world, but little real progress occurred. Races rose and fell, always falling back to the starting point, for there can be no upward trend in racial development without the solid basis of scientific knowledge to grow upon. China made great progress and developed its early civilization under scientific activity, but during recent centuries it has lived under the worship of classical tradition and has become inert.

A constant change in point of view, which is so largely brought about through developments in scientific knowledge, seems to be necessary for progress in civilization. Our civilization today differs from that of a

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* Address at special meeting American Institute Electrical Engineers, New York City, June 27, 1917.

century ago in proportion to the scientific and engineering evolution which has taken place during the period through its reactions on life in all of its phases. Such discoveries in science as the law of gravitation, the evolution of species, the laws of electromagnetic induction, etc., have probably had a more profound effect upon the development of the human race than any other acts in history.

The Engineer in Human Affairs

The engineering profession has passed through the preliminary stages of its growth and has reached a position where the engineer should work and act not only with proper attention to his work itself, but with full consciousness of the important relation of his work to human affairs in general. Among the early pioneers in engineering were many notable instances of men of great breadth of view—men like Watt, Fulton, Whitney, McCormick, Erickson and others. Specialization had not at that time begun to work its narrowing influences. Of recent years, however, under the stress of commercial development and economic conditions, increasing specialization has taken place and the engineer has become obliged to compass his mind with an ever-narrowing horizon. This specialization produces extraordinary proficiency in particular fields, but has the objectionable effect of narrowing the character and outlook of the man and of reducing his value as a citizen. We must take care lest commercial considerations and the modern mania for efficiency in the narrow sense force our engineers to lose sight of the world around them in their concentrated attention to the part rather than to the whole. This excessive specialization is a danger which threatens the future standing of the engineer.

It is interesting to recall in this connection the results of a recent canvass made by a joint committee on education on the qualities which, in the opinion of about 5000 leading men, engineers and others, best fit a man for a successful career as an engineer. As a result of this vote only thirteen points out of a hundred were assigned to purely technical knowledge as an essential, the other eighty-seven points being allotted to broader qualifications, such as judgment, character, human understanding, etc. This is merely a quantitative statement of the many general demands now being made of the engineer, and it illustrates how his work has broadened out. It is an interesting and encouraging symptom.

A most significant movement of recent times in the engineering world has been the development of co-operative action among engineers of all classes, and this tendency will, I believe, serve to offset the evils of specialization. It is the growing recognition of the fact that all branches of engineering are interdependent. We electrical engineers, I believe, are well aware how much we need the assistance of other branches of engineering for the successful fulfillment of our purpose.

The Engineering Council

This co-operative movement has quite recently been given tangible expression in the formation of the Engineering Council, an act, I believe, of far-reaching consequence. Under this organization as a beginning the Civil, Mechanical, Mining and Electrical societies, together with the United Engineering Society, are tied together for co-operative action through a joint body of twenty-four representatives. This body will meet at frequent intervals and will deliberate on matters of general interest to engineers. It is an encouraging beginning toward universal co-operation among engineers in all branches of work.

In this Engineering Council we have for the first time an engineering body representing about 30,000 engineers of sufficient scope and standing to create an engineering public opinion. Its influence is likely to be far-reaching in building up the prestige of engineers in both technical and civic affairs. A further development which has reached full recognition only in recent times is the mutual appreciation which has grown up between the engineer on the one hand and the worker in pure science on the other.

The engineer looks to the scientist to provide him with raw materials of knowledge with which to work out his application, and the scientist must look to the engineer to make his discoveries so fruitful that the full effectiveness of his work on the frontier of research can be sustained. Both are working together in order to unfold nature in the most effective way for the benefit of man.

We electrical engineers, I think, feel a particularly close bond with the pure scientist in that recent developments in physical science have disclosed an intimate relationship between electrical phenomena and the nature of energy and matter.

All of the important movements taking place at the present time which center around the engineer and his work mean, I believe, that the engineer is soon going to leave his position of isolation in independent fields of work and realize that he owes an obligation to the community broader than his daily engineering work and will contribute to the general welfare his talents and experience. It matters not whether the problems before him are political, sociological, industrial or technical, I believe that the engineering type of mind, if the proper breadth of view has been acquired, is best fitted to undertake them.

Resourcefulness and Imagination of the Engineer

It is not necessary, perhaps, in important administrative positions to have civil, electrical or mechanical engineers as such, but we do need men in those positions who have had training of the type which engineering gives, with the mental balance, the power of analysis which such a training develops, the resourcefulness and the faculty of recognizing and properly apportioning the various elements in a problem. There is a quality of mental honesty which engineering experience highly develops which is sorely needed in public life. The scientific and engineering professions should rise up and furnish such men from their ranks for the welfare of the country.

The classicist contends that a world dominated by scientists and engineers would be cold, materialistic and atheistic, and lacking in those qualities of art and sentiment and the imaginative outlook which every civilization so highly prizes. To this doctrine and its injustice to the engineer I want to take emphatic exception. The world today may be inclined toward materialism, but it is not dominated by the engineer—far from it—but by other classes.

The engineering mind, on the other hand, numbers among its characteristics a highly developed creative imagination and possesses to a high degree exactly those qualities of mind and temperament best suited to combat materialism. There have been many instances in history of great artists who have been great engineers and vice versa, and I believe that the two temperaments lie in close relationship. Furthermore, scientists and engineers as a class have a strongly developed spirit of international understanding and sympathy which may serve as an important safeguard against excessive nationalism and excessive aggression as well.

Destiny of the Engineer

And so, gentlemen, I believe that we can confidently look forward to a new era for the proper fulfillment of the destinies of the engineer. Out of this world chaos we now see men of engineering and scientific training rising to positions of commanding prominence on all sides. It is simply the working of the inevitable law of the survival of the fittest.

In this great movement not only must the individual engineer play his part, but the great engineering societies must realize the power of influence which they are developing in an ever-increasing degree in the community at large and the obligations which devolve upon them.

And so I hope that the American Institute of Electrical Engineers as it passes along from one administration to another will acquire an increasing realization of its duty, not only in furthering the growth of science and engineering, but in furthering the influence of the engineer in the affairs of the country and of the world.

THE ENGINEER'S PART IN PROSECUTING THE WAR*

By E. W. Rice, Jr.

PRESIDENT-ELECT AMERICAN INSTITUTE ELECTRICAL ENGINEERS

Modern war is a highly organized enterprize, demanding supreme sacrifices and the hardest kind of work, not only individual work but co-operative work. In this address Mr. Rice mentions some of the tasks that are ahead of us to overcome our enemy's flying start. The task of providing and maintaining adequate shipping for our own and our allies' needs, in the face of the submarine menace, is briefly discussed as a problem that must be solved by the engineer; in fact, the statement that modern war is largely a question of mechanics and engineering works ought to be true in any analysis of the subject that we attempt. For when we come to consider the means of prosecuting the war, whether it be a matter of guns, airplanes, submarines, or methods of combating these, we find that the problem is one for the engineer; it is largely a contest between the engineering abilities and facilities of the warring nations.—Editor.

No body of men can get together at the present time without soon discussing the subject of the war, which is uppermost in everyone's mind.

The war is the one dominating factor in the world life and thrusts itself before our thoughts whether we wish it or not. We are in the war at last and will remain in it to the end. Whether it shall be a bitter end or a bright end will depend largely upon ourselves, as it is now our war.

It has been stated many times that modern war was largely a question of mechanics and engineering, a statement with which we must all agree. It is, therefore, self evident that engineering must take a leading and dominant position in the war work. Now the electrical engineer stands for about the latest thing in engineering development; his activities embrace practically all other fields of engineering, being, so to speak, the last word in engineering. The electrical engineer must, therefore, realize that this is his war in a very personal and particular sense.

War calls for supreme sacrifices and the deepest devotion, but it also demands something more difficult to give, and that is work. War may be said to be the personification of work, not only individual work, but especially organized and disciplined work,—disagreeable, dirty, heartbreaking, backbreaking, nerve-racking work, but always work. No nation of loafers ever won a war. Other things being at all equal, that nation or people who are willing to work the hardest will surely win the victory. Now I wish to point out that the enemy we are fighting is recognized as the most industrious organization in the world. Our enemy has prepared for war for fifty years and has been working with ever-increasing energy ever since the war started three years ago. We made no adequate preparation during all this time and therefore started with a fearful handicap of lost time and lost opportunities. We must not delude ourselves that our enemy is exhausted, but remember that he has the advantage of a "flying start." We must accelerate at an incredible rate if we are to get our war-motor going fast enough, soon enough to catch up.

Our enemy boasts that we have started too late. We must, by the hardest work directed with scientific skill and accuracy, organize and effectively utilize all our power of work to make his prophecy an idle boast.

The country is trembling with eager anxiety to help. Men and women are offering their services and their money. All eyes are turned toward Washington and to many everything seems confusion, and, as a result, we are full of criticism. Now I think it is clear that nothing is to be gained by destructive and captious criticism. We must discipline ourselves with patience, and if we take a broad view, we must admit that progress is being made. We must remember that a democracy of a hundred million people, whose thoughts and habits have been entirely those of peace, cannot change to the methods of war in a day, or a month, or even a year.

War is a business and must be handled as a highly organized, centralized enterprise. We must, no matter how repugnant it may be to our habits and thoughts, temporarily adopt such methods of our enemy as are known to be efficient and successful, because the penalty of failure is death. War is so repugnant to our ideals that it takes time to realize the necessity for and make the colossal changes demanded in every direction. We must, therefore, as I have stated, avoid captious criticism and confine ourselves to constructive criticism, and that sparingly and sympathetically administered.

There is one idea which we must abandon. The great majority of our people, who have no acquaintance with science or engineering, is prone to imagine that this war will be settled

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by some wonderful new invention, as if by an act of legerdemain; but you engineers realize that such a thing is practically impossible. It is so hopeless that it is cruel to permit any such idea to take hold of the American people. Neither is it possible for the war to be settled by the act of some hero or superman. It can only be settled by the united efforts of thousands of men, each contributing his bit. "Team play" in our civil army at home is as essential as it is in our fighting army abroad.

I venture to suggest that we cannot all occupy desks at Washington, and it is well for us and for the country that we cannot. We can, however, put ourselves and our business in such condition as to meet whatever demand is made upon us. Only relatively few can be useful in the direct service of the Army and Navy, but there is plenty of honorable work and useful work for us to do. The most effective work for most of us will be in the shops and offices at home, and everyone who does his work loyally and well, is as much a factor in our organized war as the man at the front.

Now, properly understood, the fact that no single great invention is likely to be made which will win the war, is no cause for discouragement. It does not mean that there will be no improvement, no new inventions, no new methods devised and put into effect. It simply means that we must not wait for the miracle which will never appear, but get to work and energetically take advantage of all present knowledge. We must survey the field, get at all the facts, carefully determine our plans, and then proceed to put them into practical execution.

Take for example the matter of shipping. This perhaps presents the greatest immediate problem of the war, frightfully complicated as it is by the submarine. I feel sure that it can be successfully solved, if we are content to solve it by the simple, common-sense methods used by engineers and successful business men in the ordinary course of business. The problem must first be carefully investigated, all available data quickly obtained and checked, and all new conditions considered, after which a broad-gauged well considered plan or plans can be formulated, criticized, and then put into effect.

Of course it is elementary to say that we must provide shipping in enormous quantities to replace that destroyed and to provide for increased demands. It is evident that time is the essence of the problem. We must, therefore, build the greatest tonnage in the shortest time. The ships must be manned and navigated to their destination and the most efficient methods provided for docking, unloading and loading.

With the situation such that the race is between ship building and ship destruction, with the destruction many laps ahead, it is vitally important that ships should be loaded and unloaded with the utmost expedition. We have recently heard of an instance where a large ship, after running the gauntlet of a voyage to England, was forced to visit several different ports and waste one month's time before starting the return voyage. This loss of time is equal to the loss of a complete voyage. The net tonnage delivered per month is the only thing that counts, therefore ship-tons saved is worth more than ship-tons built. Quick means of loading and unloading at specially devised terminals, here and in Europe, should be constructed and put into operation. The methods are known. It simply remains for us to organize and apply them.

We must see to it that the kind of ships, in respect to size, material and speed, are such that the greatest tonnage may be moved across the seas in the shortest time. In the time element there must, of course, be considered the time required to build such tonnage, If an investigation should indicate that cargo ships can be built which will successfully withstand one or more torpedo attacks, and which can also be provided with speed and armament sufficient to give them a good chance of fighting off and getting away from a submarine, they should be built, no matter whether such ships cost more, or are less adapted for use after the war, or take a little longer time to construct than those of the ordinary type.

It is entirely within the range of possibility that such ships may prove to be the only ones which will be able to navigate the seas with any decent chance of surviving. It would seem clear that, unless the submarine is swept from the seas, it is hopeless to build a large tonnage of slow moving, relatively small and inadequately defended ships, as the net tonnage which could be delivered by such a fleet of ships will be too insignificant to be of any material value. We would have bet on the wrong horse and lost; therefore, I hope that we shall have the foresight to build as large a number as possible of big, comparatively torpedo-proof cargo ships, as soon as possible.

We should also, at the same time, consider whether it is worth our while to continue building large dreadnaughts, battle-cruisers, and the like, which cannot possibly be finished for years to come. Our ship-building facilities are limited, and if the facilities now devoted to the construction of dreadnaughts could be immediately diverted to the construction of large, indestructible, high-speed cargo ships, which can be built in half the time, we would be taking a great step towards solving the problem.

So much for what might be termed the "defensive method" of attacking the problem. Along with this defensive plan, we should put into execution every practical offensive plan of attacking the submarine, such as methods of detection when submerged, methods of attack by means of destroyers, mines, aeroplanes and special artillery. All such methods should be, and probably are being, developed, and while no one of them will prove to be the panacea by itself, collectively they will be of the greatest value in reducing the menace. However, I think it is well to emphasize the fact that the only safe and sane plan of action is to assume that we can only win by pushing the development of all practical-looking methods of attack and defense at the same time and to the limit of our ability.

Now I am well aware that there is nothing theatrical or startling, or novel, in the above suggested solution. For this reason it is not likely to appeal to the great non-technical public; but there is no doubt in my own mind that it represents the scientific and commonsense method, and that if followed with patience, persistence, vigor and diligence, it will prove successful, and if successful, the war cannot be lost. All the other problems of the war—the aeroplane, Army, Navy, food, manufacturing, farming, transportation, etc.—can be successfully solved by the same scientific, but simple and common-sense methods.

It is a great satisfaction to notice that this country has at last awakened to the importance of developing that great American invention, the aeroplane, and of manufacturing it on a great scale. We should do everything to help to accelerate this work. If we can get aeroplanes of the right kind to Europe soon enough and in sufficient quantities, experts tell us that it will do more to win the war than a large army.

We must also not neglect the development of the submarine, because if we fail to find a way to drive the submarine from the seas in short order, and fail to make relatively unsinkable and uncatchable ships, we may have to rely on big freight submarines, properly convoyed by fighting submarines, if necessary, in order to get food, material, and soldiers to Europe.

We must not forget that, after all, all these things must be done by men collectively, and that, therefore, it is essential for us to think and act collectively, and with reasonable unanimity. We must co-operate and not nullify our power by quarrels among ourselves. This means that we must be willing to give consideration to the views of others, be ready to make reasonable compromises and be constantly actuated by a spirit of conciliation. We must make every effort to get men of great experience, industry and sound common-sense in positions of trust and influence. We can then hope to have the helpful suggestions offered by other men of experience and wisdom given intelligent and proper consideration. We must give our chosen leaders reasonable time to make and carry into execution their large plans, and if after a long and fair trial, we find that we have made a mistake in our selection we should then promptly replace such leaders by those more competent, who will surely be found. This is the only way in which a democracy can work and form an effective and efficient organization.

I think I have said enough to indicate that there is plenty of work for engineers at home, as well as abroad; in civil life, as well as camp life. Engineers have a great opportunity in this way and a heavy responsibility. You have special knowledge, experience, and a forward looking point of view which the country needs, and it is your duty to see to it that you are given the opportunity to make effective use of your talents in the service of the Nation, and if you are not given that chance, you must persistently demand it until you get it, and then I feel certain that the victory will be on our side; our civilization will be saved, and the world will be made a safe place for all decent people, and those who survive will be able to turn again to the satisfaction and joy of a useful and peaceful existence.

METHODS FOR MORE EFFICIENTLY UTILIZING OUR FUEL RESOURCES

Coal and oil are fundamental necessities for carrying on war. The Navy, transportation by land and sea, and the manufacturing industries, as well as the welfare of the people, are dependent upon an ample supply of fuel for power, heat, and light. The producers and the transportation systems of the country are now overwhelmed by the demand for fuel. This exigency demands that the fuel users give immediate attention to the seriousness of the situation. In the series of articles, of which this is the first, we shall endeavor to "do our bit" by stimulating the development of improved methods of producing power and also by presenting in a convenient form such information and description of methods as can be applied by the fuel user to alleviate the situation. —Editor.

Part I

THE USE OF LOW-GRADE MINERAL FUELS AND THE STATUS OF POWDERED COAL

By F. Parkman Coffin*

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In this first installment of the series the distribution of the coal deposits in North America is described and attention is called to the fact that certain sections of the continent at a distance from the coal mines have large undeveloped deposits of low-grade fuel. Reference is made to the other low grades of coal which are produced as by-products of mining. The solid mineral fuels are treated in the following order: peat, lignite, bituminous coal, and anthracite. The methods of burning each of these fuels are reviewed: viz., burning on grates, in gas producers, and in pulverized form. The relative advantages of each method are discussed in detail.—Editor.

The efficient utilization of our fuel supplies is a subject of constantly increasing importance. Interest in this subject in America has usually been confined to the advocates of the conservation of our natural resources. The fuel supply is still abundant and it has usually been cheaper to burn high-grade coal, or fuel oil, than to bother with peat, lignite, or some of the poorer grades of coal containing a high percentage of ash. In some mining districts a portion of the coal is regarded as refuse and is either burned to get rid of it, used for filling, or thrown on the culm piles.

The reserves of bituminous coal and lignite in the United States are immense; but the supply of some of the higher grades, such as coking coal and anthracite may be exhausted during this century.

(1) "The unrestricted use of our better grade fuels and the ruthless waste and neglect of fuels that should be of real commercial value are phases of our national extravagance that are little short of appalling. The Bureau of Mines has repeatedly called attention to the rate at which the supplies of high-grade fuel are being depleted, and the need of investigations to ascertain how waste in their mining and utilization can be lessened or prevented."

Wastage of Coal in Mining

(2) "The amount of impure coal in nearly every coal bed in the United States varies from 10 to 50 per cent, averaging 25 per cent. At present all of this is thrown away, though much of it could be used for the making of gas for gas engines. Due to faulty mining, bad engineering, the falling of roofs, 'squeezes,' 'creeps,' and 'crushes,' approximately another 25 per cent of the coal present in the mines is never taken out and is thus lost. In other words about 50 per cent of the coal present is wasted or unused, and never to be regained. The wastage in a mine is anywhere from 40 to 70 per cent. 'If the wasteful methods of the past are to continue,' says I. C. White, 'if the flames of 35,000 coke ovens are to continue to make the sky lurid within sight of the city of Pittsburgh, consuming with frightful speed one-third of the power and half of the values locked up in these priceless supplies of coking coal, the present century will see the termination of the American industrial supremacy in the iron and steel business of the world,' "

In spite of immense resources we are now face to face with a serious coal shortage, owing to limitations of transportation and of labor at the mines. At the same time there is an unprecedented demand for coal to operate the industries of the country and for war purposes.

With the coal mining region in Belgium and northern France occupied by the enemy, and with coal exports from England largely curtailed to meet the demands of the war, the United States is expected to meet the deficit by exports to Europe and South America.

These conditions have resulted in an unprecedented increase in the price of coal

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*Mr. Coffin will be pleased to receive communications on the subject matter of this article.

and often in a decrease in the quality obtainable. Owing to shortage of mine labor, the coal is sometimes less carefully cleaned.

Parts of the country distant from supplies of high-grade fuel should endeavor to utilize their local resources to a greater extent than heretofore, in order to eliminate the expenses and uncertainties of transportation. Also the development of low-grade fuel deposits should be stimulated and established on a permanent basis.

The production of high-grade coal and petroleum is more or less localized, but nearly every section of our continent has local fuel resources within moderate distances of points of consumption. Low-grade fuels are those which have a low calorific value due to the presence of impurities such as ash and moisture. Fine screenings and dust produced in preparing certain high-grade fuels for the market may also be included since it is often difficult to burn them on the grate, when using forced draught, even when mixed with lump coal.

PEAT

None of our important natural resources has been more talked of and less utilized than peat. The amount of combustible matter in the world's peat deposits exceeds that in all the known coal fields.(24) Commercially available peat bogs are quite abundant throughout the glaciated portion of the continent east of the Dakotas and, probably, throughout the greater part of northern Canada. The southern boundary of this area includes the tier of states along our northern border, and approximately as far south as the latitude of New York City. Peat deposits are also of frequent occurrence along the Atlantic coastal plane from New Jersey to Florida, and along the Pacific coast in places where the rainfall is sufficient to maintain swamps on poorly drained land.

The greater portion of this territory contains no deposits of merchantable coal. Only along the southern border of the glaciated area in the United States do coal or oil deposits occur, and the oil is too valuable for use as crude fuel.

In northern Europe also, peat is abundant throughout the glaciated area, and considerable developmental work has been done there on methods of utilizing peat.

(3) "The most serious difficulty in producing peat fuel on a large commercial scale is the necessity of eliminating from the raw material the large percentage of water it contains. This may constitute considerably more than 90 per cent of the weight of the peat in an undrained deposit and is seldom less than 85 per cent in well drained bogs. This water, because of the mechanical structure of the partly decomposed vegetable matter with which it is associated and the peculiar chemical compounds of which it forms a part, can not be cheaply and quickly pressed out of the peat even by the use of great mechanical force. The mechanical extraction of water from peat has been attempted by inventors and students of peat problems for more than 50 years. Many types of presses have been used, but with no practical success."

Uses of Peat in Europe as Fuel

(3) "For centuries peat has been extensively used for domestic fuel by the peasantry of northern Europe. It has long been the custom there to cut the peat from carefully drained deposits in brick-shaped blocks by means of specially shaped spades and knives and to dry these blocks by exposure to the heat of the sun and air during the short summers. More recently the quantity of peat mined has been increased, and the quality, and therefore the efficiency of the fuel produced has been greatly improved, so that it can be used to produce powder. These results have been attained by the improvement of the machinery for digging and grinding the raw peat, for shaping it into blocks of convenient size, and for spreading out the blocks thus formed to dry on the surface of the bog or on special drying grounds. By far the greater part of the peat fuel used in Europe is produced by some modification of this process of air drying the wet peat. Fuel thus prepared is called 'machine peat.' "

Peat as Fuel for Steam Plants

(4) "There now seems no question that it is entirely practicable to use peat as a fuel for steam boilers if the boilers used have furnaces properly designed for this particular type of fuel and if the raw supply is located where there is a market for power. In northern Germany, at the Wiesmoor, near Aurich, there is a very large central electric-power station entirely fired by peat fuel which distributes electricity over a radius of some 25 miles and which is reported to be entirely successful from every point of view. Moreover, in the regions of Germany where brown coal is mined it is common practice to burn the raw unconsolidated fuel as it comes from

the mines, containing as high as 60 per cent moisture, under boilers having furnaces and grates of special construction. This fuel is only slightly different from half-dry, untreated peat in appearance and physical structure; and if the brown coal is successfully used, there is no reason apparent why partly dried crude peat could not be used to nearly as good advantage for generating steam if the boiler furnaces and grates were correctly designed."

Powdered Peat

(3) "Powdered peat is made ready for use as fuel by crushing and grinding machine peat blocks after they have been dried down to about 35 or 40 per cent moisture by exposure to sun and wind. The crude powder thus obtained is screened and then heated in rotary driers until the peat contains only about 15 per cent of moisture. After this treatment, the powder may be used for firing steam boilers by burning it in blast burners of a design suitable to give the most complete and efficient combustion. Good peat thus treated is reported to give nearly as much energy in the form of live steam as the same weight of good English coal, and in Sweden, where the tests were conducted, at a less cost per ton of fuel.

"The production and use of powdered peat for fuel are still in the experimental stage, but, if the report of officially conducted tests are to be relied on, have very considerable possibilities, not only for boiler firing but for metallurgical work, such as smelting and refining, and also for use in cement and other kinds of kilns, such as have already been successfully fired by burning powdered coal."

(4) "The factory at which it is produced in Sweden is reported to be turning out from 10,000 to 12,000 tons of dry peat powder per annum. It has also been successfully used in railway locomotives."

Producer Gas from Peat

(3) "Peat consumed in any properly designed gas producer yields producer gas good in quality and abundant in quantity in comparison with the yield from coal. This seems to be the most effective way to use peat fuel for generation of power, because fuel so used does not need as careful preparation nor as thorough drying as when it is to be used under steam boilers. The gas producers can be located at the bogs and the gas generated can be converted into electric energy by the use of gas engines and transmitted to centers of consumption more cheaply than the fuel can be transported. If this procedure does not seem desirable, the producer gas can be piped long distances and used for firing steam boilers, for metallurgical work, for firing kilns, or in gas engines.

"Several European manufacturers of gas producers have developed gas-producer plants for using peat fuel that have been in commercial operation long enough to demonstrate their practical value. Such plants have been used successfully in England, Ireland, Germany, Sweden, and Russia for the generation of electricity for light and power and also to furnish power directly for various manufacturing industries." (24)

By-product Gas Producers

(3) "Peat, in comparison with coal and lignite, contains a large percentage of combined nitrogen in the form of decomposable organic compounds. In much peat this nitrogen exceeds 1.5 per cent of the dry weight of the peat, and in some it is as much as 2.5 or 3 per cent, or in the proportion of 50 to 60 pounds to the ton.

"In the early stages of gasification of fuels in gas producers the more volatile substances are given off in large volume from the less strongly heated parts of the fuel. Among these substances is the ammonia generated by the decomposition of the nitrogen compounds. If the ammonia thus liberated is heated too hot, however, it is in turn decomposed into its constituent elements and is lost. By keeping the fuel bed in the gas producer at temperatures so low that the ammonia is not destroyed and yet high enough to decompose the rest of the fuel into burnable gases, at least 75 per cent of the ammonia may be separated from other gases during the purifying process or scrubbing necessary to prepare producer gas for use in gas engines and may be fixed in permanent compounds. The fuel bed is kept at the low temperature necessary for getting a large yield of ammonia by the introduction of steam at proper intervals and the ammonia is made to combine with sulphuric acid by bringing the gases with which it is mixed into contact with the acid in the form of a fine spray. The ammonium sulphate thus formed passes into solution in tanks or receptacles provided for the purpose, from which at intervals it is drawn off, crystalized, filtered, and purified. By-product gas producers are used only in plants in which 2,000 or more horse power is to be generated, because the returns in ammonia are too small to be remunerative in smaller plants.

"Other chemical compounds of value, including tar of good quality, may be recovered in purifying producer gas, but, as in peat-coking plants, the chief by-product sought is the ammonia. The tar is next in value, where a market can be found for it.

"The process of recovering ammonia from gas producers using bituminous coal was first developed by Sir Ludwig Mond, in England, and later was extended by the company controlling his patents to the gasification of peat. There are now in operation in England, Germany, and Italy large gas-producer power plants that use peat fuel exclusively and that are reported to pay all operating expenses from the sale of sulphate of ammonia recovered as a by-product, thus obtaining free the gas and the power generated by its use. One plant of this type in Italy makes no use of the gas generated beyond supplying its own requirements for power and heat, but depends entirely on the ammonia recovered for its profits. The statement has frequently been made that peat containing 1.5 per cent or more of nitrogen will yield a good profit from the ammonia which may be recovered by this method of gasification."

Peat as a Source of Ammonia

"Peat beds are therefore important potential sources of the most costly ingredient of modern chemical fertilizers, sulphate of ammonia. As the peats of the United States show, from carefully made analyses, that they are very rich in combined nitrogen, in comparison with the peats of Europe, many of them exceeding 2 per cent and some containing more than 3 per cent of the total dry weight, it would seem that a highly profitable industry could be based on them, especially when the value of the power gas to be derived from the same sources is taken into consideration."

French Fuel Shortage

(5) "The fuel famine in France has directed attention to extensive peat bogs, heretofore despised, which may aid as much to solve the problem as the lignite deposits of the center of France, provided the question of labor is solved. The 'Grand-Briere,' near Saint Nazaire, and the region of Culoz, according to expert estimates, hold 80,000,000 tons of dried peat, affording an average of 2,000 calories (8000 B.t.u.) per pound, or about half the heating power of coal. Considering the greater facility of production, it is figured that one workman can extract a number of calories in peat far superior to the average production per miner from coal."

Peat Fuel in the United States

(3) "In spite of the facts that peat has so many uses in European countries and that the peat deposits of the United States are very extensive, the domestic material has only recently been produced on a commercial scale for any purpose.

"Many attempts have been made in this country to manufacture peat fuel, with almost uniform lack of success, The reasons for failure of such enterprises have been manifold, but so far as can be determined by careful inquiry the failure was not caused by inability to sell the product after it was made, but generally by other factors, among which may be mentioned inexperience of operators, impractical machinery, and lack of sufficient capital to carry the plant over critical periods.

"In 1914, so far as reported, there were four peat-fuel plants in operation in the entire country, with an estimated production of 1925 tons of air-dried machine peat. Of these plants, one had been operated more or less regularly for several years, but on a small scale, employing but three men during the working season of 1914. A second plant was wholly experimental and was in operation only occasionally. One of the other plants was not completed until late in the season, and consequently was in operation only a short time and with an unskilled force. The fourth plant reported a prosperous and satisfactory season.

"The outbreak of the war in Europe caused an entire suspension of plans for development of large plants for using peat fuel in Florida and Georgia. To the same cause may doubtless be attributed the closing of two very promising peat-fuel factories in Canada before the end of the season."

Other methods of utilizing peat for fuel consist in briquetting or coking it, preferably recovering the by-products. Technical success has been attained by several processes but commercial success has not yet been demonstrated.

Peat can be produced with a different class of labor than coal, and, if suitable arrangements can be devised for winter production, farm labor can be utilized during the part of the year when farms are idle and fuel is most in demand. Such arrangements would probably involve roofing over the portion of the bog to be used that season, and heating the building enough to prevent the peat from freezing and make working conditions tolerable. Fans might be used for drying. Also sunlight might be admitted for drying the peat when available.

LIGNITE

Lignite is peat which is of earlier geological formation and which has been buried under sedimentary deposits long enough to be partially transformed into coal. It is abundant in some of the western states. As the coal and peat deposits are much less extensive west of the 97th meridian, lignite is the principal fuel deposit for quite a large area of the country.

Extent of Lignite Deposits

(6) "The existence of vast deposits of lignite in the West Central and Western States is well known, although the extent and importance of the deposits have not been appreciated, nor has there been an adequate economic utilization of the deposits.

"The work of the Bureau of Mines, the United States Geological Survey, and the State Geological surveys is disclosing an increasingly large area, underlaid with this kind of coal. Among the states having the largest workable deposits may be mentioned North Dakota, Montana, Wyoming, Colorado and Texas, and in several other Western States lignite occurs in smaller areas. In North Dakota alone it is estimated that the deposits cover approximately 32,000 square miles, many of them being 10 to 15 feet thick and capable of producing in all several hundred billions of tons of lignite.

"When one stops to consider what these figures mean as to the immensity of these deposits in the West, it is not strange that people are seeking to ascertain better means for deriving larger benefits from the proper utilization of those great deposits. Consequently, any proposed methods of utilization that are promising are well worthy of careful consideration."

"As the Federal Government controls great tracts of land underlain with lignite, it has a direct interest in the utilization of this fuel, and the Bureau of Mines, in its investigations of fuels belonging to, or for, the use of the Government, has co-operated in the study of lignite."

Average Compositions of Different Western Lignites

(6) "The results of many hundreds of analyses of lignite samples made under the direction of the writer indicate that the average composition of Western lignites when dry is about as follows: Fixed carbon, 51 per cent; volatile matter, 39 per cent; ash, 10 per cent. The moisture in the lignites as mined is 15 to 35 or even 40 per cent.

"The average composition of North Dakota dry lignite is probably about as follows: Fixed carbon, 49 per cent; volatile matter, 43 per cent; ash, 8 per cent. The moisture in the lignite as mined is 25 to 35 per cent.

"In a general way it may be said that one ton of Western lignite when dry will equal 0.4 to 0.7 ton of Eastern bituminous coal, the exact comparative values depending on the particular grades of lignite and of bituminous coal used for comparison."

Effect of Moisture Content of Lignite

(6) "Lignite, especially in large blocks as mined, breaks up easily when exposed to air. Such disintegration is no doubt due in large part to the rapid evaporation of water, which constitutes 20 to 35 per cent of most lignite as taken from the mines. The larger part of this moisture escapes rapidly and causes thereby checking and splitting of the lumps, eventually converting piles of lignite lumps into slack. This slacking is one of the greatest difficulties to be overcome in the commercial handling and utilizing of lignites and seems to be a general characteristic of the deposits throughout the West.

"The cost of shipping coal containing so much moisture is high, and the moisture content causes a corresponding reduction in the efficiency of the fuel. It is, therefore, important that the moisture be removed before shipment. However the tendency of the coal to form slack when burned, even after the moisture has been removed, presents another difficult problem. As a result, the utilization of lignite has been confined to comparatively narrow regions near the deposits. The utilization of this coal would be enormously stimulated could it be satisfactorily and economically converted or concentrated into fuel free from moisture and of a size and strength adapted to general commercial uses; hence the development of some economical means of briquetting lignite is highly important."

"A universal mistake is made in burning lignite coal of too large a percentage of moisture, which seriously interferes with the heating power of the fuel. If the lignite could be seasoned and broken into lumps of uniform small size before it is put on the market, the popularity and real value of the lignite would be greatly increased. Lignite that has been broken before drying does not slack as badly as when left to dry in large lumps. When the large masses dry the evaporation takes place from the surface and causes the masses to split into thin, small pieces. If the large lumps are first broken to about 3-inch size and then allowed to dry, the loss in slack is much reduced."

Firing Boilers with Lignite

(6) "For steaming purposes there is no doubt but that great improvement could be made in the methods generally employed. Many firemen in using lignite quite overlook its peculiar physical and chemical characteristics, such as its tendency to slack in the fire box, its lack of density, its non-coking qualities, its high percentage of moisture, and its richness in light volatile gases, and endeavor to operate their furnaces much the same as they would in the use of ordinary bituminous coal. The result is a high fuel consumption, extra labor costs, and loss of boiler efficiency. But when the peculiar characteristics of lignite are carefully considered in the selection of boiler grates and combustion chambers, and in the methods of burning, a great saving can be effected.

"A matter of fundamental importance in any successful method of using lignite is the proper consumption of the large volume of light volatile gases present in all lignites. In the ordinary furnace and boiler construction the heating power of a considerable proportion of these gases is insufficiently utilized or they pass out with the flue gases almost entirely unburned.

An especially successful utilization of lignite and lignite waste was made by Mr. C. L. Larsen, chief engineer of the Hughes Electric Co., of Bismarck, North Dakota. Referring to the fact that many people do not economically burn raw lignite, Mr. Larsen says:

"They have not learned the real value of lignite or how to obtain the best results. Some people will order a few sample carloads and before the fireman has used half a car of it he will condemn the coal, and, if the engineer has had no previous experience in burning lignite he will soon fall in line with the fireman, with the result that the lignite is rejected entirely.

"To break up lump coal to 1-inch and 2-inch sizes requires too much time and labor for the fireman; nevertheless this is the size that gives the best results when used with a forced draft—but not as strong a draft as some people think who complain of not enough draft.

"The ideal furnace condition is that of supplying just the amount of air necessary for complete combustion of the fuel; and the combustion should be nearly complete in the furnace, which can not be done with natural draft.

"I am very much in favor of a balanced draft. A balanced draft is obtained by regulating the air pressure under the grates and the dampers in the smokestack to such an extent that the pressure in the furnace is the same as that of the outside atmosphere.

"It is not easy to maintain a balanced draft as the thickness of the fire and the demand for more steam interfere with the adjustment of the dampers in the stack and the blast gates; but it is advisable to keep the draft as nearly balanced as possible for the reason that the fire doors must be opened rather frequently in burning lignite, and if the draft is too strong more air than is needed is supplied, and the excess air reduces the temperature of the furnace. This is proved by analyzing and taking the temperature of flue gases resulting from the use of a balanced draft. We can maintain from 14 to 16 per cent CO_2 and a flue-gas temperature of 450 deg. F. But, by opening the damper enough to produce a 12/100-inch water draft and then opening one of the fire doors, in a short time, less than 10 seconds, the CO_2 will drop to 9 per cent; this indicates that about 20 per cent excess air is admitted to the furnace."

Importance of High Temperature in Furnace

(6) "The temperature of flue gases is deceiving when lignite is being burned, as it burns much like wood.

"In the burning of coal, decomposition always precedes combustion; hence the greater the amount of volatile combustible contained in the coal the greater the flame volume and the greater the length of flame, and the probability of greater loss by the low temperature of the flame. As our lignite contains much volatile matter and is low in fixed carbon, an excess of air will rush the flame through the boiler and produce a low temperature of flue gases, also a low temperature in the furnace.

"In order to obtain a high efficiency from lignite, a high temperature is required in the furnace, and this can be obtained by a suitable grate. I have found that a flat saw-dust grate with ½-inch round holes gives the best results. Such grates contain only 15 per cent air space, but by having small openings we can maintain a higher air pressure in the ash pit, and the air passes through the small holes and through the bed of fuel at a greater velocity, which produces a high temperature in the furnace, and as the volume is small, the heat is not rushed through the boiler and up the smokestack, but is absorbed by the water in the boiler, and a low temperature in the smokestack is obtained.

"Under such conditions with a good boiler and setting, a pound of lignite containing 35 per cent moisture, 6 per cent ash, and 7,000 B.t.u. will evaporate nearly 5 pounds of water per pound of fuel.

Boiler Should Not Be Crowded

(6) "Such results can be obtained when a boiler is not crowded above its rated capacity, say 3 pounds of water per square foot of heating surface, as we can not force a boiler much over its rated capacity with lignite.

"It is therefore advisable not to burn lignite under boilers that are forced as can be done with good Eastern coal. We can force a lignite fire to burn 60 pounds of coal per square foot of grate surface per hour, and not make any more steam than when burning 50 pounds per square foot of grate surface, owing to the excess air which has carried away 10 pounds of coal per square foot of grate surface, or 70,000 B.t.u. with a boiler having 30 square feet of grate.

"Some excellent investigations as to the proper use of lignite as a fuel for power-plant boilers were carried on by Randall and Kreisinger. The conclusions reached were that for best results the lignite should be reasonably low in moisture and that the combustion chamber should be sufficiently large and of such construction that the light liberated gases should be retained and heated to combustion temperature before being permitted to pass out as flue gas.

"For the tests mentioned, a modification of the so-called Dutch-oven type, a sort of semi-producer style was adopted. This combination of boiler and furnace setting gives good results with North Dakota lignite. Steam can be made with a fuel efficiency of 55 to 58 per cent of the heat in the coal, and no difficulty is experienced in obtaining the full capacity of the boiler."

(7) "As the content of volatile matter and moisture in lignite is higher than in bituminous coal, the difficulties encountered in burning them are greater. A large combustion space is required and the best results are obtained where a furnace of the reverberatory type is used, giving the gases a long travel before meeting the tube surfaces."

Mechanical stokers have recently been developed for burning lignite.

Use of Pulverized Lignite

(5) "There is little doubt that the most perfect combustion of highly gaseous coals like lignites could be brought about by burning the pulverized material in a porperly constructed combustion chamber in a draft of air. Such a method, to a limited degree, has been employed with bituminous waste for years in connection with several industries in which large ovens are used, but the machinery and appliances required have hitherto been too large and costly to permit their general adoption in small heating or boiler plants. There seems no good reason why some satisfactory method of using lignite in this manner in small plants can not eventually be evolved. Pulverization of highly gaseous lignites produces fuel with properties closely similar to those of crude petroleum or crude gas; in fact, pulverized highly gaseous coal like dry lignite, when fed into a furnace with an air blast, gives very largely a gaseous fuel.

"With the temperature of the furnace or combustion chamber once at the proper point, by means of valves the relative supply of coal and air can be regulated so quickly and so perfectly that nearly complete combustion of the heat-producing constituents can be obtained. Besides, with the proper equipment, the feed and the fire should be closely uniform, almost automatic, and requiring comparatively little work from the fireman. When dry pulverized lignite can be used in small boiler settings to advantage, there is no reason why it should not produce a relatively high heating efficiency, for, in a proper combustion chamber, besides the combustion of fixed carbon, this method would utilize nearly all of the volatile gases, which have high calorific power, a proportion of which is lost by the ordinary methods of combustion to which lignite is subjected.

Producer Gas from Lignite

(6) "For the production of power in moderately large plants, it is clear that lignite coal can be used to advantage by converting it into producer gas and using the gas in an internal-combustion engine. During the past 10 years considerable progress has been made

in the adaptation of producer plants for the use of lignite, and the results obtained in commercial plants scattered over several of the lignite States, and in tests made by the Government indicate that this method of utilizing lignite can be successfully and economically employed in many instances and that there is an opportunity for considerable expansion in the use of this type of powe producer.

"Under the simple conditions required for boiler heating, it is questionable whether any advantage is to be obtained by the use of producer gas except, possibly, where low-grade fuels are burned. There are many fuels that can be utilized to advantage in the gas producer that can not be employed in direct steam-boiler firing.

"Producer gas from lignite would undoubtedly make a highly satisfactory fuel for use in burning brick and other clay products and, although it has not been so utilized to any great extent up to the present, it is, however, attracting the attention of the manufacturers of such products."

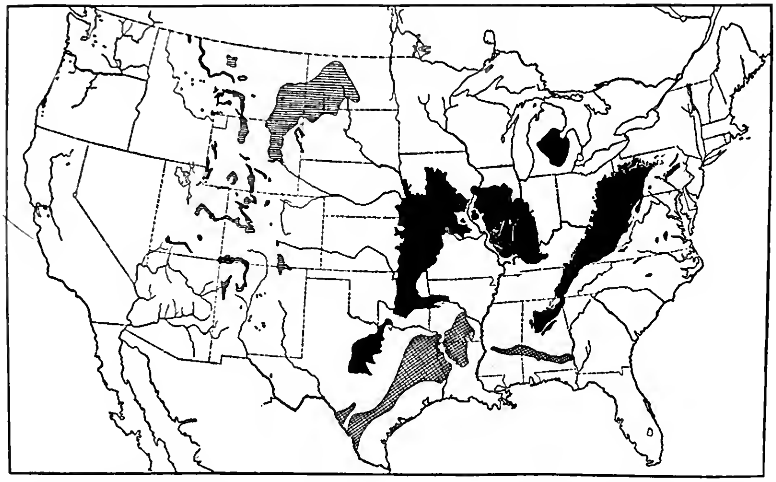


Fig. 1. Map showing Coal Fields of United States. Black areas represent older coal fields and shaded areas younger coals and lignites

Briquetted Lignite

(6) "At the present time undoubtedly by far the largest use of lignite is for domestic purposes—in heating plants, stoves, ranges, etc. For such use most of the lignite is supplied in sizes ranging from large lumps to pieces about the size of those in slack, careful sizing being employed rarely. The lignite is generally used in the most simple manner. Few special methods for burning or utilizing the lignite or for specially preparing it for the market have been adopted. However, there can be little doubt but that for most purposes, particularly for general stove and furnace use, briquetted lignite would be the most desirable form in which the lignite could be presented on the market; and lignite briquets of good quality and at a reasonable price should prove a most satisfactory and profitable fuel. Considerable success has been attained in the briquetting of both anthracite and bituminous coal wastes, and the lignites of Germany have been briquetted with some degree of success. But the briquetting of anthracite and bituminous coal waste is an entirely different problem from the briquetting of lignite, and the difficulties to overcome are comparatively simple. The German lignite also is of such character and composition that it can be briquetted with comparative ease. Furthermore, when binding materials are required for the German lignite, such materials and the labor necessary can both be obtained at a much lower cost in Germany than in this country.

"However, the process briefly explained (in Bulletin 89) is proving so successful in the experiment plant that there now seems little doubt but that if a briquetting plant, in conjunction with a gas-producing plant, is operated according to the principles and methods described, a variety of by-products can be saved and utilized, and the residue, after the gas has been driven off, can be successfully briquetted into a concentrated and valuable fuel."

BITUMINOUS COAL

Fig. 1 (²) is a map showing the older coal fields of the United States in black and the younger coals and lignites in shaded areas.

The highest grades are obtained from deposits in the great Appalachian field extending from northern Pennsylvania and Ohio to central Alabama. The "semi-bituminous" coals occur in a narrow strip on its eastern border, and west of this strip occur the best varieties of gas, steam, and coking coals.

Next in importance is the Illinois or Central Field which extends into Indiana and Kentucky and which contains a great variety of bituminous coals. Third, in order, comes the Missouri field which extends from Iowa to Texas. The coals of this field are mostly of a poor quality. Michigan has a smaller field of poor quality. Wyoming, Colorado, New Mexico, Utah, Washington, British Columbia, Alaska, and Nova Scotia produce bituminous coal also.

The "semi-bituminous" coals have the highest calorific value, ranging from 14,000 to 15,600 B.t.u. per pound. They are in great demand as steam coal for the Navy and for the railroads; also for long distance shipments and for export as the freight charges are naturally less on the basis of heat value. Much of it goes to New England and the northwest. New River and Pocahontas coal from West Virginia and Virginia, George's Creek coal from Maryland, and Cambria and Clearfield from Pennsylvania are well known varieties. Low ash and moisture content account for the high heating value of these coals. They are preferred for hand-fired boilers, and the fines and slack are used for stoker-fired boilers.

Mechanical Stokers

Mechanical stokers can handle much poorer grades of coal than can be burned satisfactorily by hand firing, and with less smoke. The underfeed types are capable of burning bituminous coal with considerable ash, especially if steam be injected upon the clinkers which fall against the bridge wall and side walls to prevent them from adhering to the bricks, but the output of the boiler is reduced in proportion to the leanness of the coal. Power operated ash dumps are also effective for handling large amounts of ash and for breaking up clinkers.

Some low-grade western coals are burned on chain-grate stokers which are adapted to handle large percentages of ash. In some of the central states large power stations are burning coal on this type of stoker with as low a calorific value as 9000 to 10,000 B.t.u. and a high percentage of volatile matter. Large combustion chambers and long paths for the gases to travel before being chilled by contact with the tubes are necessary.

THE GAS PRODUCER

The gas producer and gas engine have been widely advocated as the most efficient combination for the production of power from solid fuel. Producers have been developed for gasifying almost any kind of solid fuel and some English manufacturers claim that their producers will gasify colliery refuse containing 45 to 55 per cent ash. The better practice, however, is to wash the refuse before using it, which will reduce the ash content from an original value of more than 50 per cent to about 25 per cent in the final product.

The gas producer has limitations similar to those of the steam-boiler furnace in that its maximum output is roughly proportional to the heat value of the coal used. Therefore, low-grade coals require a larger grate area for a given output.

Mr. R. H. Fernald comments, in part, as follows on European practice:

(¹) "One of the most serious difficulties encountered in the use of high-ash fuels is excessive clinkering. The interruptions from such clinkering and the failure of the plant to develop rated capacity for continued periods make the satisfactory use of such fuels questionable. The attempt to use these poorer grades of fuel is not new, but their commercial application on a scale large enough to make their use really worth while industrially, and on a scale large enough to be a real factor in economic fuel utilization, is a recent development.

"The demand for a gas producer to handle all grades of fuel, especially those grades usually sent to the dump, has recently brought to the European market the revolving eccentric-grate producer. This producer appears in several forms, the superiority of each form being firmly established in the minds of its advocates.

"Experience with European fuels has shown that even with the eccentric revolving grate and the usual producer-shell construction clinker troubles are not entirely eliminated when a low-grade fuel with low ash-fusing temperature is used. A further important feature—probably the most important single item—for overcoming clinkering and the tendency of the ash to fuse with the producer lining is water jacketing the part of the producer shell surrounding the hot zone.

"The cost of construction of these revolving-grate jacketed producers is necessarily high, and a direct comparison of their cost with the simpler stationary-grate jacketless type is of course detrimental to the former.

"During the past five or six years many installations of these producers have been made in Germany and other continental countries for gasifying low-grade fuels that have heretofore been neglected. Indifference to the use of high-ash clinkering fuels has been equally marked in England, but within the past few years a notable change in attitude toward this problem is evident, and several installations have been made for the express purpose of utilizing low-grade material.

"An engineer of London, however, who seems vitally interested in the greater economy desired in the use of our fuel resources, believes that for the present the commercial solution is not in the use of low-grade fuels, but in the more efficient use of the better grades. With the eccentric revolving grate producer he believes it quite possible to handle almost any fuel, but the commercial economy is so low with the poorer grades, as the capacity of the plant is so greatly reduced, that he believes it to be a serious financial loss to use anything but good fuel. He does, however, feel that tremendous savings can be made in the processes now in vogue, and is studying several devices that he believes will be of material aid in the solution of the problem. He intimated that the greatest development connected with the economic utilization of fuel is in the United States and that there is little new in this field in England. He believes that powdered fuel is perhaps the most promising solution of our fuel problems."

Use of Colliery-Refuse Heaps as Fuel

(1) "A large plant in connection with a colliery and iron works equipped with eccentric-grate producers was reported by the producer representative to be using high-ash 'batts.' On visiting the plant, however, the author found that the producers had not been operating upon 'batts' for some time, although the general manager was seriously interested in the use of waste material and in the economies that are essential today in a well operated plant. He believes that sane and practical efficiency in a large manufacturing plant requires careful consideration of the power-plant economy and the reduction of the fuel cost to a minimum.

"The colliery-refuse heaps in that vicinity have been accumulating and standing unused for years. A few years ago he began using selected 'batts' from these dumps; that is, the larger pieces of shale containing a good percentage of coal. He has put in a crusher at the dump and is crushing the larger material and mixing in the fine, so that the whole dump is being reduced. This material is not used directly in the producers, but is sent first to the washers, and the washed coal is used; 115 tons of the unwashed material give 60 tons of numbers 1, 2, and 3 nuts and 40 tons of slack. This material was reported as containing about 25 per cent ash when used in the producers.

"Samples taken at the time of the inspection of the plant and sent to the Washington office of the Bureau of Mines were analyzed. The calorific value averaged about 10,200 B.t.u. per pound."

An interesting installation of Mond gas producers for utilizing colliery refuse at the mine, and burning the gas under the boilers of a steam-turbine power station, will be described in a forthcoming issue of the General Electric Review in an article on "The Fushun Colliery of the South Manchuria Railway."

The Status of Gas Engines and Producers

(8)"The large gas engine continues to lose ground as a prime mover for central-station work. At the present time gas engines are not being installed except where local conditions are particularly favorable to their use.

"In the majority of localities where steam coal can be purchased at reasonable cost the large gas engine cannot compete with the modern steam turbine, in spite of its low fuel economies. The steam turbine, combined with the steam generating equipment has made such rapid advances in the last few years in generating capacity per unit and simplicity of installation, that the fixed charges on steam installations have been very materially reduced. These low fixed charges of the steam plant are so much below the fixed charges on a gas engine installation that they more than counterbalance any operating economies obtained from the generation of gas power.

"Where however an abundant supply of natural gas, by-product coke oven gas, or blast furnace gas is available at an extremely low cost, and in those sections of the country where the price of steam coal is prohibitive, installations of gas engines are still attractive.

"The development and adoption of the gas producer as a method of utilizing solid fuels for power purposes has been a disappointment in many respects. The anthracite and lignite producers have been successfully developed and are installed in those localities where such fuels are available at reasonable cost. The bituminous producer, however, has made practically no advance. This is due to the fact that the recent development in steam boiler construction has given the boiler similar advantages over the producer that the steam turbine possesses over the gas engine. These advantages are large capacity per unit, low first cost, simplicity and flexibility of operation, ability to carry high overloads for an extended period of time, and low labor cost."

In plants of 2000 h.p. and upwards, the recovery of ammonia and coal tar may be profitable when burning high grades of bituminous coal. In this case the gas may be considered the by-product and burned under steam boilers, or utilized for industrial heating. Colliery refuse and some low-grade coals, however, are too poor in by-products to be profitably utilized in this way.

Gas firing has many advantages over the burning of coal on a grate, such as cleanliness, ease of instantaneous control, saving of labor in cleaning fires, and in firing (except in the case of mechanical stokers). When generated in a producer, the plant as a whole has the disadvantage of having fire in two places with consequent inefficiency and expense, both in first cost and in maintenance and operation.

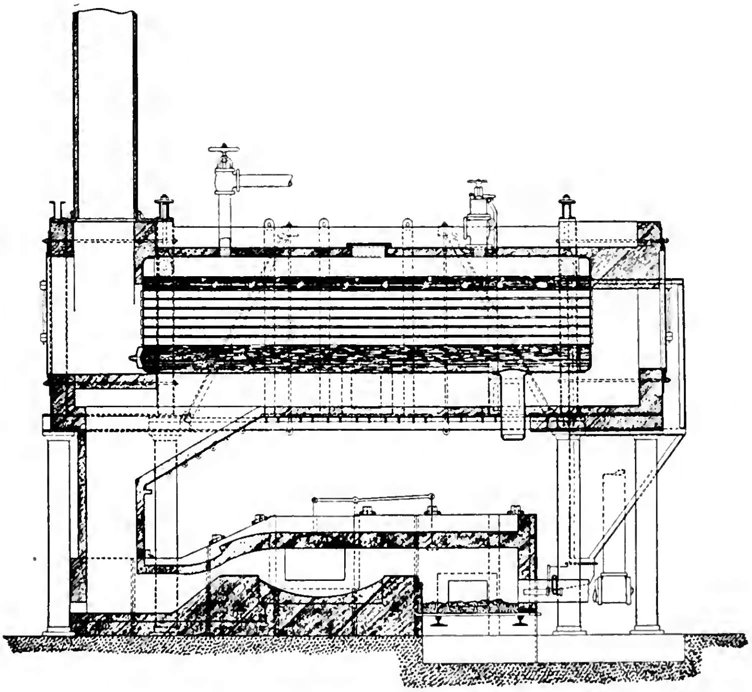


Fig. 2. Puddle Furnace Fired with Powdered Coal and Equipped with Waste Heat Boilers

POWDERED COAL

Coal can be pulverized more cheaply than it can be gasified and the first cost of a plant for drying and pulverizing is less than for a producer-gas plant. When thoroughly mixed with a blast of air in correct proportion, it is practically a gaseous fuel. Powered coal firing has most of the advantages of gas or oil firing for steam boilers, when properly applied, and in industrial heating its field of application is constantly growing.

The principal difficulty is in connection with the ash produced in the flame. This is often the feature which limits the practicability of powdered coal firing for industrial furnaces.

It has been used in the Portland cement industry, since 1895, (11) for firing rotary kilns. In this application there is plenty of space for complete combustion in the long kiln lined with hot fire-brick. The constituents of the coal ash are elements which also enter into the composition of the cement, so it is only necessary to analyze the ash and allow for the addition of its constituents when mixing the charge of raw materials. The Atlas Portland Cement Company were the pioneers in this application.

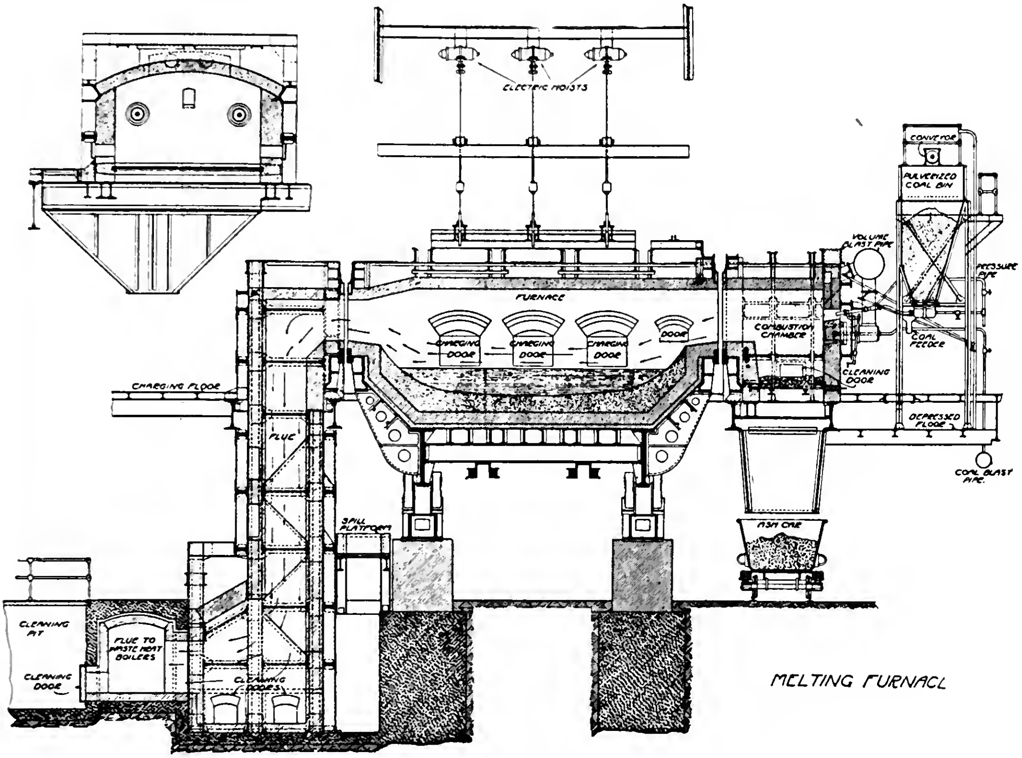


Fig. 3. Open-hearth Furnace Fired with Powdered Coal and Equipped with Waste Heat Boilers

The American Iron & Steel Manufacturing Company of Lebanon, Pa. was the first firm to use it in metallurgical furnaces on a large scale. Figs. 2 and 3 show a puddle furnace and an open-hearth steel furnace fired by powdered coal and equipped with waste heat boilers.

Mr. C. J. Gadd, Chief Engineer, says, in part: (9) "The process of burning powdered coal is the best method by which to obtain perfect chemical combination of the air and coal, and by which the highest degree of perfection in combustion may be obtained if properly applied. There is no other fuel so responsive to correct application. The greatest precision is required in its control, and it may be said that, so far as the art of burning powdered coal has been developed, it is perhaps in too great a measure dependent upon the human equation.

"The use of powdered coal as a fuel necessitates the installation of an efficient crushing, drying, pulverizing, conveying, and distributing equipment, and, in addition, ample storage room for coarse coal.

"From the time the coal leaves the dryer to its delivery in the furnace the whole system between these points should be dust-proof and the greatest care should be taken to prevent leakage. This should be guarded against systematically, as leaks, however small, may permit the surrounding air in the room to become impregnated with coal dust to such an extent that a serious explosion may result.

"Coal, after pulverizing, should be handled in bulk. All types of aerial propulsion and transfer in the form of dust clouds should be avoided, for the reason that accidental ignition may at any time wreck the whole system.

"The storage of powdered coal in large or small quantities for any length of time is not advisable, owing to its tendency to fire, collect moisture, and pack.

"In its normal state powdered coal is light and fluffy; after forty-eight hours' standing in storage, however, the physical arrangement of the particles produces a dense packed mass. So dense does the fuel become that one's fingers cannot make an impression even one-half inch deep. To meet ideal conditions, powdered coal should be kept in motion.

"With properly designed machinery and storage bins, having twelve hours' supply placed at each furnace, the coal may be kept in motion and repairs and adjustments made before the supply becomes exhausted.

"Low-grade bituminous coals, anthracite, lignites, and even coke breeze in a powdered form, can be burned with good results, certain types of heating furnaces now being operated with such fuels.

"It should be understood that the first cost of fuel used is not the correct index by which to judge of economy when fuel must be prepared and pulverized. Low-grade bituminous coals, being high in non-combustible content, cost more to pulverize than high-grade bituminous coals. Slack coal is preferable to other forms; it costs less, requires less power for pulverizing, owing to its fine state, and materially increases the capacity of the pulverizer.

"One of the disturbing factors in the use of powdered coal is that of the large accumulation of ash deposited within the furnace, only a small proportion escaping through the stack. When using even a good grade of coal, ash will accumulate rapidly, and therefore fuel of low ash content is always most to be desired.

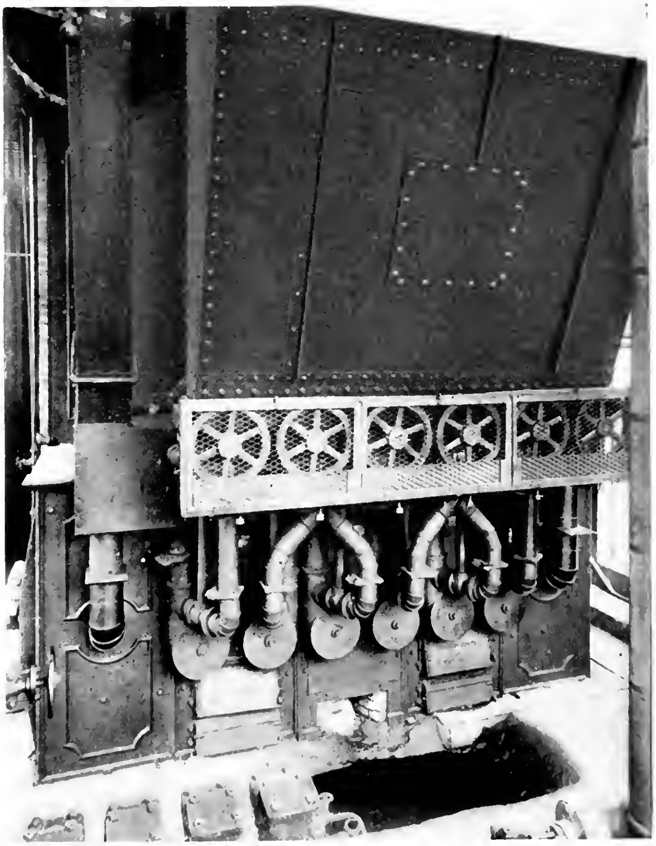


Fig. 4. Isolated Boiler at the Schenectady Plant of General Electric Company changed over from oil burning to powdered coal

"While the presence of sulphur in small quantities in powdered coal has no ill effect in heating and annealing furnaces, it should be given careful attention when used in the reduction and refining of metals or ores.

"Generally speaking, therefore, the fuel available for burning in metallurgical furnaces has a restricted range both as to species and quality. Only the best bituminous coals, high in volatile content and low in both sulphur and ash, are desirable.

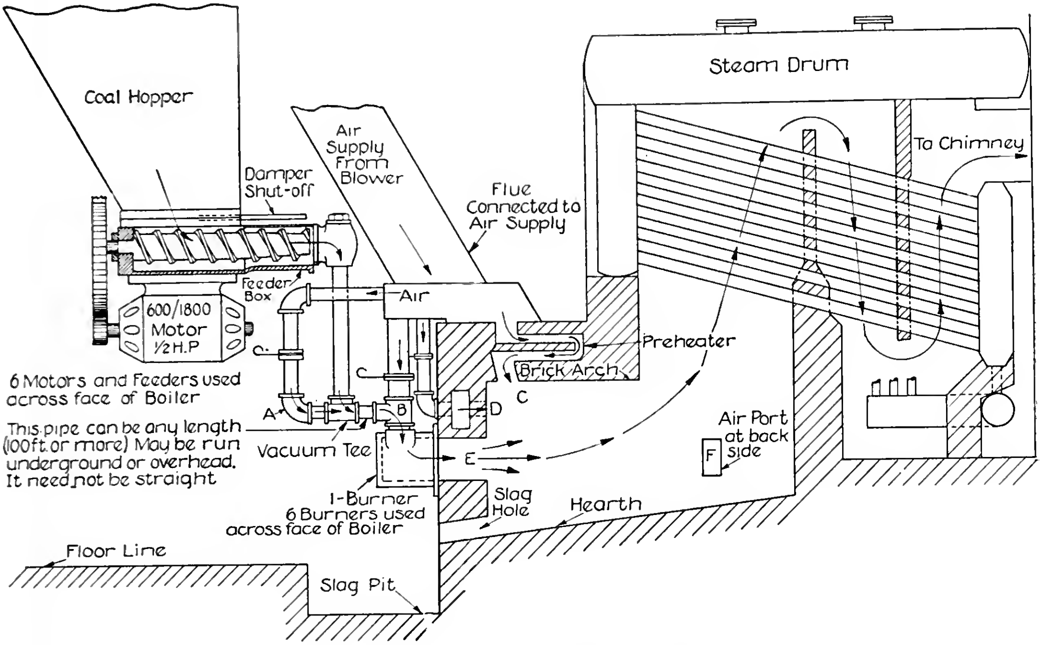


Fig. 5. Sectional View of Boiler shown in Fig. 4

"Coal used in heating and puddling furnaces should closely approximate the following analysis:

Volatile matter	Not under 30.00
Fixed carbon	Not under 50.00
Moisture	Not over 1.25
Ash	Not over 9.50
Sulphur	Not over 1.00

"In open-hearth furnaces a still better grade is desirable, a suitable analysis being as follows:

Volatile matter	Not under 36.00
Fixed carbon	Not under 52.00
Moisture	Not over 1.25
Ash	Not over 6.00
Sulphur	Not over 1.00

"The power consumption of the pulverizer will vary according to quantity of output and degree of fineness of the finished product. Pulverizing mills of the type described, having a capacity of about four and one-half tons per hour, pulverizing to a fineness so that 95 per cent will pass through a 100-mesh sieve and 83 per cent through a 200-mesh sieve, will consume about 10.5 kilowatts per hour per ton of product.

"In a plant having an average output of 200 tons of powdered coal per day the cost is as follows:

	Per gross of ton of coal produced
Fuel for dryer	$0.030
Repairs, buildings, machinery, and equipment	.200
Labor	.150
Power and light	.215
Supplies	.005
	$0.600

"The above figures include all costs, from the receipt of the coal in the cars to its delivery in a powdered state in the furnace. No allowance has been made for overhead and depreciation.

"Shrinkage in the coal becomes a prominent factor, and must not be lost sight of. It may vary from 150 pounds to 270 pounds per gross ton.

"In the metallurgical processes powdered coal has been applied with commercial success.

to various types of furnaces, such as annealing, puddling, heating, open-hearth, ore nodulizing, etc.

"In order to insure success in applying powdered coal to furnaces, no matter what their type may be, one general rule must be obeyed: namely, that it be fed to the furnace at a uniform rate in a thoroughly atomized state, and that the furnace be so designed that complete combustion may take place while the coal is in suspension.

"As to the economy of fuel on puddling furnaces, the use of powdered coal has shown an average saving of about 30 per cent to 36 per cent, and on heating furnaces 15 per cent to 25 per cent. For every pound of coal fired the waste-heat boilers show an evaporation of from seven to eight pounds of water.

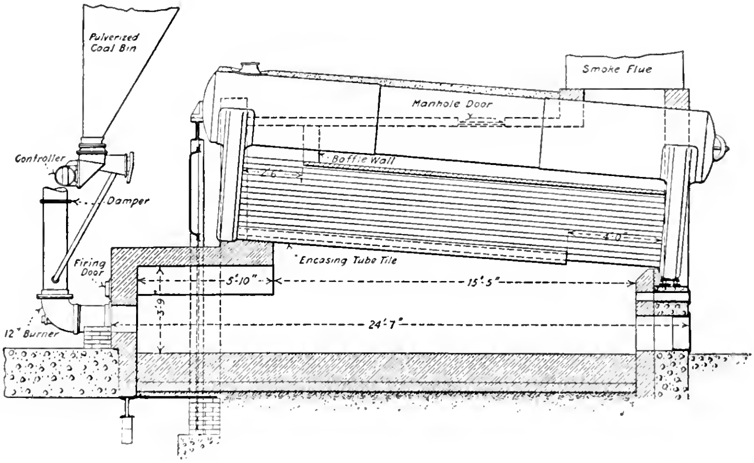


Fig. 6. 300 h.p. Franklin Boiler at the Schenectady Works of the American Locomotive Company changed over for Powdered Coal. This furnace proved unsatisfactory owing to melting down of furnace walls and arch, and inability to carry full load

"The use of powdered coal as a fuel in soaking pits represents probably the latest application of this form of fuel in the metallurgical arts.

"Another recent application of powdered coal is in open-hearth furnace practice. At this time four different steel plants are using this form of fuel in open-hearth furnaces with encouraging results. While all the installations are more or less in an experimental stage and not as yet fully developed, owing to the limited time of application, the results obtained thus far have fully demonstrated the economy of powdered coal over oil and show equal economies with producer gas.

"The high economy and efficiency of powdered coal in the metallurgical processes, under the limited application of this fuel and the limited development of apparatus, provide an index of its possibilities under more general use. With a further development of apparatus this form of fuel doubtless will eventually supplant oil, tar, and producer gas in the varied fields where they now hold supremacy."

The American Locomotive Company (12) at Schenectady and several other manufacturing plants have made considerable use of powdered coal for metal working furnaces. The American Locomotive Company have a number of furnaces in the hammer shop and forge shop fired with powdered coal. The two largest are connected to waste-heat boilers.

The General Electric Company (10) equipped nine heating furnaces in the blacksmith shop at Schenectady for burning powdered coal, about three years ago. Owing to the high class of work handled by these furnaces, it proved to be a wrong application as the ash clung to the work as slag, and consequently the furnaces have been changed back to oil firing. The work handled included drop forgings for turbine buckets and other small articles where smooth finish and accuracy of dimensions are important. Also, high-speed steel was affected adversely by the slag clinging to the work.

It will be seen that fuels low in ash are required for metallurgical furnaces, which eliminates many low-grade fuels. However, Mr. Gadd mentions coke breeze as suitable in some cases. This consists of fine screenings from coke prepared for blast furnaces. As mentioned under peat, pulverized peat has been used in Sweden for firing metallurgical furnaces. Lignites with low ash content should also be available in some parts of the country.

Powdered Coal for Firing Boilers

In the firing of steam boilers the conditions are much simpler than those encountered in industrial furnaces where the flame comes into direct contact with the work. Nevertheless, the art has been very slow in development owing to faulty applications and, principally, to the competition of the mechanical stoker, which was first in the field, and to conservatism on the part of owners of plants and operating engineers.

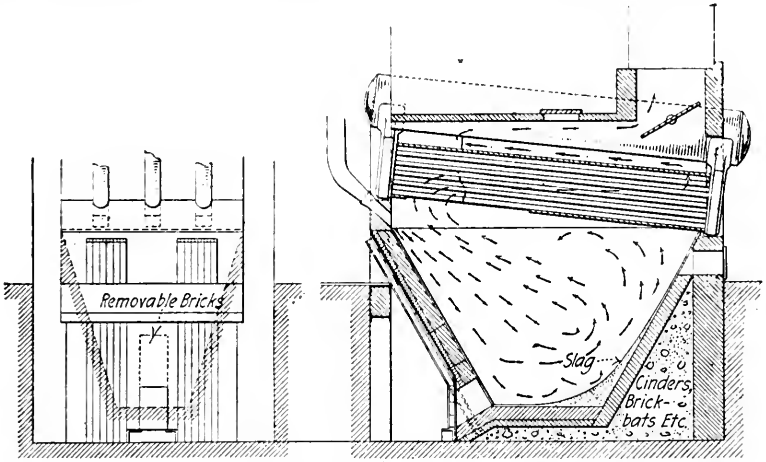
Some experimental applications have been made by readapting the furnaces of boilers formerly fired with coal or oil. The size of the combustion chamber has been too small to secure the best results. The temperatures of the fire may be too high, or the air supply insufficient, with the result that the ash slags and sticks to the tubes, making frequent cleaning necessary; or freezes in the ashpit and requires hard work in breaking it for removal.

An isolated boiler in the Schenectady Works of the General Electric Company was changed over from oil burning to powdered coal about two years ago, (^{10}) Figs. 4 and 5 show how the powdered coal equipment was installed. This was a 500-h.p. Munoz boiler used intermittently for supplying steam for testing purposes. A substantial saving was effected in the fuel bill with the prices of fuel then prevailing. One test showed an efficiency of 75 per cent without an economizer.

This boiler has given fairly good service but requires frequent cleaning. The combustion chamber is small for burning powdered coal and consequently the ash slags. The location is such that it would be an expensive matter to excavate a larger space in the ground under the boiler.

(^{14}) A boiler which has been very successfully fired with powdered coal is shown in Fig. 7. This is a 300-h.p. Franklin boiler in the factory power-plant of the American Locomotive Company at Schenectady. Similar boilers in the same plant are fired with Roney stokers. This one was changed over to powdered coal firing in November 1914, enlarging the furnace but little, Fig. 6. (^{13}). Trouble was encountered in the melting down of the furnace walls and arch, and in an inability to carry full load.

A new furnace was therefore constructed, Fig. 7, by digging in the ground a hole shaped like an inverted cone but rectangular in plan. Slag which runs to the bottom of the cone may be tapped off occasionally through the slag hole. The designer's idea was (^{14}) "that the only way to prevent the destruction of vertical walls and arches was not to have them, and substitute incandescent surfaces



This Drawing Illustrates the Temporary Construction of the Furnace as Originally Made Early in March 1915 and which is in Continual Daily Service without having been Changed or Altered

Fig. 7. Furnace that Replaced that shown in Fig. 6. The two sets of vertical pipes support the front wall of the furnace

formed by simple outwardly inclined walls which would be automatically maintained by a coating of protecting slag. This furnace has now been in continual service since March 1915 without a single repair expense on the hopper-shaped furnace walls. These walls are coated with 1 inch to 3 inches thickness of slag and are seemingly in as good condition as at the time they were built."

This furnace has plenty of room for combustion, the double path of the gas being about thirty feet long from the burner around the furnace and back again to the first tubes. The ash, when analyzed, shows practically no carbon. No slag is carried up among the tubes as all ash remaining in the gas is carried through the tubes and up the stack as dust. Only occasional blowing is required to dislodge ash dust from the tubes or baffles.

When first put in operation slag was produced in considerable quantities. This was found to be due to insufficient air for combustion as carbon was found in the ash. An increased air supply reduced the temperature of the fire.

The temperature of the fire was also regulated, independently of the mixture, by changing the location of the baffles. The lower baffle, as shown in Fig. 5, was used as a radiation screen; varying the opening in the pass changed the area of tube surface exposed to direct radiation from the fire. As the heat absorbed by direct radiation, per unit of area of tube surface, is much greater than by gas convection it is apparent that an increase in the length of tubes exposed will reduce the temperature of the fire, and that the gas will be cooler when it reaches the first tubes. Ash particles that have fused in the fire and have not dropped out of the gas may solidify before reaching the tubes.

The change in location of the first pass from the lower end to the upper end of the tubes, also improved the circulation.

When the furnace was reconstructed the burners were also improved. Now the boiler will operate continuously at 150 per cent load, or 450 h.p., with an efficiency of about 72 per cent. This boiler, and one of the similar stoker-fired boilers, are equipped with

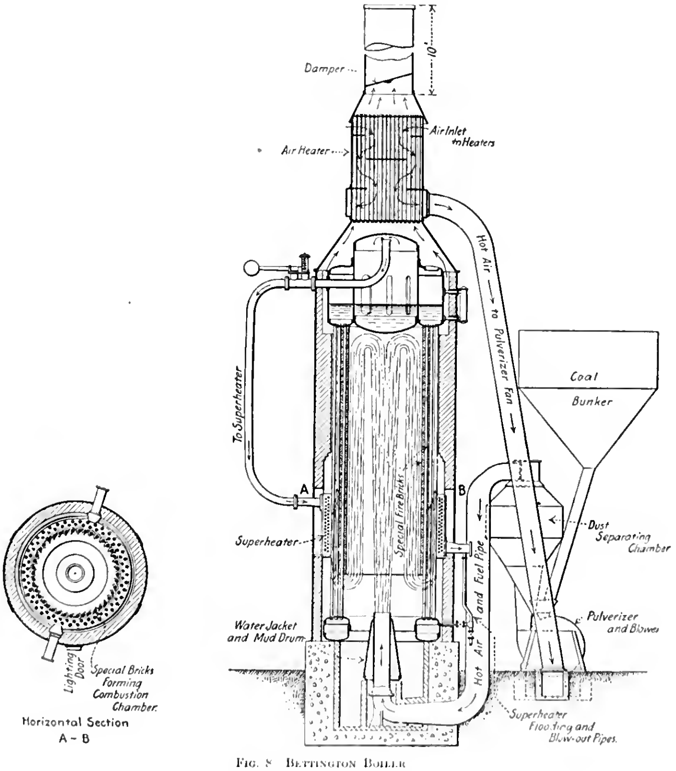


Fig. 8. English Type of Vertical Boiler designed especially for burning Powdered Coal

steam flow meters. The other boiler will only carry 325 h.p. under similar conditions, and with an efficiency of 62 per cent. The three original inlet tuyeres are yet in service. They consist of ordinary wrought steel pipes, ten inches in diameter and two feet long. The "secondary air" is fed to these at a pressure of about 0.2 of an inch of water. The "primary air," carrying the coal dust from the mixer, is injected into the center of each 10-inch pipe four or five feet back from the end of the tuyere, through a two-inch pipe and elbow, and under a pressure of about 6 oz., which can be varied according to the load.

The 10-inch pipes here are made of light sheet iron, and a 45 deg. bend intervenes between the injection pipe and the tuyere, which assists in mixing the primary and secondary air. The long tuyeres also allow air and coal to mix thoroughly before ignition.

A CO_2 recorder is used on the flue and shows an average CO_2 content of 15.5 or 16 per cent in the gases. Readings as high as 18 per cent have been recorded; this indicates complete combustion without excess air. The coal used in this boiler, and in that of the General Electric Company, contains about 30 per cent volatile matter and about 10 per cent ash.

(1) (12) Among earlier boilers which have successfully burned powdered coal is an English type designed especially for the use of this fuel by Claude Bettington of Johannesburg, South Africa, Fig. 8. The flame is projected vertically upward in a brick-lined combustion chamber surrounded by a circle of vertical tubes. The first pass is at the bottom of the tubes. The temperature of the fire is high and fuses the ash which falls in a pit at the bottom. The bricks are cooled by radiation to the tubes. The air is preheated and a small pulverizer is connected to the tuyere, without intermediate storage for powdered fuel. The latter feature is not now regarded as good practice.

Several of these boilers have been used in South Africa, in Great Britain, and in Canada.

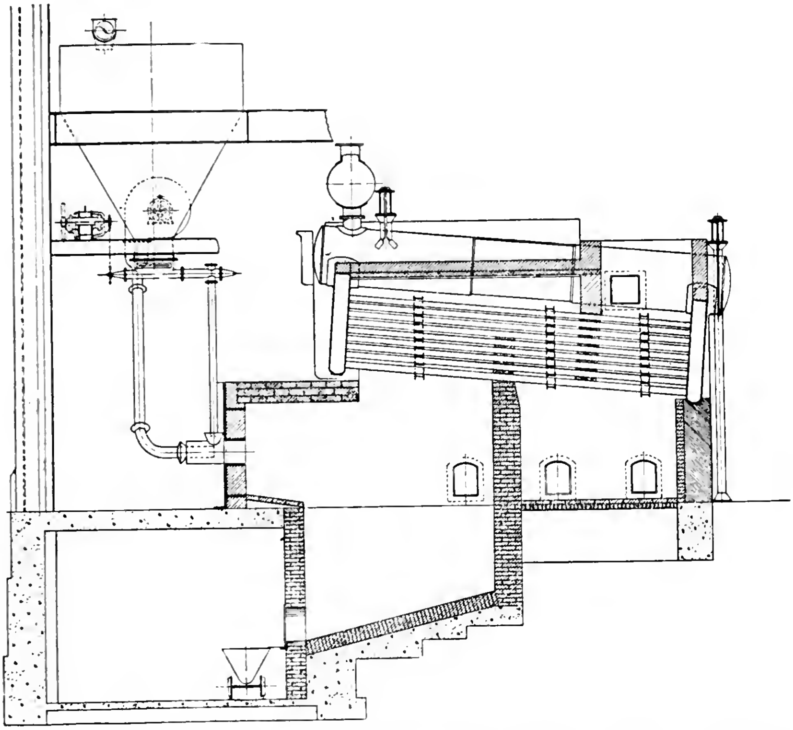


Fig. 9. Boiler in the Shops of the Missouri, Kansas & Texas Railroad Company, Parsons, Kansas. Converted from oil firing to low-grade pulverized coal firing

"Tests of one of the Rand boilers show an efficiency of 82.6 per cent, with coal analysis as follows:

Moisture	2.15 per cent
Volatile	22.8 per cent
Fixed Carbon	57.5 per cent
Ash	17.5 per cent

The CO_2 is carried at 15 per cent in regular practice."

The first installation in this country, of notable size, for burning low-grade pulverized coal under a battery of boilers was made last year in the shops of the Missouri, Kansas & Texas Railroad at Parsons, Kansas. Eight O'Brien Boilers of 250 h.p. rating were equipped, Fig. 9.

(15) "With Kansas coal containing approximately 22 per cent ash, the horizontal baffles allowed too much ash accumulation, so a Dutch oven approximating a 6-ft. cube was built in front of the boilers and vertical baffles were inserted, replacing the former horizontal ones. With these changes highly gratifying results are being obtained. No slag is formed, and the ash is readily blown off the floor of the rear chamber with an air hose once a week."

(16) These boilers have been successfully operated with pulverized lignite, as well as with coal of the following composition:

Ash—as high as 26.0 per cent
Volatile—as low as 25.0 per cent
Sulphur—as high as 7.5 per cent

The following is a letter from the Assistant Superintendent of Motive Power of the Missouri, Kansas & Texas Railway to the company that installed the equipment (17) dated Feb. 24, 1917:

"You have referred us several times to various articles in different magazines concerning the impracticability of the use of pulverized coal under stationary boilers. In some of these articles it is stated that pulverized coal under stationary boilers is only in the experimental stage, and it is doubted if it ever can be successfully used unless some other radical changes not thought of now are developed.

"I only think it fair to you to call your attention to the fact that the installation that you put in for us under eight of our 250-h.p. O'Brien boilers has been in operation continuously since July, 1916. These boilers were formerly operated with natural gas and later, oil.

"This winter we have had very cold weather and in addition to this we have been called upon to develop considerably more horse power than ordinarily on account of the activity in our shops, and I do not hesitate to say that the pulverized coal installation in connection with our boilers has been an entire success.

"We have frequently, when called upon, without any difficulty operated our boilers well above rating. We have been able to obtain practically perfect combustion and also smokeless operation. We have made a number of tests obtaining between 70 per cent and 75 per cent combined boiler and furnace efficiency. We also obtain 8 to 9 lb. water evaporated from and at 212 deg. per pound of coal burned with coal containing 11,580 B.t.u. with 26 per cent ash.

"We are having no trouble in our regular operation with the furnace refractories, and therefore there is no question in my mind as to the suitability of the adoption of pulverized fuel to boilers of this size and larger."

In another letter, dated May 12, 1917:

"Complying with your request, am sending you actual cost figures for fuel expense with

TABLE I

	FEBRUARY		MARCH	
	Tons	Cost	Tons	Cost
Coal	1,758.25	$2,285.73	1,850.85	$2,406.11
Pulverizing		685.72		721.83
Total for coal		$2,971.45		$3,127.94
Equivalent cost of oil		4,923.10		5,182.40
Saving		$1,951.65		$,2054.46
Saving		39.6 per cent		39.6 per cent

Coal cost $1.30 per ton
Pulverizing 0.39 per ton
Total coal 1.69 per ton

Oil, contract price $0.80 per barrel
Equivalent price $2.80 (for 3½ barrels = 1 ton coal).

pulverized coal for the months of February and March, 1917, these being two normal operating months and include operation after we added the steam turbine compressor, and this also covers steam heat losses in shops.

"Turbine operated on high-pressure steam. To make comparison we base oil at 3½ barrels equal one ton of coal in this district which is standard practice: (Table I).

Mr. Barnhurst writes: (18)

"From a financial standpoint, the Parsons, Kansas installation has been a wonderful success, and we know that pulverized coal will be the standard method of firing.

"Another installation is being put in by us at the Ash Grove Portland Cement Co., Chanute, Kansas, and we have just received contract from the United Verde Extension Mining Co., for pulverized coal equipment under two 400-h.p. boilers for them, and other furnaces.

"Boilers have been used a great many years in connection with furnaces using pulverized coal as a fuel, utilizing the waste heat from the furnaces, the furnace acting as a combustion chamber.

"We are positive that when the subject is understood fully that there will be a wonderful increase in the use of pulverized coal in connection with boilers, on account of the advantages which will be obtained from its use.

"Most of the installations which have heretofore been made have been failures due particularly to the fact that pulverized coal has been applied to boiler furnaces designed for other methods of firing.

"In order to burn pulverized coal successfully, the proportions or cubical contents of the furnace must be in proper ratio to the amount of coal burned per minute. In other words, there is a limit to the velocities of the gases passing through the furnace, and where they come in direct contact with the firebrick walls of the furnace, which when hot are in a more or less plastic condition, subject to erosion, if the velocities of the gases coming in contact are excessive.

"Large volume means slow velocities, hence less wear on the furnace refractories.

"The quality of the ash of the coals is another feature, in that, a coal with a low melting point ash will not require as large a combustion chamber as a coal with a high melting point ash.

"The analysis of the ash of some coals will no doubt have some effect on the refractories in certain cases."

A more recent application has been made at Seattle, Washington, on a boiler formerly fired with oil.

(19) "Prompted by the large amount of unmarketable fine coal which is piled up at numerous nearby coal mines, the Puget Sound Traction, Light and Power Company has investigated the practicability of burning powdered coal. This coal is a form of lignite particularly adapted to use in the powdered form owing to the high volatile constituent and the very high fusing point of the ash.

"The coal which has been investigated by the Puget Sound Company is dried and pulverized by the Pacific Coast Coal Company at its briquetting plant, near Renton, which is equipped with a Raymond pulverizing plant. It is then loaded in a box car having a metal-lined hopper. The car is spotted at the steam plant over a chute which is connected to the car by a flexible hose. The chute feeds a small metal-housed conveyor which elevates and dumps the coal into a bunker adjoining the power plant.

Coal analysis:

Moisture	5.4	per cent
Volatile	37.2	per cent
Fixed carbon	47.0	per cent
Ash	10.4	per cent
Calorific value	11760.	B.t.u.

Average flue gas analysis:

CO_2	17.	per cent
Oxygen	2.	per cent
CO	0.	per cent

(19) "During the test it was noted that the boiler could be forced to 200 per cent of rating without any apparent damage to brick setting or tubes. The stack was perfectly clear under these conditions and there was no fusing of the ash. About one-third of the ash was found deposited in the second and third passes of the boiler, none whatever being found to have collected on the tubes.

"The results of the experiment tend to refute most of the adverse criticism of this method of burning coal. There was no formation of slag in the furnace or on the tubes, there was no shower of cinders and ashes emitted from the smokestack, and there was no damage done the boiler from heavy overload under these conditions.

"From the experiments in burning these various fuels it was found that—assuming pea coal at $1.60 per gross ton—the prices which could be paid for other fuels on the basis of equal heating values are as follows: Pea coal on chain grates, $1.60 per gross ton, delivered;

fuel oil, 56 cents per barrel, delivered; and powdered coal, $2.20 per gross ton, delivered."

Powdered Coal *vs.* Stokers

The cost of pulverizing coal in small plants is higher than when working on a larger scale. Labor, building, and machinery can be utilized more efficiently for large scale production. A good deal has been said about fineness of grinding aiding good combustion. Fine grinding increases the cost, and the engineer of one plant which has used powdered coal extensively told the writer that they had decided it did not pay to be too fussy about fineness.

The cost of grinding in plants actually in use is said to range from 39 to 60 cents per ton. Manufacturers of equipment claim that the cost may be reduced to 25 cents per ton for large plants.

By increasing the load-factor on a pulverizing plant, by operating with two or three shifts, and shutting down only during the hours of peak load on the station, the overhead charges may be reduced and free power obtained. All other power station auxiliaries have to operate continuously, but storage capacity can be provided for powdered coal so that even in the cases where high ash coal is pulverized the power can be obtained cheaply.

With mechanical stokers 50 per cent or more excess air is required for combustion, and about 100 per cent for hand-fired boiler furnaces, owing to uneven distribution of air through the fire. For powdered coal only about 25 per cent excess air is required as fuel and air are more evenly mixed and in intimate contact. This reduces the stack loss and increases the boiler efficiency about 3 per cent, theoretically, but in practice the percentage of CO_2 in the flue gas can be held more constant with powdered coal firing, which should result in a further saving. Another 1.5 to 3 per cent may be saved by the reduction of the amount of combustible matter in the ash, the small size of the grains of coal allowing complete combustion with a proper air mixture.

Therefore, without making allowance for the steam consumed by the stoker engine, and for injection on the ash, powdered coal may be credited with a gain of 5 per cent, or more in boiler efficiency. Probably this saving will more than provide the amount of power required for the pulverizing plant and the coal burned for drying. When the pulverizing plant is located near the power station, the drying may be done with waste heat by tapping the flue gas on its way to the stack.

The first cost of a pulverizing plant might be brought down to the level of the cost of a good stoker equipment by continuous operation. Maintenance and repair items may be lower for the former than for the stoker and furnace brickwork.

There is therefore ground for believing that even high-grade pulverized coal may be able to compete with stoker firing when applied to a new plant, or when remodelling an old one. But the margin, if any, would not warrant changing a good stoker equipment for a pulverizing plant.

If this be the case with high-grade coal there must be a greater margin in the case of low-grade coal. The cost of pulverizing would probably not increase the total expense of operation as much as the charges for interest, maintenance, and depreciation incidental to the larger furnaces and stokers required for handling low-grade, or high-ash, coal. It is true that large furnaces are required for burning powdered coal. The increased dimensions however, are obtainable in a vertical direction and by encroaching on space usually occupied, in part only, by ash handling equipment in the basement. In buildings having no basement, extra space has been obtained for furnaces by excavating in the ground under the boilers. The problem of handling the ash seems to be simple in those plants where powdered coal has been burned under boilers, as it is tapped off as liquid slag from the bottom of the combustion chamber or blown out as dust from the boiler setting.

Larger furnaces and stokers for burning high-ash coal have, in some cases at least, been obtained by horizontal extensions and by setting the boilers farther apart. This means a larger building.

With pulverized fuel no larger furnace is required in the case of low-grade fuel than with high-grade; and, as the proportion of combustible matter in the ash is negligible, this loss will be no greater.

The power required for grinding good bituminous coal is 9 to 10 kw-hr. per ton, which is a little less than one per cent of the power generated by burning this coal. Coal with 14,000 B.t.u. when utilized at 15.5 per cent, efficiency of station, will generate 1110 kw-hr.

([16]) As to the first cost of the pulverizing plant:

"In making comparisons of stoker and pulverized-coal installations, I find that in plants of from 3000 to 4000 h.p. and upward, a first-class pulverized-coal equipment will not exceed in price that of a first-class stoker equipment, taking everyting into consideration."

Transportation and Storage of Powdered Coal

The boilers and furnaces at the General Electric and American Locomotive Works are supplied with powdered coal by forcing it in bulk through pipes from a hopper-shaped tank by applying air pressure on top of the mass. This method works well for distances of 200 yards or so.

A method which might be available for longer distances would be the blowing of the coal through pipes as a dust cloud with an inert gas. The only gas which is cheap enough is flue gas. Flue gas from a well regulated powdered-coal fire contains only 2 or 3 per cent of oxygen. If this prove safe from danger of explosion it might be cooled, compressed, and then cooled again, and the moisture drained off, as in compressing air.

Coal stored under water is safe from spontaneous combustion. Why not store powdered coal in flue gas? It takes fire more quickly than lump coal, for it has more surface to absorb oxygen. If blown into the storage tank with flue gas the interstices will be filled with inert gas when it settles. This should greatly reduce the rate of oxidation, and consequent spontaneous heating. The storage bin should be nearly air-tight. If located near a power plant, fired with powdered coal, flue gas may be tapped off, cooled, and dried, and then fed through a small pipe into the bin to maintain an inert atmosphere, and prevent air and moisture from leaking in.

Storage in a neutral gas may allow the concentration of production in large pulverizing plants for shipment to small consumers in sealed tanks. Isolated plants are now mostly dependent upon hand-firing, as mechanical stokers are too expensive.

Powdered Coal for Steamships

Such methods may also make it possible to carry powdered coal in a ship's bunkers at sea and make the firing of ship's boilers practical by this means, without the necessity of carrying a pulverizing plant on board. By blowing it aboard with flue gas the more cumbersome method of coaling ships with lump coal may be superseded, and the operation be made as simple as pumping fuel oil aboard.

When burning coal on shipboard, the practice of hand firing is universal. The use of pulverized fuel would put the burning of solid fuel more nearly on a par with liquid fuel.

Powdered Coal for Locomotives

Powdered coal firing for locomotive boilers has been experimented with for a number of years with various degrees of success. It has now been successfully applied by several of the railway companies. It should have a double advantage in this field; first, as a method of mechanically stoking a locomotive; and, second, as a method of utilizing cheap fuels from local sources in some parts of the country to supplement unreliable supplies from present sources when these are located at a distance. As a mechanical stoker, its only competitor is oil-firing, and oil is a high-grade fuel, and must be transported long distances for use in the northern and eastern parts of the country. In time of war the supply is uncertain, as the Navy and transport service must have preference.

Several of the advantages which powdered coal shares with oil are:

Hand labor eliminated for firing.

Ease of regulating the fire.

Less time required for raising steam from a cold boiler.

Less back pressure in cylinders, due to increase in area of exhaust nozzle, strong suction not being required to draw air through coal on grate.

Less time required for cleaning fires.

Freedom from smoke, cinders, and incendiary sparks, which cause fires along the right of way.

More fuel can be burned per hour, hence the engine can do more work.

Locomotives have been constantly increasing in size and power, with the result that the fireman's physical inability to keep up with the demand for steam often limits the performance of the engine.

The Delaware & Hudson, the New York Central, and the Chicago & Northwestern have recently equipped experimental locomotives for burning powdered coal, and have had considerable success. Mr. J. E. Muhlfeld, presented a paper before the A.S.M.E (20), recently on this subject, and the following extracts are taken from the discussion which followed:

"Mr. W. L. Robinson said that the application of powdered fuel would be a practical advantage on his own road on account of the irregularity of the supply of coal and the car shortage. Using pulverized coal would do away with this entirely.

"He thought the biggest thing that would appeal to the conducting-transportation side was the delays at terminals. On one of the larger roads, which uses about 6,000,000 tons of coal a year, the average mechanical delays at some of the heaviest maintaining stations are between 10 and 11 hours, and the lowest delay at despatching stations is from 3½ to 5 hours, or an average of 6 hrs. 7 min. There is no question but that if you could eliminate the ashpit delays you could cut the delays nearly in half.

"One statement of the author that impressed him was that with pulverized coal more skilled manual control of combustion and assistance to the engineer in the operation of the locomotive and observation of track and signals were secured. He thought that would help a great deal toward safety."

"C W. Corning (21): I am familiar with many of the results from the use of pulverized fuel as stated in Mr. Muhlfeld's paper, having for several months had charge of an Atlantic-type locomotive in first-class passenger service, burning this form of fuel.

"Of the many things which contribute toward the lightening of the enginemen's cares in the discharge of their duties, probably the two most essential are the proper working of injectors and the free steaming of the engine.

"In all of the runs made by the engine mentioned, it never failed to deliver all the steam pressure required (in the language of the fireman, it is "two o'clock" all the time by the steam gage). In the event of the failure of the injectors it is a simple matter to shut off the supply of fuel until such time as the matter can be remedied and the fire re-lighted.

"A very prominent feature of the pulverized-fuel engine is the fact that the draft appliances need not be changed for different grades of fuel, or climatic conditions of the various seasons of the year. The locomotive has been operated in all kinds of weather, in very heavy rain storms, snow storms, extremely hot and dry weather, and when the temperature was several degrees below zero, and there never was any noticeable change in the steaming qualities of the engine.

"Last, but not least, of the many good qualities stated in Mr. Muhlfeld's paper is that of the possibility of enlarging exhaust-nozzle openings. The area of the exhaust-nozzle opening on the C. & N. W. engine has been increased about 40 per cent. In summing up, what is nearest the heart of an engineman is a free-working engine, and this is obtained by burning pulverized coal."

"W. A. Evans. Only two of those discussing the proposition suggested what has always been the one difficulty in obtaining powdered fuel combustion under boilers; viz., the difficulty of maintaining the brickwork with its necessity of large combustion space for this form of burning. One of the men stated frankly that his company had experimented with powdered coal, and found when forcing the boiler, as is necessary in locomotive practice, that the brickwork was difficult to maintain."

"J. H. Manning (22). Mr Muhlfeld's paper accords with our practical experience with engine No. 1200, having a boiler the principal dimensions of which are as follows:

Diameter, first course	86 in.
Firebox, size	114 in. wide, 126 in. long
Equivalent heating surface	5004 sq. ft.
326 2-in. tubes.	
46 superheater units.	

This boiler supplied steam to 27 by 32-in. cylinders, and developed through a medium of 63-in. wheels, 60,000 lbs. tractive effort at the drawbar, carrying 205 lb. of steam.

"This company, the Delaware & Hudson, is closely connected with a territory that produces about 80,000,000 tons of anthracite per year. It is not hard to understand that a great deal of extremely fine coal and dust accumulates in the process of marketing. This cannot be burnt on the grates, but, if at all, in suspension in a refractory furnace. For this latter purpose we have available in our neighborhood 550,000 tons per month. This latter and the fact that there were located around us a number of industrial plants successfully burning bituminous coal in pulverized form, encouraged us to build an experimental locomotive of the dimensions stated above, producing approximately 2700 cylinder horse power. To guard against the possibility of failure, the entire firebox, boiler and locomotive were so constructed that the application of the powdered-fuel mechanism chould be readily removed and the firebox, etc., arranged for burning fuel on grates.

"We soon found out that it would be impossible to burn clear anthracite coal in pulverized form. Due to the low volatile content, it would promptly snuff out if the engine should happen to slip or work extremely hard, and the firebox temperature would not permit it to flash again. We therefore arranged a program and determined to start with 75 per cent bituminous and decrease until it was found that this objectionable feature was removed. This was continued until a mixture of 60 per cent anthracite and 40 per cent bituminous was obtained. We find this gives splendid results, the engine steams freely with very little smoke and is very nicely controlled by the fireman to the extent of keeping the engine within three pounds of the maximum pressure continuously without popping under the different operations necessarily obtaining in a day's work with an engine of this character, experiencing no firebox trouble whatever.

"Such difficulty as we have had with the pulverized fuel mechanism for the introduction of the fuel into the firebox has been satisfactorily eliminated and the successful burning of pulverized fuel in suspension in a locomotive firebox, to my mind, has passed beyond the experimental stage. It is now a question of economy only and this depends upon the source of supply in a great measure."

"J. E. Muhlfeld: With respect to the points that Mr. Robinson brought out, I would say that he has looked at this matter from a strictly practical standpoint, and, in my opinion, the advantages that he names, through ability for the railway to pool the various grades and qualities of coal that they secure from the different mine operations along their line, reduction in fire building, ashpit and other terminal delays, and the elimination of arduous labor on the part of the fireman, are among the most important items with which the railways are contending today. The advantages of pulverized fuel with regard to all of these have already been demonstrated in road and terminal operation."

"Mr. Randolph brought out the matter of liability of dust explosions. From the fact that about 8,000,000 tons of pulverized coal are now being burned in the United States per annum, it is thought that general practices with respect to the handling, drying, pulverizing, storing, and disbursing of the same have been pretty well taken care of, and and the general results with the various cement and industrial plants using this kind of fuel indicate this to be the case. Where we have had our designs of fuel-preparing, handling, and burning equipment installed, up to the present time no trouble whatsoever has obtained.

Mr. Basford's idea of prolonging the life of existing locomotives by modernizing them through the application of pulverized fuel was well taken, and an enormous amount of work remains to be done along this line which will enable the reclaiming of motive power that in its present condition is ineffective and uneconomical."

"Mr Evans brought up the difficulty in maintaining brickwork, with the necessity for large combustion space in the use of powdered fuel in boilers, and requested data on that subject. The answer is: Reduce the velocity pressure of the combustion gases to the minimum; eliminate restricted areas in the brickwork through which these gases must flow, and bring these gases into contact with heat-absorbing surfaces as quickly as possible after the combustion process has been completed. We have found that owing to the rapidity of oxidation large combustion space and brick area are not necessarily essential to effective results."

"Mr. Manning says that on his road a mixture of 60 per cent of anthracite and 40 per cent of bituminous is now giving splendid results in locomotive service. I desire to elaborate on this and state that the 60 per cent consists of anthracite slush, a heretofore waste by-product of mining, and that the 40 per cent consists of bituminous unwashed screenings, all of which is mixed and pulverized.

"This mixture gives a fuel of about 15 per cent volatile as compared with the heretofore generally recommended practice of not less than 30 per cent volatile."

The Delware & Hudson Company published the following information a year ago, when its locomotive was exhibited at the Railway Conventions at Atlantic City:

"This locomotive is the largest one of the consolidated type on this continent and is equipped with every modern appliance for economical operation. Its most distinctive feature is a device for the burning of anthracite or bituminous fuel in pulverized form—coal dust and shiftings which have been in the past mostly waste. The entire regulation of combustion is controlled by small operating levers in the cab, which are readily manipulated by the fireman from his seat. Besides turning into account fuel which has hiterto been of small value, this engine eliminates the waste products of combustion, fire hazards, etc.

"No sparks, fire or smoke are emitted from the stack, a feature notable only in electric and oil-burning locomotives, a great advantage where engines are operated in large terminals or in thickly wooded country.

"This new gaint of the rails, weighing 293,000 pounds, including tender 486,200 pounds with tractive effort of 61,400 pounds, burning powdered coal, bids fair to mark an important epoch in the construction of locomotive engines."

ANTHRACITE

Anthracite at present is produced on a large scale in only one district, Eastern Pennsylvania. It is a high-grade fuel used largely for domestic purposes, and for hand-fired boilers. It is preferred in small boiler plants in cities for its smokeless burning. It is occasionally burned on chain-grate stokers designed for anthracite. The Coxe stoker is suitable for this fuel.

In former years the fine screenings from the breakers were a waste product, and were thrown on the culm-piles, or used for filling old mine workings. These screenings are now sold at prices sufficiently low to encourage consumers to mix them with other coal, either with larger sizes of anthracite, or with bituminous coal. They are also used by the coal companies and the railroads in the anthracite region, in a similar way, for generating steam.

The old culm piles are now being reduced and put through the washers. Refuse coal is also being recovered from the river bottoms by dredging. At the present rate of consumption, the culm piles will be reduced to rock in about five years time.

Powdered Anthracite

Some of this material may be utilized more advantageously by pulverizing it for firing locomotives, as has been done so successfully by the Delaware & Hudson Company. Experiments have also been made recently, in the anthracite region, with pulverized anthracite culm for firing a stationary boiler, but with less favorable results, owing to difficulties in maintaining the brickwork.

In order to ignite anthracite powder, even when mixed with bituminous powder in the proportion of half and half, it is necessary to maintain a high temperature in the furnace, above the melting-point of the bricks. Fire-brick melts at about 2700 deg. F. and frequent shut-downs are required for repairs.

With a locomotive the case is different, as it is not in continuous service like a stationary boiler, and the time required for repairs to firebox brickwork is no greater than in the case of a locomotive burning lump coal. In the present state of the art, therefore, the burning of powdered anthracite culm is limited to locomotives; it usually contains a high percentage of ash. Pulverized anthracite of good grade is used in a few metallurgical furnaces. Anthracite requires more power for pulverizing than bituminous coal.

The Bettington boiler would seem to be a good type in which to burn powered anthracite. A high temperature may be maintained in the combustion chamber without injury to the brickwork because it is supported and cooled by the inner ring of tubes.

In Colorado, New Mexico, and Virginia are some local anthracite deposits. Another area underlies southeastern Massachusetts and Rhode Island. This is a graphitic anthracite of low grade, which burns with difficulty. It usually contains a high percentage of ash and moisture, but it dries easily, and also reabsorbs water with equal facility.

This coal is located near tide-water, and in the midst of a highly developed section of the country which has to obtain coal from Pennsylvania or West Virginia. Various attempts have been made during the past hundred years to develop this field, which has an area of about 500 square miles, but without financial success. The cost of mining it has been estimated as high as $2.50 a ton ([23]).

Possibly grinding machines might be devised to grind it to powder directly from the solid in the mine, provided it were sufficiently proof against danger of dust explosions. Then it might be entrained in air by suction, blown out of the mine through pipes, and delivered aboard cars or vessels for transportation.

In this way, mining the coal, pulverizing, hoisting, conveying, loading and, possibly, drying could be accomplished in one operation. Also the ventilating of the mine. It might later be mixed with pulverized bituminous coal or peat, for firing locomotives.

CONCLUSION

Low-grade fuel may be burned on grates in furnaces of special construction for each class of fuel, and mechanical stokers are available for burning high-ash coal and lignite. It is probable, however, that low-grade solid mineral fuels of all kinds can be burned to better advantage in pulverized form.

Lump coal, when burned on the grate in a hand-fired furnace, usually requires about 100 per cent excess air. With modern mechanical stokers the usual practice is to use about 50 per cent excess air. With most kinds of pulverized fuel 25 or 30 per cent excess air is sufficient, and with proper attention the amount may be reduced almost to zero. However, the resulting temperature of the fire is a limiting factor. Other factors having a bearing on this being the construction of the furnace, the proportion of heat radiated directly to the tubes, and the fusibility of the ash. A properly constructed furnace and burners should be able to burn any form of pulverized fuel which has sufficient volatile content.

In the case of peat, and high-grade bituminous coal rich in combined nitrogen, the value of nitrogen as a fertilizer makes the by-product gas producer worthy of very serious consideration for large installations. (24) (25) The gas generated may be burned under boilers feeding steam turbines as the large gas engine has not proved commercially attractive.

Very little has been done in America in following this line of European development. Possibly the higher cost of machinery in this country has caused our engineers to look askance at a type of plant which requires a considerable initial investment. Also, the American farmer has not yet been educated in regard to the advantages of fertilizer for the intensive cultivation of crops.

American chemists, however, have been endeavoring to awaken our people to the importance of the nitrogen industry (26); and the generation of large amounts of power in hydro-electric plants has been advocated for the special purpose of making synthetic nitrogen compounds. Why not recover the nitrogen content in our fuels before burning them under the boiler? Why not invest the capital required for such hydro-electric developments in by-product gas producer plants for firing existing boilers? Later on this hydro-electric power can be utilized where *power* is required; then we can have our nitrogen compounds for fertilizer and explosives, and we shall have our power too. The production of more sulphate of ammonia for fertilizer will release Chili saltpeter for the manufacture of explosives. It may be argued that the recovery of ammonia from recent installations of by-product coke ovens will be sufficient. The saturation point for the use of fertilizers in America, however, is still far away.

For the firing of steam locomotives, pulverized fuel offers a method of mechanical stoking that is beyond competition in all parts of the country where oil fuel is not already in use. It also furnishes a means of utilizing neglected fuel.

REFERENCES

[1] R. H. Fernald; Notes on the Use of Low-grade Fuel in Europe; Bureau of Mines Tech. Paper 123, 1915.
[2] C. Schuchert; Text Book of Geology, 1915.
[3] C. A. Davis; Production of Peat in 1914.
[4] C. A. Davis; Production of Peat in 1913. Mineral Resources of United States: U. S. Geol. Survey.
[5] News Item, June 22, 1917.
[6] E. J. Babcock; Economic Methods of Utilizing Western Lignites; Bureau of Mines, Bul. 89, 1916.
[7] Babcock & Wilcox Company; Steam, its Generation and Use.
[8] Report of Committee on Prime Movers; Proceedings of National Electric Light Association, 1916.
[9] C. J. Gadd; Use of Powdered Coal in Metallurgical Processes; Journal Franklin Institute, September, 1916.
[10] A. S. Mann; Powdered Coal; General Electrical Review, September and October, 1915.
[11] R. C. Carpenter; Transactions A. S. M. E., October, 1914.
[12] F. R. Low; Transactions A. S. M. E., October, 1914.
[13] Wm. Dalton and W. S. Quigley: Transactions A. S. M. E., October, '14.
[14] C. L. Heisler; Use of Powdered Coal as a Fuel; Jour. A. S. M. E., December, 1916.
[15] H. G. Barnhurst; Pulverized Fuel Installation Serving Ten 250 H.P. O'Brien Boilers; Jour. A.S.M.E., October, 1916, page 799.
[16] H. G. Barnhurst; Pulverized Coal Under Boilers; Power, February 27, 1917.
[17] Letter from Mr. W. H. Maddocks, Asst. Supt. of Motive Power, Missouri, Kansas & Texas Railway to the Fuller Engineering Company, Allentown, Pa.
[18] Letter from H. G. Barnhurst, Chief Engineer, Fuller Engineering Company to the writer.
[19] H. Hull; Utilizing Coal Mine Waste; Test plant on Pacific Coast; Electrical World.
[20] J. E. Muhlfeld; Pulverized Fuel for Locomotives; Jour. A. S. M. E., December, 1916.
[21] Chief Smoke Inspector, C. & N. W. R. R., Chicago.
[22] Superintendent of Motive Power, Delware & Hudson Company, Watervliet, N. Y.
[23] G. H. Ashley, Rode Island Coal, United States Geological Survey, Bulletin 615, 1915.
[24] The Utilization of Peat; Nature, Vol. 97, p. 19; March 2, 1916.
[25] A. H. Lymn; Gas Producers with By-product Recovery; A.S.M.E., December, 1915.
[26] Helen R. Hosmer; Literature of the Nitrogen Industries; G. E. REVIEW, January, February and March, 1917.

THE WAR'S EFFECT ON PUBLIC UTILITIES*

By Henry G. Bradlee

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The author points out that as a result of the war, and for the first time in our experience, the public utility companies will probably be face to face with a combination of conditions that will tax the ingenuity of their ablest executors. These conditions are, briefly, a period of great industrial activity with an unprecedented demand for labor and materials falling upon a shortage in both; and little or no new capital for extensions and improvements owing to the need by the government of the peoples' savings for the prosecution of the war. While the means for meeting this situation are not at all clear at present, partial relief is promised by the adoption of certain practices that are mentioned by the author.—Editor.

A little over three months ago, Congress met in special session and declared war against Germany. While this action was expected, little preparation had been made and the nation now finds itself almost overwhelmed by a great number of new and untried problems, all calling for immediate settlement. As might be expected under these conditions, this early period of the war has been one of great confusion and uncertainty. There were no precedents to guide us in matters of business policy or personal action, and until the government made some progress in organizing its forces and outlining its general campaign, there was little to be done beyond following the general progress of events and trying to see where they would ultimately lead.

Fortunately this first confusion is gradually disappearing and we are beginning to see a little more clearly the character and extent of the problem which has been undertaken. There is, of course, much that is still uncertain and indefinite, but two facts seem to be reasonably well established which have a very direct bearing on the operation of public utilities.

These facts are:

First: That the period of the war will be one of great industrial activity with an unprecedented demand for labor, both skilled and unskilled.

Second: That the annual savings of the people, which are ordinarily invested in public improvements and the extension of industrial property will be largely or entirely required by the government for the prosecution of the war, and little, if any, new capital will be available for such improvements and extensions.

Let us consider these two facts a little more in detail. Under the plan outlined by the government, we propose to divert several million active workers from their present occupations and employ them in ways which will be industrially unproductive. These men will be employed in our army and navy and in the work of government departments and of organizations for war relief. To this extent our regular working forces will be reduced, and these men and their families must be supported by the productive work of others. We propose to loan to our Allies during the next year $3,000,000,000, all of which is to be expended in this country for food and supplies required by these Allies for the prosecution of the war. We must provide all of the labor necessary to produce and deliver these supplies. We propose to build cantonments and equip an army of at least a million and a half men (including additions to our regular army and militia) with uniforms, rifles, rapid-fire and heavy guns, ammunition, aeroplanes and all of the other implements of war; we propose to increase very materially our navy and our facilities for coast defense. We propose to increase our merchant ships to the greatest possible extent to counteract the efforts of the German U-boats; we propose to encourage our farmers to plant larger areas and to cultivate their crops very intensively that we may provide food for our Allies as well as for ourselves. Each of these efforts requires labor not merely in small amounts, but on a most extensive scale. This labor can be secured only through increased efficiency, through longer hours of work, through a greater employment of women, and through the curtailment of other activities, particularly the curtailment of unnecessary development work on public improvements. With help from all these sources, it is still probable that the demand for labor will exceed the supply, and unless a determined effort is made to eliminate all unnecessary work, our prosecution of the war may be seriously handicapped.

In the past, industrial activity has been accompanied in nearly every case by an abundance of investment capital, and it has been possible for industry to extend and increase its facilities to meet increasing demands. This is a condition with which we are familiar and which we know how to meet. Now the situation is to be reversed and we have before us an entirely new problem. We are to have industrial activity and industrial prosperity for the laborer and for many industries, but this is to be coupled with a material shrinkage in capital available for development work and for public improvements. The government proposes to raise

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* From Stone and Webster Journal

$7,000,000,000 during the coming year for war purposes. This money is to be obtained through taxes and the sale of bonds, and heavy taxes and further sales of bonds may be expected during the continuance of the war. England has now been at war for nearly three years, and during this period her average expenditures for war have been a little over $7,000,000,000 per year. The finances of England and France are already severely strained by the burdens the war has imposed, and it is fair to assume that the United States must from now on furnish a very considerable part of the necessary "sinews of war."

It is difficult for us to form any clear idea of an amount of money so great as $7,000,000,000. It is so much in excess of the figures to which we are accustomed that the mind fails to grasp it. From such figures as are available, it appears that this sum is at least equal to, and probably exceeds, the total amount which we as a nation save each year for investment purposes and so add to our national wealth. If this is correct, it is clear that the savings which we should ordinarily apply to the further development of industry and to public improvements must be used to carry on the war, and we shall have little, if any, new capital available to increase and extend industrial properties unless we can materially increase our ordinary savings through the practice of economy and the reduction of consumption.

Below are some figures taken from tables published in the *London Economist* showing how new capital has been applied in Great Britain during the years 1914, 1915 and 1916. These tables are of particular interest for they show that the extension and development of industrial property has been almost entirely discontinued since the early days of the war except in industries which contribute directly to war requirements. The figures given in the *Economist's* tables for public utilities and for municipal loans are typical, and when converted from pounds sterling to dollars they appear as follows:

	NEW CAPITAL INVESTAD BY GREAT BRITAIN	
	In Public Utilities	In Municipal Loans
1914	$66,500,000	$15,500,000
1915	5,000,000	0
1016	600,000	2,500,000

In commenting on these figures, the *London Economist* calls attention to the fact that the investment of new capital in Great Britain is now, and has been practically since the beginning of the war, under the direct control of the government.

We quote from the *Economist* of January 1, 1916:

"With the Treasury exercising a strict control over the capital market, London's functions as money lender to the world have been narrowed down almost exclusively to the raising of money for the direct war purposes of the United Kingdom, the Colonies, and the Allies;"

and from the *Economist* December 30, 1916:

"The control exercised by the Treasury Committee over the issues of new capital has had an even stronger effect in the past year than it did in 1915, for apart from the British Government borrowing, and subscriptions in London to the second French loan, only sixteen millions (pounds) was raised for other purposes, and of this, six and one-half millions was issued by Colonial Governments, so the industrial concerns raised less than ten millions during the war."

Let us now consider how the business of the public utilities of the United States may be affected by this general situation and what must be done to meet the new conditions.

It appears that we may have for the first time in our experience, and continuing during the entire period of the war, a combination of conditions somewhat as follows:

First: An unprecedented shortage of labor, materials, and supplies, and consequently an abnormally high price for those actually available.

Second: No new capital available for extensions and additions to property.

Third: A condition of general industrial activity and prosperity with consequent demands for additional service.

It is hard to imagine a more difficult combination of circumstances for a public utility, and it will require the combined ingenuity of the utilities to meet this situation successfully and furnish satisfactory service to the public.

The utilities must devise ways and means to hold down their demands for labor and capital, and above all they must, if possible, find some way to provide for increases in business without making any material increase in plant.

The best methods to be adopted and the changes to be made to secure these results are by no means clear, and can be worked out only after careful study of each local situation. A few considerations, however, can be touched upon at this time.

Within a few weeks, many of the employees of the public utilities may be drawn for military service under the provisions of the selective draft bill. The companies will then have the opportunity to present to the local exemption boards such reasons as they think proper to secure the exemption of any or all from draft. The government has already considered the case of public utility employees and recognizes the importance of maintaining the service to the public. There should, therefore, be no great difficulty in securing exemption for any employee who is really needed to enable a company to give adequate service.

The utility companies should make a careful study of their employees in order to ascertain how each may be used most effectively in making good the deficiencies occasioned by the draft.

The employment of women in the place of men who enter the army or leave for any other cause should also be carefully considered. Experience in England and in Canada shows that women may be employed to great advantage in many departments of public utility work. They have been found particularly efficient, it is said, in some of the lighter mechanical work—for example, meter repairs and adjustments.

In every organization there is a natural tendency toward a steady increase in detailed work. This is the time to cut out all unnecessary detail and devote one's whole effort to essentials. A utility company should make a careful investigation of every department of its work with a view of discontinuing all operations which can be temporarily or permanently dispensed with without loss of efficiency or impairment of service. This investigation should be undertaken promptly, as it may conduce to a rearrangement of work which will preclude the taking on of new employees to replace those drafted or leaving for other reasons.

The increase of one-man operation of cars should everywhere be encouraged. In England, women have been very generally substituted for men as conductors, and it is understood that they are also being used successfully as motormen. In this country, the use of the one-man car is already started and has demonstrated its possibilities even on large double-truck cars. We are satisfied that all street railways will gradually change to one-man operation for most, if not all, of their business, and by so doing will be able to improve materially the service rendered the public. Such change at this time will meet our present needs and will be in line with probable future development. One-man operation may, therefore, be considered far preferable to the use of women as conductors.

An effort should be made to decrease the peak demand on public utility plants and to increase the load factor. As the war progresses, the public will obtain a much clearer knowledge of the needs of the situation, and undoubtedly the utility companies will be able to secure the co-operation of their customers and of the public authorities in their efforts to readjust the demand for peak load service.

This belief has been encouraged by two recent incidents, one illustrating possibilities in the lighting and power field, and the other in street railway work.

The operator of a Canadian electric light and power plant not long ago made the statement that he thought that his power plant was well loaded when the war began, but that during the war he has increased his connected load fifty per cent with no increase in plant capacity.

In Seattle, during the past two years, there has been a very rapid development in the manufacturing district. The company has been able to prevent material increase in peak load on the street railway in this district by securing the co-operation of the manufacturers and arranging for different hours of closing or of changing shifts in different factories.

Unquestionably, similar results may be secured in many directions by a careful study of existing load conditions and of persistent and diplomatic effort for readjustment.

Renewals and replacements will have to be postponed in so far as this can be done without serious detriment to the service and without permanent injury to the property. This should be done because the cost of all such work at this time is excessive and because the surplus which the utility companies are able to accumulate from earnings may be the only fund on which they can draw for absolutely necessary additions to the property.

The construction work now under way should be discontinued in so far as this may be practicable.

Careful consideration should be given to the study of rates charged for public utility service. With the constantly increasing cost of all labor, materials and supplies, general increases in rates may be necessary to permit the public utility companies to carry on the business and serve the public. The companies should be prepared to act promptly and intelligently should such an occasion arise. It is suggested that all future contracts for power, and that renewals of all existing contracts should contain a clause providing for a readjustment of the rate with changes in cost of fuel. The rate written in the contract should be based on a normal average fuel cost and adjustments made from this point as the price of fuel increases or decreases. It must be borne in mind that the price of fuel is largely dependent upon the general market price of labor and materials. It is, therefore, fair to assume that an increase in the price of fuel will be accompanied by a similar increase in general labor and material costs and provision for this should be made in the adjustment of the power rate.

The necessity for an increase in street railway fares is now being urged in many sections of the country and the public are beginning to realize that some readjustment must be made or service will be seriously impaired. Figures recently prepared show that increases have already occurred in the case of at least thirty-six street railway properties and are being publicly discussed for many others.

We are facing a situation which is country-wide, in fact, world-wide, and completely beyond the control of the public utility companies. The aim of such companies during the war should be to manage their properties in the way that will be most helpful to the national government and that will give the best possible service to the local public consistent with national duty and the restrictions imposed by war conditions. In working along these lines, the public utility companies should have the cordial support of everyone.

It is to be hoped that city and state officials will appreciate the importance of conserving labor and capital in the interest of our national requirements and, following the example of England, will postpone bond issues and local public improvements during the period of the war.

THE PLIOTRON OSCILLATOR FOR THE PRODUCTION OF LARGE CURRENTS OR HIGH POTENTIAL AT HIGH FREQUENCIES

By William C. White

Research Laboratory, General Electric Company

The pliotron is an unusually versatile device. The article below, while not featuring this point, shows how a single pliotron can be employed, on the one hand, to obtain 25 amperes at 100,000 to 1,000,000 cycles and, on the other hand, 12,000 volts at 100,000 cycles. The device is proving itself very useful in calibrating, testing, etc., where a relatively small amount of electrical energy is sufficient.—Editor.

The fundamental principles of the passage of current between electrodes in a high vacuum by means of pure electron discharge have been given in a previous article in the Review.*

Also, in a more recent article,† the writer has given a brief description of the pliotron and its operating characteristics. A method of obtaining a frequency as low as one-half cycle per second was given, as well as a second method of obtaining a frequency as high as fifty million cycles.

In brief, the pliotron when used as an oscillator for the production of alternating current from a direct-current source of energy has the characteristics of an amplifying relay. That is, the wave shape of any variable electromotive force applied between the electron emitting cathode and the grid (or controlling member) will be faithfully reproduced by the current in the main anode to cathode circuit.

Therefore, the input of a small amount of alternating-current energy will set up a relatively larger amount, identical in frequency and wave shape. Now by utilizing a small proportion of the alternating-current energy thus produced to feed back to the input circuit, the system can be made self-exciting. Alternating-current energy can thus be obtained from a direct-current source, the pliotron and its auxiliary apparatus forming a type of converter.

The type of pliotron utilized in the arrangements to be described is shown in Fig. 1, and is of the same design as used for the circuits referred to in the previous article.

For laboratory and testing purposes, there is considerable use for constant-amplitude high-frequency electrical energy.

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*"The Pure Electron Discharge and its Applications in Radio Telegraphy and Telephony," by Langmuir, General Electric Review, May, 1915, p. 327.

†"The Pliotron Oscillator for Extreme Frequencies." General Electric Review, September, 1916, p. 771.

For instrument and meter calibration, heavy high-frequency currents are often desired, the actual amount of electrical energy dissipated being comparatively small.

In the case of tests on insulating materials to ascertain dielectric strength and dielectric losses, high-voltage high-frequency is often necessary, although in this case also the amount of electrical energy required is small.

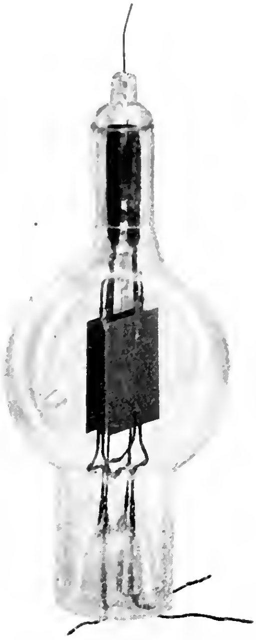

Fig. 1. Pliotron for Large Currents or High Potential at High Frequency

In this article, two pliotron oscillator arrangements for high-frequency will be described, the first for the production of relatively large current and the second for the production of relatively high voltage. In each case the amount of energy involved is comparatively small, of the order of 150 watts or less.

Heavy High-frequency Current

In a resonance circuit the current will rise until the losses become equal to the input energy. With practical circuits the lower limit of power-factor obtainable is about one half of 1 per cent, unless unusual precautions are taken. This means that the maximum resonance current produced is about two hundred times the value of the true energy current fed into the resonance circuit.

Therefore, where large currents are desired from a small quantity of energy, the total volt-amperes of the circuit must be kept small; and this condition requires that for such a resonance circuit a large capacity and small inductance must be used.

There is another principle which must be kept in mind. If the amount of electrical energy which can be furnished by a certain source is limited by the definite amount of primary power available, or by the losses in transmission, it is important to so adjust the resistance of the load to the voltage of the supply that the energy is most economically utilized. In the present case, this means that the resistance of the heavy current circuit must be given the apparent value most suitable for insertion in the pliotron circuit. This adjustment of apparent resistance is accomplished by electro-magnetic coupling or transformer action.

The diagram of an arrangement to produce currents of from ten to twenty-five amperes from one pliotron tube at frequencies between 100,000 cycles and 1,000,000 cycles is shown in Fig. 2.

Suppose it is desired to calibrate a hot-wire ammeter by means of direct comparison with a standard. These two ammeters are represented by A and A_1 and are connected in series as part of a resonant circuit, the inductance and capacity of which are shown at L_3 and C_3 respectively. The product of the values of L_3 and C_3 to be used for any particular case is found by the usual resonance formula:

$$f=\frac{1}{2\pi\sqrt{LC}}$$

As mentioned in a previous paragraph, a low power-factor and volt-ampere product is desirable; and therefore the inductance value of L_3 is made the minimum possible, consisting usually of only one or two turns of heavy conductor. With the range of frequencies specified, this gives values for C_3 of the order of about 0.1 microfarad. In this heavy-current circuit, it is of course very necessary to use condensers of low energy loss and to reduce the ohmic resistance of the conductors to a minimum.

The inductance L_3 obtains energy by electromagnetic coupling from the coil L_2 which is located in the plate circuit of the pliotron.

By means of an adjustment of the values of L_1, L_2, and C_1, the pliotron system can be made to set up a high-frequency current corresponding in period to the tuned heavy-current circuit.

Owing to the relative values of L_2 and L_3, the apparent resistance in the plate circuit of the heavy-current load circuit is greatly multiplied, but still is not of a sufficiently high value to absorb all the available energy. To further increase this apparent resistance, a variable capacity C_2 is shunted about the inductance L_2. Then, by simultaneous variation of these two factors, the apparent resistance of the load can be adjusted to give the largest energy output available.

The heavy-current output is dependent upon the voltage of the direct-current source *D*, a useful range being between 200 and 750 volts.

Pliotrons may be operated in parallel to produce a load current larger than that obtainable from one tube.

High-frequency High-voltage

For the production of high-voltage in a resonance circuit, the conditions are almost a reverse of those in a heavy-current circuit; that is, with a fixed value of inductance and capacity to give the desired frequency, the capacity must be small and the inductance large, relatively speaking. There is a practical limit, however, to this increasing of inductance and lowering of capacity; and it is reached when the distributed capacity effect in the inductance becomes comparable to the capacity of the condenser used for resonance.

A pliotron oscillator arrangement for the production of high voltages is shown in Fig. 3. The high voltage is obtained across the condenser *C*, and may be tested by the gap *G*. A condenser in the form of two metal plates suspended in air* is the most convenient, and it may have a capacity value between 20 and 200 microfarads for a frequency of 100,000 cycles. By means of a hot-wire ammeter *A* in circuit with the condenser and by knowing the frequency, the voltage produced across *C* may be simply calculated.

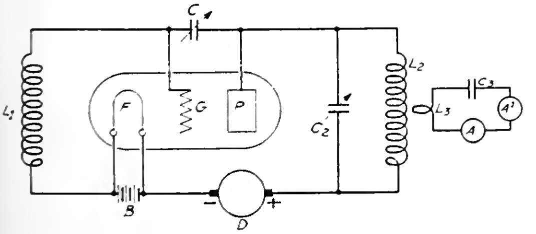

Fig. 2

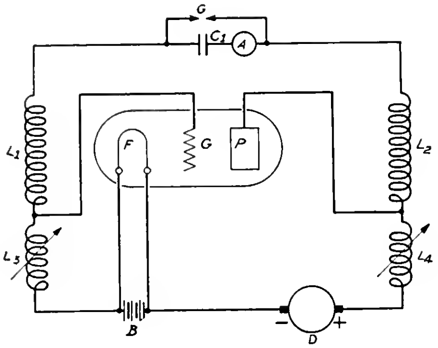

Fig. 3

The inductances L_1 and L_2 are similar and each has a value of about 8 milli-henries. The inductances L_3 and L_4 are also similar to one another and each has a maximum value of about 2.5 milli-henries. They should preferably be of the variometer type, continuously variable in the range 0.5 to 2.5, although a variation by a dozen to fifteen steps is fairly satisfactory.

The object of having L_4 variable is for the purpose of applying the high-frequency energy from the pliotron to the resonance circuit at the correct voltage, so that the energy available is used most advantageously in the resistance of this circuit.

The inductance L_3 is made variable so as to supply to the grid just the right amount of high-frequency energy to make the system self-exciting and to excite it in the most efficient manner.

As in the case of the arrangement for heavy currents, a suitable range of potential for the direct-current source is from 200 to 750 volts.

With such values of inductance and capacity that a frequency of 100,000 cycles is obtained, a voltage of 12,000 may be produced from one pliotron tube operating from a direct-current source of 500 volts.

Pliotron tubes may be operated in parallel for the production of a voltage higher than that obtainable from a single tube.

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* Two metal plates, each 10 in. by 10 in. and spaced ½ inch apart, give a condenser having a capacity of approximately 40 micro-microfarads.

These huge sea fighters of Uncle Sam's each house nearly a thousand officers and men, every one of whom has his battle station

CHARGING STORAGE BATTERIES OF ELECTRIC VEHICLES

By J. J. Kline

Apparatus Division, Ft. Wayne Works of General Electric Company

The construction of the storage cell and its chemical, thermal, and electrical actions on charge and discharge are briefly reviewed in the introduction of the following article, in order to make more readily intelligible the description and discussion of the constant-potential system of charging which form a large part of the article. After a very complete treatment of the constant-potential system, there appear descriptions of the charging apparatus, including switchboards, automatic switches, individual charging sets, automatic charger, etc.—Editor.

Many changes have been introduced into the methods of charging electric storage batteries in the last few years. These changes have come about very largely through improvements in the methods of manufacturing the batteries themselves and through experimentation on the action which results in charging at various rates. Some years ago it was the practice of manufacturers of lead batteries to mark their product with the starting rate and the finishing rate, and that practice is still carried out quite generally.

Recent Rules

However, their more recent experiments and improvements in construction have enabled them to disregard these starting rates particularly, and to adopt some very general rules in regard to charging. These rules may be briefly stated as follows:

> A well-constructed lead acid battery in good condition may be charged at any rate so long as the battery does not overheat nor gas violently. The temperature must be kept below certain limits, 105 deg. F. being selected by some manufacturers and 110 deg. F. by some others.
>
> This condition of heating and of gassing takes place near the end of the charge; and, therefore, it is the finishing rate of the charge that should receive careful consideration to limit the heating and the gassing.

Cell Construction

Before explaining the various processes of charging the battery and the reasons for the recommendations just mentioned, a study of the essential parts of the battery may perhaps be worth while. Each battery is made up of a number of cells. These cells are usually connected in series, that is, the positive terminal of one cell to the negative terminal of the next cell, and so on to the completion of the series.

Each cell consists essentially of two groups of plates which are separated from each other by wooden (or other non-conductive) separators; and these two sets of plates constitute the element of the cell. One group of plates is positive, the active material being lead peroxide, and the other group is negative in which the active material is metallic lead in a spongy form. Except in the case of the couple which is a two-plate cell, and a type not used in vehicle battery work, there is always one more negative plate than positive plates in each cell. For example, in a 13-plate cell there are seven negative plates and six positive plates.

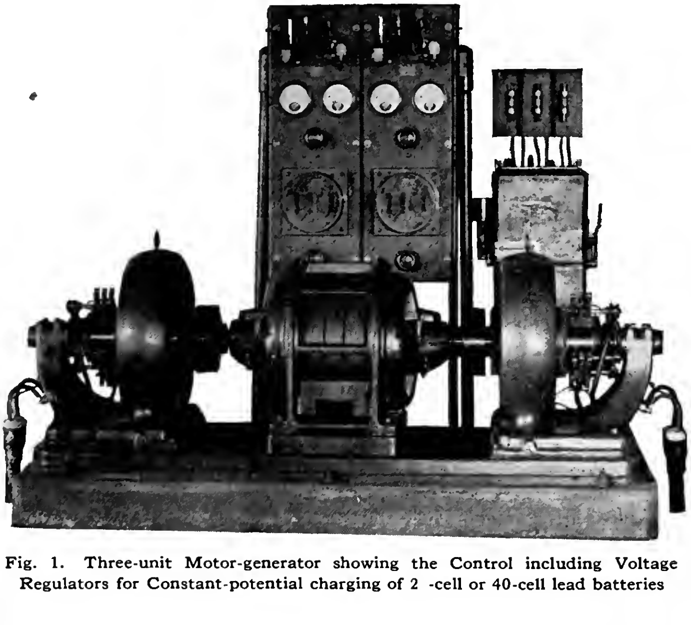

Fig. 1. Three-unit Motor-generator showing the Control including Voltage Regulators for Constant-potential charging of 2 -cell or 40-cell lead batteries

The element of a lead acid battery cell is immersed in a solution of sulphuric acid. The density of this acid varies somewhat with different battery manufacturers; but, in general, the specific gravity of the electrolyte in a fully charged battery will be about 1.280.

Discharge

As the battery discharges in doing its work, it will be found that the specific gravity of the electrolyte lessens and gradually decreases with the discharge until it stands at 1.175, or even at 1.125, depending upon the type of cell; and the discharge should then be stopped and the battery be recharged as soon as possible. An examination of the battery plates will reveal that lead peroxide is no longer the predominating material of the positive plate, nor is metallic lead the predominating material of the negative plate, but that the active material in both plates has been quite generally changed to lead sulphate. The chemistry of the action then seems quite evident; viz., under the action of the discharging electric current the plates have been changed to lead sulphate by the sulphur dioxide radical extracted from the sulphuric acid during the discharge.* These results are shown by the physical condition of the battery; in that the specific gravity of the electrolyte is only 1.150 or thereabouts, and the color of the plates has actually changed from the chocolate brown of the positives and the lead gray of the negatives to a rather whitish gray, and very little more electric energy can be obtained from the cell. That is to say, the cell is discharged and has approached an inert condition. The open-circuit voltage will probably be about 2 volts per cell, but on attempting to discharge further the voltage will immediately drop to 1.7 or even to 1.65.

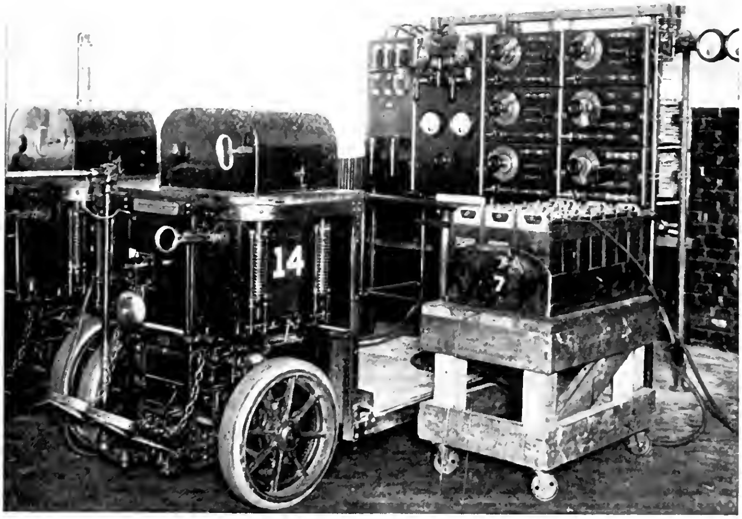

Fig. 2. Switchboard Serving Industrial Trucks in a Factory

Charge

If the battery in a discharged condition is then properly placed in circuit with a direct-current source of energy and controlled in the proper way, the flow of current will reverse the chemical conditions and change the physical conditions in the battery in the following manner:

The lead sulphate will disappear from both the positive and negative plates. The plates will gradually change to their original colors (chocolate brown and metallic lead color) and the specific gravity of the battery will rise, approaching 1.280 as the final gravity of the fully charged battery. The voltage of each cell will also rise and the final result in voltage will probably be 2.65 or even 2.7 volts per cell at the final moment of charge before the circuit is disconnected.

When the battery is in a discharged condition, the charging current can be applied at a very high rate without causing the cell to give off gas or to heat abnormally. However, as the cell approaches a state of complete charge, the temperature rises more rapidly and gassing occurs. To reduce this rising temperature and gassing, the flow of current must be reduced. The explanation is simple when consideration is given to the chemistry of the battery. When the battery is discharged there is a large amount of lead sulphate present; and, upon charging, the energy of the electric current is expended in breaking up this lead sulphate to form lead peroxide

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* The term "sulphate" has two meanings when applied to a lead acid battery. As used in this article, it refers to the normal chemical change that takes place in a battery in good condition every time the battery is charged or discharged. The other refers to a battery in bad condition, which means that the normal sulphate condition has become abnormal and the lead sulphate has become fixed or set so that it does not respond to the charging current. This latter sulphate condition is injurious and occurs upon allowing a battery to remain in a discharged condition.

on the positive plate, metallic lead on the negative plate, and to return the sulphur dioxide radical to the electrolyte which results in producing sulphuric acid of a higher specific gravity. If the same quantity of electrical energy is forced into the battery as it approaches complete charge, that energy must be dissipated in some other manner for the lead sulphate is no longer present to absorb it. The electric current, therefore, attacks the water in the sulphuric acid, breaks it up into its component gases, hydrogen and oxygen, and in so doing liberates the heat of chemical combination which raises the temperature of the battery as a whole. In the formation of the component gases from water, the volume occupied by these gases is very much greater than that previously occupied by the water and, as a result, the gases destroy the plates mechanically by their expansion, for the electrolyte is in the plates as well as around them, the plates being porous. That is the explanation of the heating and the gassing of the battery at the end of the charge, and also the explanation of the fact that a high current rate may be used at the beginning of the charge without injury to the battery.

One well recognized manufacturer of lead batteries has determined a general rule for the maximum permissible rate for charging a lead battery. This rule follows:

> "The charging rate in amperes must never exceed the ampere-hours out of the battery. Any method of charging that keeps the charging current within this limit will not overheat the battery or cause it to gas. In applying this rule, it is not necessary to reduce the charging rate below the 'finishing' rate recommended by the battery manufacturers. If an ampere-hour meter is used on the vehicle, so arranged as to indicate the ampere-hours out of the battery, it also indicates at all times the maximum permissible charging rate. It will be noted that the maximum charging rates are no longer a function of the size of the battery or its relative state of discharge, but depend only on the actual state of discharge."

Constant-potential System of Charging

Another rule laid down by this manufacturer is very useful in rapid charging. This is the so-called "constant-potential" or "fixed-voltage" system. It has been determined after long study that if 2.3 volts per cell is applied to the terminals of a lead battery in good operating condition without any series resistance in circuit, the battery will not be injured and the charge may be put in rapidly. The conditions resulting are somewhat as follows:

Let us take for example, a Type MV "Hycap" 13-plate cell. The normal rate of charge is 30 amperes and the finishing rate 12 amperes. If the cell is discharged to a specific gravity of about 1.150 and 2.3 volts is applied to its terminals and maintained at that value, the current will start to flow at 150 to 165 amperes and the current value will fall rapidly as time progresses. At the end of the first ten minutes the rate will be about 120 amperes; at the end of the first 30 minutes, about 83 amperes; at the end of the first hour, about 55 amperes; at the end of the second hour, about 28 amperes; at the end of the third hour, about 16 amperes; and at the end of the fourth hour, about 10 amperes. By that time about three-quarters of the charge will have been put into the battery and it will be ready to do almost a full day's work.

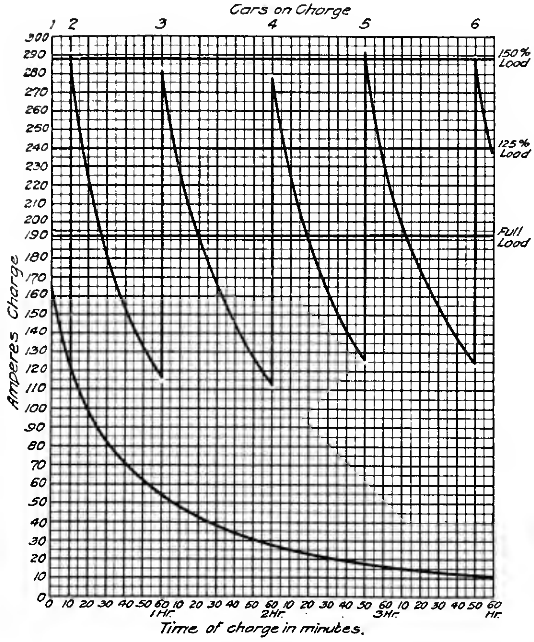

Fig. 3. Theoretical Curves showing Constant-potential Characteristics of a 13-plate "Hycap Exide" cell and the result of loading a generator with six such batteries at stated intervals

The voltage must be maintained very accurately at 2.3 per cell at the battery terminals.

About once every five or six charges, the battery should be given a soaking charge to bring the specific gravity up to its normal value, or 1.280, and this is done by gradually raising the voltage after the constant-potential charge has lasted for at least 3½ hours. The purpose of this finishing or cleaning charge, as it is called, is to remove all of the sulphate that may have remained after the previous charges and to bring the electrolyte in the cells to a uniform density. In other words, to completely fill the battery.

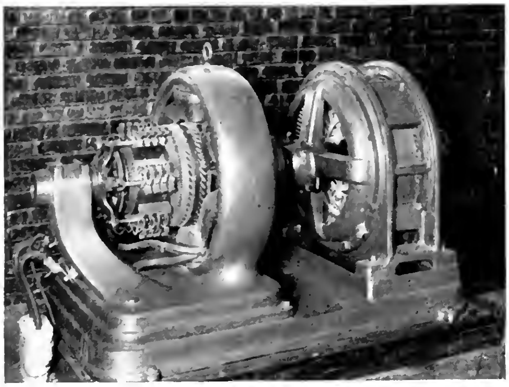

Fig. 4. Induction Motor Driving a Low-voltage Generator to Serve Industrial Trucks

This is the ideal system of charging a battery where there are a number of vehicles each equipped with the same number of cells; for example, a fleet of trucks for a department store or express company, etc. There is no energy wasted in series resistances and the charge is put into the battery in the minimum length of time with the minimum of attention and with the assurance that the batteries will not be overheated nor gas violently.

The equipment for charging by this constant-potential method requires careful selection and, as previously stated, the voltage must be maintained constantly at 2.3 per cell at the battery terminals. For this service a very dependable device, the Type "TD" voltage regulator, is available. The method requires that the generator, from which the direct current is derived, shall be under the direct control of the voltage regulator and of the operator who does the charging.

The current values of this constant-potential method are high during the early period of the charge; and, therefore, the wiring of the switchboard and the circuits must be liberal to take care of these relatively high current values.

The distribution of energy in the form of alternating current by central stations and public utility companies is becoming more and more general so that this constant-potential method of charging is the logical one to adopt where alternating current is to be transformed into continuous current; and the motor-generator set, with either an induction motor or a synchronous motor, is the proper means of making the transformation. The continuous current is then under the direct control of the operator and the voltage regulator. For this battery charging service the regulator is furnished with an adjustable resistance in place of the usual fixed resistance so that the regulator may be set to maintain any predetermined voltage value at which the circuit is to be held. For example, assume that there is to be charged a group of batteries, each made up of 40 cells. At the battery terminals a voltage of 92 is desired and, neglecting the voltage drop in the connections, the voltage regulator is adjusted to operate on the generator to maintain 92 volts.

A consideration of the characteristic charging curve already described will show that it is not commercially practical to charge but one battery by this constant-potential method. Where six or more batteries are to be charged, however, the method is very desirable for then it will be economical to

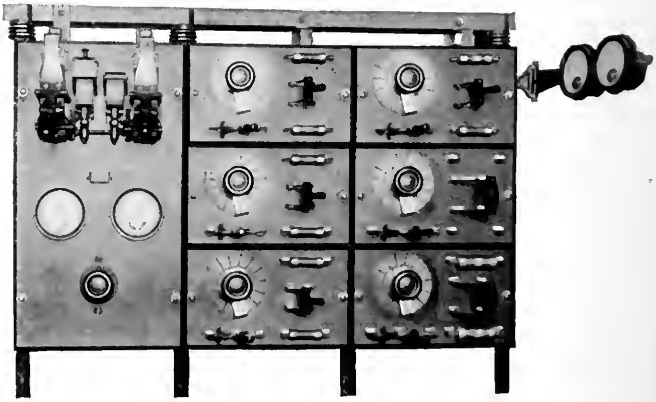

Fig. 5. Charging Board of Standard Section, Series Resistance Control

install a generator whose continuous capacity is equal to or above the instantaneous demand created by one battery; i.e., 150 amperes or more. The method is applied in somewhat the following manner:

Assume for convenience a generator whose continuous output is 190 amperes and a 40-cell lead battery that is to be charged. The generator voltage is then started at 92, neglecting the line drop, and then thrown on the first battery which starts charging at about 165 amperes. The generator will deliver momentarily 50 per cent overload or 285 amperes. After the first battery has been charging for about ten minutes, the current will have dropped to 120 amperes. It is then possible to throw on the second battery, or 165 amperes additional, making a total of 285 amperes or 50 per cent overload on the generator. In a little less than 60 minutes after the first battery was connected, the sum of the currents taken by batteries Nos. 1 and 2 is 120 amperes. The third battery can then be thrown on, arriving again for the moment at 285 amperes, and by the end of an hour and 55 minutes the total current flowing into the three batteries is about 120 amperes, so that the fourth battery can be thrown on and not produce more than 50 per cent overload on the generator. By continuing this process, six fully discharged batteries can be connected to that generator in somewhat less than four hours; and, as the charging current value of the first battery will have fallen to 10 amperes in about four hours, the first battery will nominally be charged by the time the sixth battery goes into circuit. This, therefore, is a continuous process for in less than an hour from the time the first battery is taken off the seventh battery can be placed in circuit and the process continued without overloading the generator beyond its capacity and without wasting energy in series resistance.

With a larger generator installed, the charging can be done more rapidly and the batteries may be thrown on the busbars at shorter intervals. A 35-kw. generator is a very convenient size.

The preceding is the simple process when all the vehicles are equipped with the same number of cells. However, it is not always possible to arrange that all batteries shall have the same number of cells. There may be some with 40 cells, others with 42 cells, and others with 36 cells, and it is this condition which brings about the most serious problem that is encountered in charging vehicle batteries. It is best described as the public garage problem.

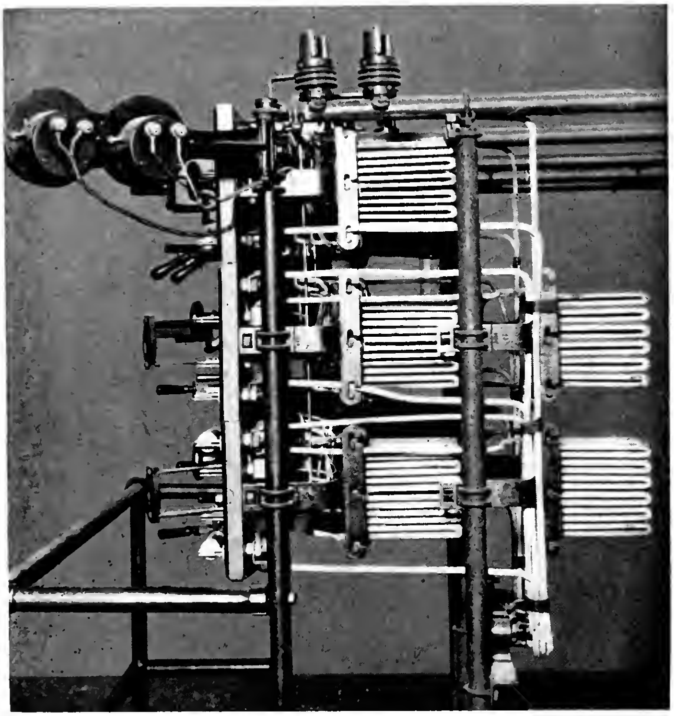

Fig. 6. Side View of Board in Fig. 5 showing method of mounting standard sections and additional rheostat capacity where needed, and also the construction which affords very complete ventilation

If the constant-potential method of charging is attempted in a public garage, the battery makers recommend the use of counter-electromotive cells rather than series rheostats. Where a rheostat is used the drop across the rheostat is the product of the resistance of the rheostat and the current value. It is clear, therefore, that if the current varies the drop will vary; therefore, a constant potential at the battery terminals can not be maintained by the use of series resistances. However, the counter-cells have the curious property of maintaining a fixed drop of about 3 volts per cell independent of the current value; hence, if the busbars are set for 92 volts and it is desired to charge a 36-cell battery at the same time by the constant-potential method, the difference of 9.2 volts must be taken care of by the introduction of three counter-cells, figuring 3 volts per cell. These counter-cells consist of jars containing the standard electrolyte and sets of plate grids without active material in them. There is no danger of injuring these by violent gassing and it is only necessary to maintain the electrolyte at its proper level. The counter-cells may be mounted permanently adjacent to the switchboard and arranged with taps so that the various charging stations in the garage may be provided with the desired voltage.

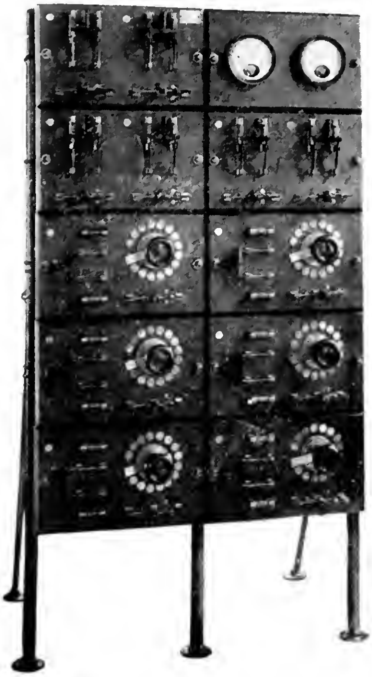

Fig. 7. Switchboard for Battery Charging Service with constant-potential and series-resistance circuits

In the preceding discussion, the theory of the lead acid battery and the methods of charging without the introduction of series resistance has been briefly outlined. The other general method of charging this same type of battery is the series resistance method which is probably familiar to all. The flow of current into the battery is determined by the resistance interposed between the source of direct-current supply and the battery terminals. The problem of this method is to determine a rheostat that will carry the current without overheating, that will be of reasonably small volume, that can be conveniently mounted, and that is moderate in price.

The other type of storage battery which needs serious consideration is the nickel alkali battery, generally known as the Edison storage battery. The methods pursued in charging this battery are quite similar to those employed in charging the lead acid battery. However, the conditions are not identical and a careful study of the battery makers' recommendations should be made.

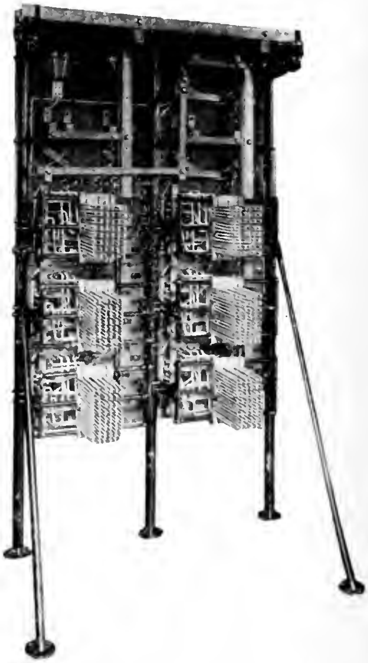

Fig. 8. Back View of Switchboard shown in Fig. 7

For the basic charging of an Edison battery, current is recommended at a fixed rate for a given number of hours, depending upon the type of cell. For the "A" type, this rate should continue uninterrupted for 7 hours. For the "G" type, it should continue for 4¾ hours. There is this distinct difference; for lead batteries the current value tapers during the charge, but for Edison batteries it should be maintained constant. The Edison battery may be charged at a variable current rate by increasing the flow to 50 per cent above the rate recommended, for the particular type of cell, and then letting the charge progress without changing the series rheostat. The current value will decrease to a value below the normal rate, but an average value equivalent to the normal rate will result. This is a compromise method, and the operator should always remember that it is a waste of energy to charge an Edison battery at any rate below the normal rate.

Of course, there are the other well-known recommendations made in connection with the Edison battery; viz., that the cells may be charged at any rate so long as the temperature of the battery does not exceed 110 deg. F. and the batteries may be boosted readily without injury, etc.

It is not possible to describe or to discuss here all the characteristics or the methods of treatment for charging lead acid and Edison batteries, but the literature published by the various battery companies may be obtained readily from the makers, and this literature should receive careful study by anyone actively engaged in battery charging problems.

Factors Determining Charging Apparatus

The prompt and efficient charging of batteries of either the lead acid or the Edison type, under the various conditions in which these vehicle batteries are found in commercial service, require standardization of the charging apparatus. The many factors which enter into these problems may be conveniently grouped for consideration in the following manner:

1. Source of Power:
    - (*a*) Alternating-current, single-phase or multi-phase, 25-, 40- or 60-cycle.
    - (*b*) Direct-current, 125-, 250- 550-volt 2-wire service or single-wire grounded return or 125/250-volt 3-wire service.
2. Kinds of Garage:
    - (*a*) The individual vehicle with no probability of extension of service as in the case of a private garage.
    - (*b*) Fleets of vehicles as in the case of a delivery system maintained by a department store or express company or other concern where all batteries are alike and there is a regular schedule of service so that systematic methods of charging may be practiced.
    - (*c*) A public garage where there are all sorts of batteries in a great variety of conditions and which may require charging at any time of day.
3. Kinds of Batteries:
    - (*a*) Lead acid or Edison type.
    - (*b*) Type and number of cells.
    - (*c*) The size of the individual cell or the number of plates per cell.
4. Methods of Charging:
    - (*a*) Series-resistance method.
    - (*b*) Constant-potential method.
    - (*c*) Constant-current method.
    - (*d*) Mixed method.

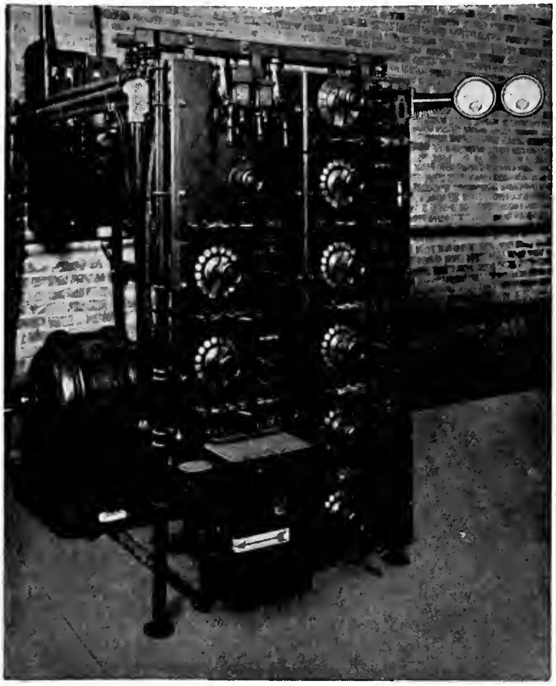

Fig. 9. Charging Equipment in a Public Garage

5. Kinds of Equipment:
    - (*a*) Standard.
    - (*b*) Special.

Switchboards for Large Garages

Switchboards for large garages, both public and private, are now usually made up from standard sections which facilitate prompt shipment, flexibility, ready assembly and at the same time permit of obtaining a good looking symmetrical installation. Some of these panels are shown in Fig. 9.

Where series rheostats are required, they are generally of the cast-grid type and are supported by the same brackets which fasten the slate of the framework. This construction permits of an assembled shipment for each circuit, which reduces to a minimum the number of connections to be made after delivery. Rheostats should be worked at relatively high temperatures to be most effective, and the liberal air spaces around the grids and about the wiring and bus work prevent the heat from being confined.

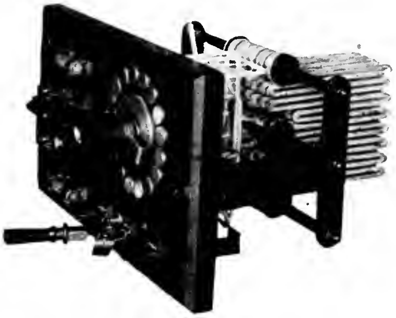
Fig. 10. Standard Series-rheostat Section

The boards are generally free from automatic devices, except for the overload and reverse-current circuit-breakers, voltage regulators and such devices, but there are installations where some further automatic control is desirable.

Automatic Switch for Battery Charging

To provide the reliable protection of one battery against the others, or against the failure of the power supply, etc., the automatic switch has been developed. The switch makes a double-break single-pole contact and the switch parts are enclosed by a molded glass cover, which may be sealed in place. The switch is controlled by the series rheostat and will only close when all the resistance is in series with the battery.

The operation of the circuits is as follows: When the charging plug is inserted in the vehicle, the current from the battery lights the pilot lamp and energizes certain coils of the automatic switch.

The moving of the rheostat blade, Fig. 11, to the proper button energizes other coils by current from the busbars. If the busbars and the battery are of correct polarity, the automatic switch will then close due to the proper coils working in conjunction, and the charge will proceed at the lowest rate permitted by the resistance of the rheostat. The desired rate may then be obtained by cutting out resistance.

If the busbars and battery are of opposed polarity, the coils of the automatic switch are in opposition, and no movement of the rheostat blade or any other part of the control apparatus (except tampering with the automatic switch) will cause it to close. Thus, the charge cannot proceed until the battery connections are reversed to correspond with the busbars, and the coils brought into conjunction, when the operation will proceed as previously outlined.

The functions of the automatic switch are the same as those in Fig. 11 except that its carrying capacity is arranged for constant-potential charging, with no series resistance. If the switch coils are in conjunction, the switch will close when the knife switch is pressed to engage an auxiliary contact.

In any of these automatic switches the current cannot pass through zero after charging has begun. The switch will open when the current value drops to 8 or 10 per cent of the current rating of the switch.

The current ratings are for normal continuous service and the switches are capable of handling, without overheating or other injury, the considerable overloads that take place for short periods in constant-potential charging, etc.

Any interruption of the continuous flow of current into the battery will cause the automatic switch to open and, as these circuits are arranged, the complete starting cycle must be repeated to make the automatic switch close again. (It is not necessary, however, to disturb the plug in the vehicle, if it is properly inserted.)

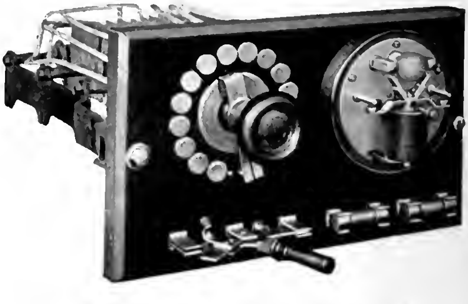
Fig. 11. Series-rheostat Section with Automatic Protection Device

This is the most perfect battery protection that has yet been designed for:

1. It refuses to close the circuit if the polarity is wrong.
2. It will open the circuit should the polarity be reversed during the charge.
3. It refuses to allow the battery to discharge into the busbars or into the other batteries in case of failure of the charging supply.
4. Its action is positive and very quick.
5. Its glass case makes it practically dustproof and it can be sealed as a meter is sealed, making it tamperproof.
6. It gives continuous protection.
7. It operates on a "safety-first" principle; viz., if conditions are not correct, the switch will not close. This is a very valuable feature in that it does away with the breaking of abnormal current values.

The automatic switch is equally suited to the charging of Edison or lead batteries by the constant-current, constant-potential, or boosting systems.

Individual Charging Set and Its Operation

From a study of the constant-potential method of charging it will readily be seen that it is not economical to attempt to charge but one vehicle and one only from a motor-generator set large enough to take care of the first rush of current; therefore, the problem has been to develop a scheme that will approach as near as possible to the constant-potential method and yet keep within a reasonable expenditure for the first cost of apparatus. Fig. 13 shows the individual vehicle charging set which is the result of this investigation and which has been accepted by the National Board of Fire Underwriters. The set is not automatic in the sense that it starts and stops itself, etc., but it is automatic in its manner of reducing the current and raising the generator voltage as the charge of the battery progresses. It is the finishing rate which is the real important one. If the charge is finished at too high a rate, the battery will gas and overheat and, therefore, if the battery is on the circuit too long it will be damaged.

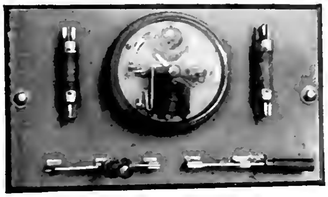

Fig. 12. Constant-potential Circuit Control with Automatic Switch

The batteries usually have stamped on the trays a starting rate and a finishing rate, e.g., an 11-plate Type MV "Hycap" will start at 24 amperes and finish at 10. This is the old method of marking. If the battery is completely discharged, it will be economical to start the rate at about 35 amperes or perhaps 40 amperes, provided the current falls off as the voltage of the battery increases so that at the end of the charge the flow will have fallen to about 7 amperes. It is practically certain that if this condition is arranged correctly, the battery will not overheat and will not gas violently and, therefore, it will not be injured. The battery should thus be completely charged in from 8 to 10 hours. The condition of complete charge is best determined by the use of the hydrometer. Each cell should show a specific gravity of 1.280, or whatever the battery manufacturer has recommended for that particular battery. The voltage of the battery will also be up to about 2.65 per cell and be quite stationary. The voltage must be taken while the battery is under charge for voltage readings taken with the battery open circuited are of no value whatever.

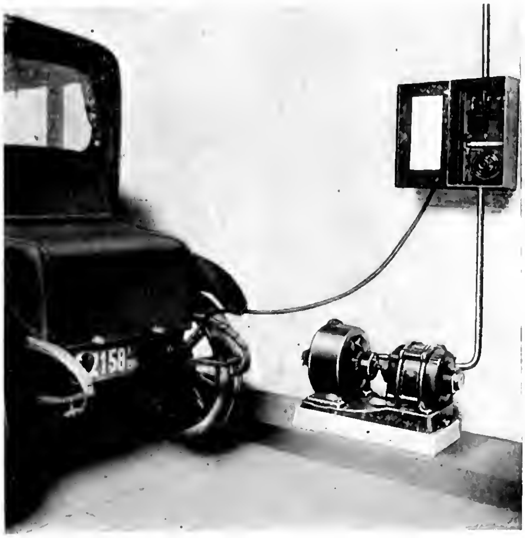

Fig. 13. Standard Taper Individual Vehicle Charging Equipment

The voltage is highest at the last part of the charge, hence the current flow must be kept low and of a steadily decreasing value. The rough rule is given that the current values toward the end of the charge should be not greater than 1.4 times the number of positive plates; e.g., in a 13-plate cell (13-1) divided by 2 and multiplied by 1.4 equals 8.4 amperes. A current flow not greater than this value for a 13-plate battery may continue almost indefinitely without injury. This shows the importance of using the proper taper of the charging current curve of an automatic charging set and the necessity of calling for an exact description of the particular battery to be charged by such a set.

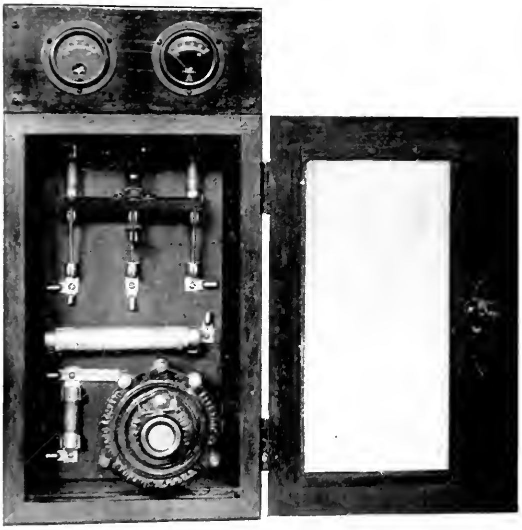

Fig. 14. Standard Wall Cabinet with Instruments

Overnight charging may be easily accomplished with these sets, on the understanding that the operator starts the charge at about 10 or 11 p.m. He need not bother about attending to it during the night and he can set it so that the battery will be very well charged by 7 to 9 o'clock the next morning, provided there has been no interruption of the alternating-current supply.

Should the alternating-current supply fail during the night, practically no harm will result as the set will continue to run in the proper direction but it will draw from 2 to 5 amperes from the battery. When the power returns to the line, the set will immediately pick up the charge again and continue it. If the battery is discharged but still retains sufficient energy to move the vehicle, there will be sufficient power in the battery to run the set reversed at a discharge of 2 to 3 amperes for so many hours that there is really no danger of injuring the battery as long as provision is made to charge the battery promptly after this abnormal discharge is discovered.

Ordinarily, the better type of vehicles are equipped with voltmeter and ammeter, hence these instruments are omitted from the charging set. If the vehicle is not provided with the instruments, a wall cabinet as shown in Fig. 14 may be used. Ordinarily, however, the meters on the car serve every purpose in this connection and they should always be consulted, especially the ammeter, to see that the current is flowing in the right direction to charge before the set is left running for any length of time.

Automatic Charger

Many vehicles are now equipped with ampere-hour meters which have special contacts for opening the charging circuit when the battery is charged. Where an automatic equipment of this character is wanted, the panel illustrated in Fig. 15 is used instead of the steel wall cabinet. The method of starting the motor-generator set and of charging is similar to that used in the other equipment; but when the contact on the ampere-hour meter closes, the circuit-breaker opens, thereby disconnecting the generator from the battery and the motor from the line.

Fig. 15. Individual Vehicle Charging Panel with Automatic Protection for use when ampere-hour meter is installed on the vehicle

The individual charging sets are built for charging either Edison or lead acid batteries, but the sets are different, to take care of the different characteristics of the batteries.

THE FLOW METER AND ITS RELATION TO PLANT ECONOMY

By J. H. Hough

The big opportunity for reducing costs in the average power plant lies in the boiler room. In many cases batteries of boilers are operated in parallel with no means being provided for indicating how they are dividing the load. The installation of a draft gauge and a steam flow meter for each unit would eliminate the need for guess work and show at any moment the performance of each boiler. Another large field for the efficient use of the flow meter is in measuring steam for manufacturing purposes; in fact, this device will be found useful for the measuring of a great number of fluids that are handled in quantity, such as hot and cold water, compressed air, oils, and non-corrosive gases.—Editor.

The present day high cost of fuel together with the attending difficulty of obtaining it, lend strong testimony to the cry for improved operating methods. These facts will require that every possible effort be exerted to get the most from the heat energy stored in the coal pile.

The engineer has accomplished much in improving the efficiency of the transformation from steam to electrical energy, yet increasing the economy of transformation from coal to steam still remains a fruitful field of endeavor in many plants.

The world has progressed through knowledge; and if knowledge is power, more knowledge is more power. This idea when applied to the engineering and manufacturing world means that the men in charge must know without question what is taking place in their plants. One of the chief sources for obtaining this information is in an equipment of proper meters and instruments.

When visiting the average power plant, instead of spending time in the turbine and operating rooms where there is installed an up-to-date switchboard equipped with every type of electrical instrument, make a short survey of the boiler room. What a contrast to the finely equipped turbine room! The fireman struggles gamely to hold the load on the boilers with no guides to assist him but a pressure gauge and a water column. The electric generators, operating in parallel on the bus-bars, are equipped with wattmeters to show exactly the load on each. The steam boilers operating in parallel on the main header are being operated blindly with nothing to indicate in what manner they are dividing the load. The man who approves the coal bills does not stop to analyze the load efficiency curve of the boiler. He perhaps does not know that at one particular rating the best thermal efficiency is obtained and that this efficiency drops rapidly when the boiler is very much below or above this point. A short time ago the cost of coal represented 70 per cent of the total cost of producing electrical energy. At the present time this percentage has increased considerably due to very high coal costs. Doesn't it seem the height of inefficiency to burn up all this money with scarcely a thought as to how economically it is being consumed?

It is to be noted that these remarks apply to the average manufacturing plant and not to the modern central station where improved methods in the boiler room are used with consequent high economies. To a great many plant superintendents and chief engineers the coal bill is accepted each month as a necessary evil; yet the following digest of a recent editorial in an engineering magazine will show that the subject is receiving the attention of thinking men.

Saving in the Boiler Room

"The big opportunity for reducing costs lies in the boiler room. No one would expect the electrical end of a plant to be operated satisfactorily without some instruments to guide the operators. Yet the pressure gauge and the water column have been and are about all the average boiler attendant has to help him. For the rest he is supposed to be able to get along by using his eyes to judge the condition of the fire. There are some men naturally gifted who can do fairly well under even these circumstances, but why leave to human judgment a problem that is easily simplified until it is no trick at all, by providing a few thermometers, a steam flow meter and a draft gauge?

"There is nothing mysterious about burning coal so as to get the most heat out of it where and when it will do the most in turning water into steam, but it cannot be done continuously and consistently without the means mentioned to show the fireman when it has happened, and if it has not, why."

"At the present time the flow-meter finds its greatest field of usefulness on individual boiler units. It is the ammeter of the boiler. Various designs of the instrument have been brought out for this use, each having its respective field of application.

"One large plant has standardized on the indicating instrument for installation on the boilers. The scales are calibrated to show the output of each unit at any instant in boiler horsepower. The plant is subjected to the sudden peaks occasioned by a railway load; and, as these peaks are transmitted almost instantaneously to the boilers, it is important for the boiler room engineer to know whether *each* of the units is taking its share of the increased load. The loafing of one or two of the boilers at such a time will result in either a drop in pressure or in an excessive overload on the remainder of the battery which consequently lowers the overall efficiency. The indicating instrument will only prove efficacious where there is a competent boiler room engineer in constant attendance. When this is not practicable and the engineer is only able to make periodic trips to the firing aisle, the indicating meter should have the graphic recording feature added, thus giving a continuous record of the boiler performance over any period. These records will be available each day for the engineer's inspection and by proper analysis should enable him to detect any irregularity or defect in the operation of the various units.

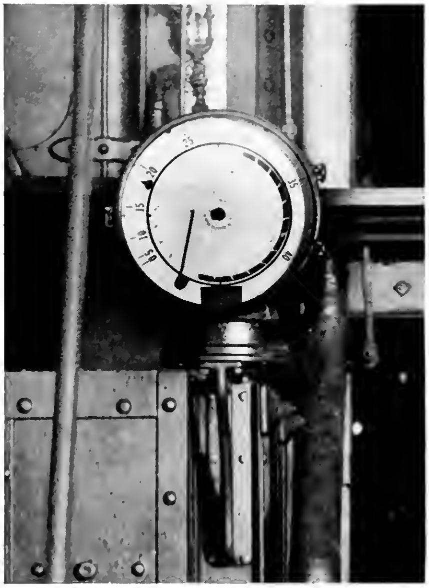

Fig. 1. One of 32 Indicating Recording Flowmeters measuring the steam output of boilers in the Fisk Street Station of the Commonwealth Edison Co., Chicago, Ill.

"In a great many plants it is not possible to measure the coal supplied to each unit, but when this can be done the steam flow meter should be equipped with an integrating attachment giving the total water evaporated over any period of time. With this arrangement the engineer can keep an actual evaporation record of each boiler over the three watches."

Fig. 2. Indicating Recording Integrating Flowmeter measuring maceration water in the Central Santa Rosa Sugar Mill, Santa Rosa, Cuba

At a recent meeting of the Production Committee of the Empire Gas & Electric Company a bonus system for boiler room operators was described wherein the flowmeters were employed as a basis for the records. The fireman can only be stimulated to increased efforts by dividing with him the amount saved as a result of those efforts, so one of the fundamentals of improved economy in the boiler room is an equitable bonus system.

The second largest field for the flow-meter is probably in the measurement of steam used for manufacturing purposes. The applications of the meter in this field are almost limitless. Take for example the oil industry: In the refinement of oil a large quantity of live steam is required which is often wastefully employed. By installing meters on the lines to the stills, the most economical range of operation can be determined empirically and the operator (usually of a very low class) be made to duplicate the established standard. The average oil refinery is made up of a number of practically independent departments, each manufacturing its own by-product. These departments obtain their steam from a central generating station, and as it is necessary to apportion the steam supplied to each a steam flow-meter on the various department lines permits this segregation to be made intelligently.

Fig. 3. Two Types of Indicating Steam Flowmeters measuring the steam output of boilers in the Port Morris Station of New York Central & Hudson River Railroad, New York City

The meter also finds application in the refinery for measuring oils, it only being necessary to have the oil of uniform specific gravity. Several meters were recently installed in an oil refinery for measuring the air used for aerating oil. Air is blown through the large tanks of oil and the grade of oil produced is dependent upon passing an exact quantity of air for a definite period.

In many other large plants each department and often each process is charged with the amount of steam used. Here the flow meter is of great value in obtaining actual costs of manufacture as well as showing any wastes that may exist. One large rubber factory employs over one hundred flow meters for this purpose.

In copper refineries, cement mills and other plants using waste heat boilers it is usually desired to credit to the furnace the steam produced. This can readily be done by the use of a recording steam meter on the boiler. The information obtained from this meter will also enable the engineer to determine the number of coal fired boilers to bank during the operation of the waste heat units.

Flow meters are finding increased application in the centrals of many of the large Cuban sugar companies, where the cost of steam forms a considerable portion of the complete manufacturing cost. But not only as a check on the steam generated is the instrument valuable. The quality of the syrup produced is dependent entirely on the care and skill of the attendant, and a meter installed on the steam line to the sugar pans and on the maceration water line should be of material assistance in obtaining good results.

The portable test flow meters for general testing and research work are almost indispensable in every manufacturing plant. This meter has been perfected to cover a wide operating range of conditions for almost any uniform density medium. The principal uses for this type of meter will be for measuring the flow of high and low pressure steam, hot and cold water, compressed air, the lighter oils and non-corrosive gases.

Fig. 4. Indicating Recording Integrating Flowmeter installed in a 14-inch line supplying steam to the mills of the Pennsylvania Steel Company, Steelton, Pa.

The flow-meter also finds ready application in paper and pulp mills, tanneries, steel mills, soap manufactories, paint factories, cotton and woolen mills, and in fact any plant where live steam forms a part of the manufacturing process.

COMPARATIVE COSTS OF DEVELOPING POWER FOR PUMPING IN THE OIL FIELDS

By S. G. Gassaway

General Electric Company, San Francisco, Cal.

A very vital national necessity now exists in increasing oil production and conserving the available supply in every way possible, because of the great excess of present consumption over production. A comparison of the operating data and costs in this timely article indicates the large saving in oil which is obtained by the use of electric power, and the further saving made in operating expense which can be applied to the development of new wells. The basis of these remarkable economies is the standard oil-well motor now so widely used.—Editor.

An engineer prominent in the efficient design of industrial power plants, such as are found in the more congested manufacturing centers of the United States, made the remark upon his return from a trip through the oil fields that the tremendous inefficiency in power development, which he saw there, actually gave him a nightmare. To one trained in engineering matters, but unfamiliar with the problems of petroleum mining, this same conclusion might be reached. Such "inefficiency" however can be defended on the score of expediency, lack of finances and lack of knowledge of such matters by those in charge of production. The successful oil field superintendent is primarily a "production" man and his value is usually reckoned by the number of barrels of oil he produces regardless of methods or economies effected.

Production in the oil fields is just as much an art as any of the other recognized professions. Drilling wells and keeping them producing is not merely a matter of routine as the layman unfamiliar with such problems may suppose. Each well drilled has its own peculiar problems and when it is "put on production" these problems are not all solved by any means; in fact it is often here that the "fun" only just commences and throughout the life of the wells there are new problems, troubles and worries cropping up daily. Water may break in, the casing may collapse, the oil sand may shift, a neighbor's well may be flooding the sand with water, or perhaps the roustabout gang has carelessly dropped a string of tubing which means an expensive fishing job. This proves that the production boss's life is not just one continual round of pleasure.

After due consideration of the various problems, we should hardly expect the production man to design and erect the most efficient power plant, but we should rather expect him to erect a boiler here or a pump there and another boiler at some other place as he needs them. Properly the design of such a plant should be given to one experienced in such matters. Until very recent years such an engineer was a rare or almost unknown person in the oilfields.

There are three common methods of pumping in the field; (1) namely, by steam engines, gas engines supplied with natural gas, and by electric motors. The power for the steam engines is usually generated from natural gas obtained on the lease, or if this is lacking, by burning under the boilers, a part of the oil produced. With motors, power may be purchased as in the case of the California fields from the large hydroelectric power transmission systems, or generated on the lease by steam, gas or oil engines. This article considers five schemes of pumping the wells both "on the beam" and by "jacks."

A. Installing electric motors at the wells and jacks.

B. Installing gas engines at the wells and jacks, and small gas-engine driven plant for lighting.

C. Generating plant using gas engines.

D. Generating plant using condensing steam turbines.

E. Steam engines at wells and jacks, including boilers.

We have also prepared four propositions which give the operating costs.

V. When purchasing power with equipment A.

W. Operating with individual gas engines, no power plant, equipment B.

X. Generating power with plant C and motors installed on wells and jacks, equipment A.

Y. Generating power with plant D with motors installed on wells and jacks, equipment A.

Z. Steam engines at wells using oil for generating fuel, equipment E.

The figures are based on the average of a number of operating results obtained on plants in the oilfields and elsewhere.

To the end that the figures given might be applicable to as many different field conditions as possible the conditions as given below have been taken as best suited to meet these requirements. Comparatively deep wells (2700-3600 ft.) with an average production (80 bbls.) have been taken as representing the more severe and expensive production conditions and shallow "jack" wells as representing the other extreme, as representing cheap production.

There may be some questions as to the amount charged to lost production because of shut downs. This is a question on which there are about as many differences of opinion as there are operators. All operators however are agreed that the more hours the beam is kept bobbing up and down the larger will be the net production at the end of the year. Therefore, if the wells are shut down because of repairs or other interruptions, it is to be expected that the yearly production will fall off correspondently. Account has been taken that these shut downs do not occur in one continuous period, but that the total shut down is made up of many shut downs of varying length throughout the year. Also, as there will be a "head" of oil on the wells when they are started up, the loss in production for a short shut down will not be as great as for a long shut down. To be on the safe side, no lost production is charged to the jack wells, as 16 hours a year shut down with motor drive would not actually result in any lost production, although with the larger shut downs due to gas engines a loss in production would result.

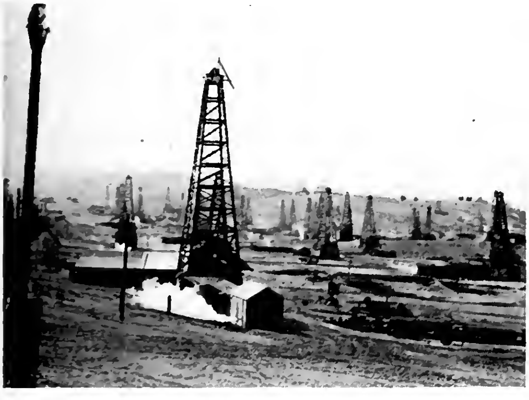

Fig. 1. It is only on a cold day in California that the steam-engine exhaust can be seen. This is a section of the McKittrick oil field as it appeared in 1913

There are more than 2000 electrically operated oil wells which have been operating for periods of from 1 to 11 years in which the repair expense has not equalled 1 per cent of the first cost. Likewise, there are several hundred gas engine wells which have operated not more than 4 or 5 years in which the maintenance exceeds 11 per cent. A maintenance of 2 per cent on electric motors and 9 per cent on the gas engines installed at the wells has been assumed. A maintenance charge of 6 per cent is allowed on the gas engines and electric machinery in the power plant as there will be standby units and the plant is under more expert supervision than in the field. Likewise for the turbine driven plant, 2 per cent for maintenance is allowed. For steam engines and boiler plants in Z, 5 per cent is allowed for maintenance.

Fig. 2. Pulling rods with motor drive in the Midway field in California

There may be some difference of opinion as to the earning capacity of money invested in new wells. This article assumes that the money invested in new wells will at least bring a net return, after all operating expenses have been paid, of 20 per cent.

Fig. 3. A gas-engine-driven oil well near Taft, California

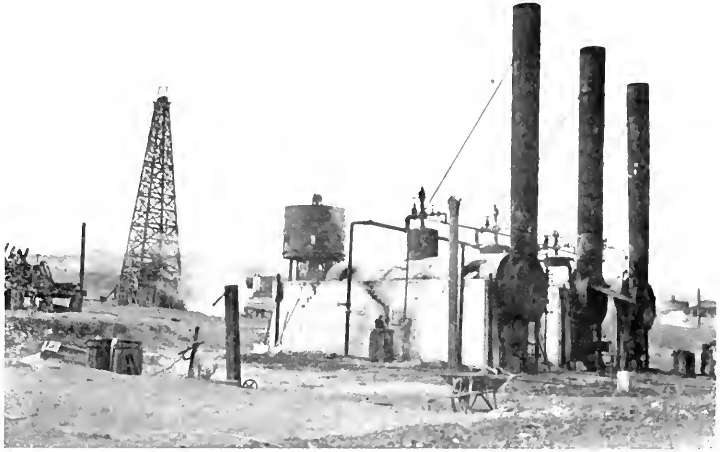

Fig. 4. Most oil field boilers are not as well installed as these three in the Midway field in California

Fig. 5. Oil wells in the Kern Field in California. Many are electrically operated, and the one in the foreground is a jack-well pumped from a central motor-driven power

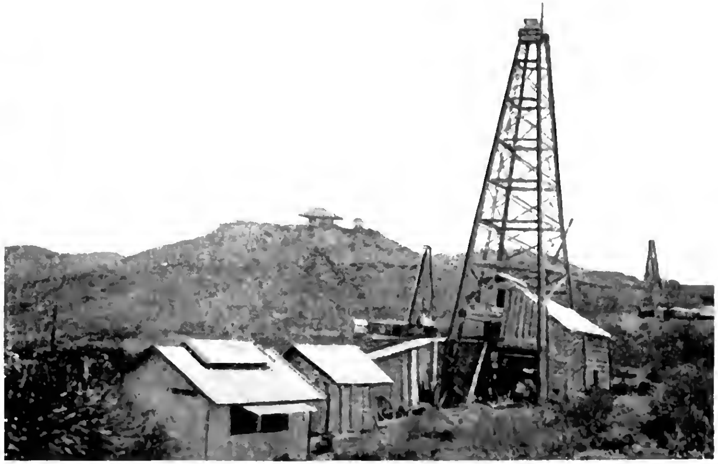

Fig. 6. A well in the Singu field in Upper Burma, India, which is pumped, pulled and cleaned by two-speed variable-speed oil-well motor drive

The conditions taken are as follows:

Connected Load:

30 wells "on beam"—depth 2700–3600 ft.
65 wells on 4 "jack powers"—average depth 550 ft.
Size tubing, beam wells—2½ in., Jack wells—2 in.
Size pump, beam wells—2½ in., Jack wells—2 in.
Gravity oil 33° B. Average production, beam wells—80 bbls.

Lighting:

30 kw. for 3 hours.
20 kw. for 9 hours.

Initial Unit Cost Installation at Wells (2)

Beam Wells—including engine and motor house and all equipment within the house except band-wheel belt, lease piping for gas and water and steam, water tank, electric transmission line on lease and boiler plant in case of steam engines—all installed ready to operate

Steam Engines	$ 1,400.00
Electric motors	1,350.00
Gas engines	1,900.00

Jack Power Plants—17 wells each

With 30 horsepower gas engine including building, jerk lines to the derrick (but not including pumping jack at wells), and gas and water lines	$ 6,000.00
Ditto with 25 horse power electric motor with transmission line on lease	$ 5,100.00
Ditto with 30 horsepower steam engine and boiler	$ 6,000.00

Power Demand

Assuming daily load as follows—
29 pumping wells, beam.
1 pulling well, beam.
4 jack powers.
Lighting load as above.
Average power demand will be 377 h.p.
Peak—425 h.p.
This is equal to 280 kw. and 315 kw. respectively.

INSTALLATION COSTS AT WELLS

A. *Electric:*

30 wells at $1,350.00	$ 40,500.00
4 jack plants at $5,100.00	20,400.00
	$ 60,900.00

B. *Gas Engine:*

30 wells at $1,900.00	$ 57,000.00
4 jack plants at $6,000.00	24,000.00
	$ 81,000.00
30 kw. generating plant for lights.	4,500.00
	$ 85,500.00

C. *Generating Plant:*

3–150 kw. 250 h.p. gas engine driven generators with necessary switchboard, step-up station transformers and distribution transformers for power, with high tension distribution lines on lease, and necessary station building—installed ready to operate	$ 74,500.00

D. *Generating Plant*

Ditto except 2–300 kw. Curtis turbine driven generators operating condensing complete with boilers arranged for gas or oil firing, and necessary jet type condensing apparatus and complete spray cooling system with concrete pond—installed ready to operate	$ 58,800.00

E. *Steam Engine:*

30 wells at $1,400.00	$ 42,000.00
4 jack plants at $6,000.00	24,000.00
	$ 66,000.00
30 kw. generating plant for lights.	$ 3,800.00
	$ 69,800.00

OPERATING DATA

V. **Purchasing Power** at 1 cent per kilowatt hour.

Operating Cost:	Per Year
Six pumpers at $105.00 mo. each	$ 7,560.00
1–electrician at $125.00 mo.	1,500.00
Lubricating oil	75.00

Interest —6. per cent
Sinking fund —7. per cent
Maintenance —2. per cent
Insurance and taxes—1. per cent

16 per cent × $60,900.00 (A)	9,744.00
Power bill 2,452,800 kw. hrs. at 1 cent	24,528.00
Lost production on 30 beam wells, producing 80 bbls. per day each, due to shut down of 16 hours per year due to power failures and all electrical troubles—10 bbls. loss per well per year at $1.00 per bbl.	300.00
Total operating expense	$ 43,707.00

W. **Individual Gas Engines:**

Operating Cost:	Per Year
8 Pumpers at $105.00 per mo.	$ 10,080.00
1 Electrician to operate light plant —$125.00 per mo.	1,500.00
2 gas engine repair men 1 at $150.00 per mo. 1 at $105.00 per mo.	3,060.00

Interest —6 per cent
Sinking fund —7 per cent
Maintenance —9 per cent
Insurance and taxes—1 per cent

23 per cent × $85,500.00 (B)	19,665.00
Lubricating Oil	2,040.00

Lost production on 30 beam wells, producing 80 bbl. per day each, due to 210 hours per year (average 4 hours per week) shut down because of gas engine, mixture and gas supply troubles and time for repairs—400 bbls.

loss per well per year at $1.00 bbl.	$ 12,000.00
Earning power of $24,600. Difference cost A and B if invested in new wells at 20 per cent net	4,920.00
Total Cost Operation	$ 53,265.00

To operate will require 219,000 cu. ft. gas daily with flow to carry over peak loads at rate of 244,000 cu. ft. day.

X. **Generating Power with Gas Plant C**

	Per Year
Cost operating Equipment A same as operating cost V except no power bill	$ 18,179.00
Cost operating Plant (C) Interest —6 per cent Sinking fund —7 per cent Maintenance —6 per cent Insurance and taxes—1 per cent 20 per cent × $74,500.00 (C)	14,900.00
Labor 2 engineers 3 oilers and helpers 1 machinist	10,000.00
Lubricating oil and supplies	900.00
Earning power of $74,500.00 Cost of power plant C, if invested in new wells—20 per cent net	14,900.00
	$ 58,879.00

This plant will require 108,000 cu. ft. gas per day.

Y. **Generating Power with Steam Plant D**

	Per Year
Cost Operating Equipment A same as operating cost V except no power bill	$ 18,179.00
Cost Operating Plant D Interest —6 per cent Sinking Fund —7 per cent Maintenance —2 per cent Insurance and taxes—1 per cent 16 per cent × $58,000 (D)	$ 9,408.00
Labor same as Plant X	10,000.00
Lubricating Oil and Supplies	300.00
Earning power of $58,800. Cost of Plant D, if invested in new wells 20 per cent net	11,760.00
Total Cost	$ 59,647.00

This Plant will require 166,000 cu. ft. gas per day.

Z. **Steam Engines—oil fuel**

	Per Year
8 pumpers at $105.00 mo.	$ 10,080.00
1 Electrician to operate light plant $125.00 mo.	1,500.00
8 firemen for boiler plants (3) at $105.00 mo.	10,080.00
Lubricating Oil	1,200.00
3 boiler repair men	4,200.00
Interest —6 per cent Sinking Fund —7 per cent Maintenance —5 per cent Insurance and taxes—1 per cent 19 per cent × $69,800. (E)	13,262.00
Lost production on 30 beam wells due to engine and boiler troubles, 10 bbls. per well year at $1.00 per bbl.	300.00
Earning power of $8,900 (diff. cost A and E) if invested in new wells at 20 per cent net	1,780.00
Selling value of 98,100 bbls. fuel oil at $1.00 bbl.	98,100.00
Total Operating Cost	$152,182.00

In the foregoing no account is taken of value of the oil land, office expense, superintendence, drilling and well crew expense as these amounts are a fixed charge regardless of the power system used.

No charge is made for water used. It is assumed this is produced on the lease. The

RECAPITULATION

	Cost Equipment at Wells	Cost Power Station Equipment	Yearly Operating Cost
Electric Motors, Power purchased at 1 cent kilowatt hour	A $60,900.00	—	V $43,707.00
Gas Engines	B $85,500.00	—	W $53,265.00
Electric Motors, Power generated by gas engines	A $60,900.00	C $74,500.00	X $58,879.00
Electric Motors, Power generated by steam turbines	A $60,900.00	D $58,800.00	Y $59,647.00
Steam engines at wells, including boiler plants burning oil	E $69,800.00	—	Z $152,182.00

charge for water today in the California fields varies from 2 cents to 5 cents per barrel. It cost as much as 17 cents to 20 cents per barrel during the early development of the fields and in a few cases even more. No value is given the gas used for fuel as often no market is available for this.

The figures arranged in the Recapitulation Table are in their order of economy of operation, namely, electric motors with power purchased, gas engines with free gas, electric motors with power generated by gas engines with free gas, electric motors with power generated by steam turbines from free gas, and steam engines with power generated from oil fuel. Should the power for the steam engines be generated with free gas, steam engines would appear third in the Table. The arrangement of the Table will vary according to whether there is a charge for water or gas, a different charge for electric power, oil fuel, etc. The conditions taken are, however, approximately the average ones met in the California fields. It is obvious that, regardless of the charges for fuel and water, when purchasing power at 1 cent per kilowatt hour the electrical equipment would be the most economical power plant to install.

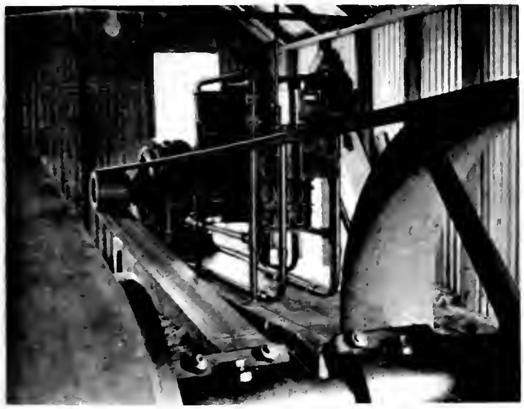

Fig. 7. A Kansas installation of a two-speed variable-speed oil-well motor equipment for pumping, pulling and cleaning work

A decided advantage in motor drive is the very steady motion imparted to the beam and the fact that the number of strokes when once set on the controller will remain the same year in and year out until the controller is set at some other speed. The motor does not pick up the rods with a jerk as in the case of steam and gas engines, the speed of the band-wheel being practically constant for the entire revolution. The rods, therefore, are less liable to crystallize with resulting breakage causing shut down due to rod troubles. It is a fact that the net production has been increased because of the steady motion of the motor. This has been borne out by the experience of those operators who are using the latest type of two-speed variable speed motors.

Fig. 8. Pulling tubing with motor drive in the Midway field in California

When electric motors were first put in the oil fields the designing engineers had many problems to solve. After years of experimenting, redesigning, etc., they have finally succeeded in developing an electric equipment which will perform all the functions required of it by the production man as successfully as his time-honored steam engine. This is borne out by the testimony of a large number of operators who have been operating several hundred of this latest design of electric equipment for the past 3 or 4 years.

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(1) Compressed air is also used in the ordinary "air lift," usually for wells giving water in large volume, and also at low pressure and superheated for operating engines installed at each well. These installations are not common.

(2) The average cost of installing 57 California gas engines at Coalinga in 1912 was $1,277.17—not including gas and water mains. Average cost of installing 100 motors in Kern River Fields of California in 1911-1912 was $758.75. Costs have advanced since then. Thomas Cox, in U. S. Bureau of Mines Technical Paper No. 70, gives ratio of cost of motor to gas engine as 100 to 195—our ratio is 100 to 140. Ratio steam to electric 100 to 100.

(3) About the smallest number of boiler plants would be four because of distance to wells and contour of ground—not unusual to find six or eight plants to this number of wells.

SPHERE-GAPS FOR LIGHTNING ARRESTERS

By V. E. Goodwin

Lightning Arrester Engineering Department, General Electric Company

The aluminum, or electrolytic type of lightning arrester is recognized as being the most efficient type of arrester by virtue of its high discharge rate, large heat absorbing capacity, and its ability to discharge lightning disturbances without interfering with line conditions owing to the quick action of the aluminum cell. The addition of sphere gaps to the arrester for alternating-current circuits increases the speed with which the arrester discharges lightning impulses and consequently further increases the efficiency of the arrester. The description of the application of the sphere gap in the following article therefore records a marked improvement in the art of protecting electrical apparatus against lightning.—Editor.

A number of articles have appeared in this magazine and one paper has been presented before the American Institute of Electrical Engineers, describing the theory and action of sphere-gaps and dielectrics under transient electrical stress.*

It is well known that all forms of insulations possess the valuable property of requiring a definite time of application of an abnormal potential before actual rupture or breakdown of the material occurs. This property is known as the "dielectric spark-lag," sometimes more briefly termed the "lag."

This property of insulating materials has to be considered regardless of whether the medium be solid, liquid, or gaseous. The time duration of this lag while definite for any one set of conditions varies with different materials, the thickness of the material, the rate of application of the abnormal potential, and the shape of the electrodes at which the potential is applied. By varying these conditions, lags may be obtained varying from a fraction of a micro-second to several minutes in duration.

Since the lag decreases very rapidly with an increase in the rate of application of potential, it is evident that it becomes a very important factor when dealing with lightning or other abnormal potentials which have steep wave-fronts.

Investigations of lightning troubles in stations frequently results in apparent inconsistencies. One frequently finds that arcs have taken place across spaces which are much greater than others on the same circuit, all being apparently subjected to the same voltage. Again, one will find failures of bushings or insulators by puncture, when previous tests had shown that the potential required for arc-over was much lower. Many of these peculiar failures can be explained by carefully analyzing the conditions which existed at the time of failure and giving proper consideration to this property of dielectric spark-lag.

Let us assume for example that we have two or more pieces of insulation in parallel, such as air, oil, or porcelain, and that they have different lags due to variations in the factors just mentioned. If, now, we instantly apply a voltage much above the value required to rupture the best test piece, it is evident that they will break down in succession according to their individual time-lags. This assumes that the abnormal voltage is sustained until the lag of the slowest part is exceeded. In actual practice this seldom occurs since the breaking down of the first one short circuits the abnormal voltage; and sometimes the normal voltage, and prevents further breakdowns. In this case the insulation having the shortest lag breaks down, thus protecting the others which have the greater lags.

This phenomenon of variation of spark-lag was demonstrated by the tests illustrated in Fig. 1. Fig. 1 shows a circuit containing an insulator *A*, a needle-gap *B*, a horn-gap *C*, and a spere-gap *D*, all connected in parallel and subjected to high-voltage steep-front voltage waves. (Air was the only dielectric studied in these particular tests). In the case of insulator *A*, arc-over may take place across the surface between the porcelain and the air, or may take a path entirely through the air. Arc-over of the horns, spheres, or needles is confined to a straight air path.

In these tests the voltage of the impressed impulse was high enough to bread down any of the four test pieces. The only known variables were the shape of the electrodes and their spacings. These were varied in the succeeding tests. In this first test, Fig. 1, the gaps *B*, *C*, and *D* were spread so that

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* "Electrical Characteristics of Solid Insulations," by F. W. Peck, Jr., General Electric Review, November, 1915.

"Factors Determining the Safe Spark-over Voltage of Insulators and Bushings for High Voltage Transmission Lines," General Electric Review, page 483, 1916.

"Spark-over Voltages of Insulators and Bushings for High Voltage Transmission Lines," General Electric Review, page 567, 1916.

"Lightning," General Electric Review, page 586, 1916.

"The Effect of Transient Voltages on Dielectrics," by F. W. Peck, Jr., A.I.E.E., Aug., 1915.

the discharge is seen flooding the surface of insulator *A*, which has a 60-cycle spark potential of 157 kv. Furthermore, it should be noted that the 60-cycle arc-over took the shortest air path from the cap to the pin; whereas the high frequency takes a much longer path by following around the surface of the petticoats, thus indicating a very much shorter lag along the porcelain surface.

Fig. 2, shows the same outfit when the needles of gap *B*, had been reduced to a point corresponding to a 60-cycle spark

Fig. 1

Fig. 2

Fig. 3

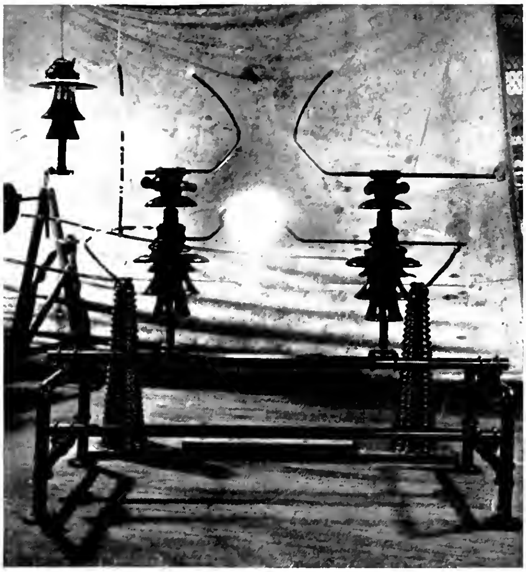

Fig. 4

The above cuts illustrate the relative dielectric spark lags of needle, horn, and sphere gaps in comparison with a standard insulator. The tests were made with steep front high voltage impulses. Fig. 1 shows the whole discharge going over the insulator which has a 60-cycle arc-over of 157 kv. In Figs. 2 and 3 the insulator is faster than either the needles or horns which are set at 130 kv. and 140 kv. respectively. In Fig. 4 the spheres discharge before the insulator arcs over, even though set at a higher value, thus showing the high speed of the sphere gaps.

potential of 130 kv., but still no discharge took place indicating that the insulator had a shorter lag or, in other words, was faster than the needles.

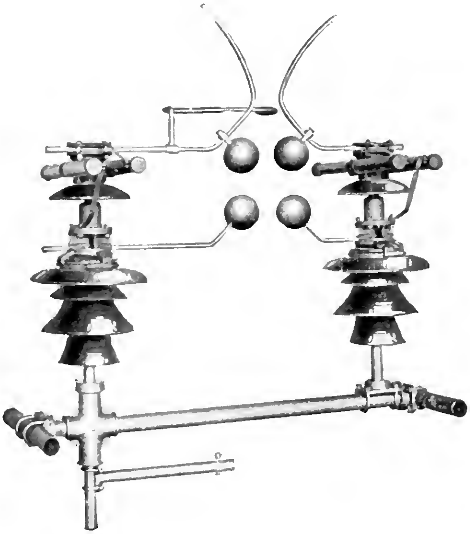

Fig. 5. Sphere-horn Gap for use with 70,000 Volt Aluminum Arrester

Fig. 3 shows the effect of reducing the horn-gaps. In this view the needles remained at the 130-kv. setting and the horns were reduced to a 60-cycle setting of 140 kv. before they had any effect on the discharge over the insulator even though the latter had a higher 60-cycle test. This view shows a part of the discharges going over the horns.

In Fig. 4 the needles and horns were left exactly as in the previous tests, namely, at 130 kv. and 140 kv. respectively. The setting of the spheres had been gradually reduced until discharge occurred across them. This setting corresponded to a 60-cycle setting of 170 kv. It will be noted in Fig. 4 that no discharge now took place over the insulator even though its spark potential was 13 kv. lower than that of the sphere gap, thus indicating the greater speed or shorter lag attained by the sphere-gap. Absence of corona is also noted on both the horn and needle-gaps.

The tests illustrated are but characteristic of many that have been made during the study of dielectric spark-lag. Many other forms of electrodes and special gaps were studied, but the shortest lags were obtained with properly proportioned sphere gaps. In these tests the insulation is air, but similar variations in the dielectric spark-lag have been noted for other insulating materials.

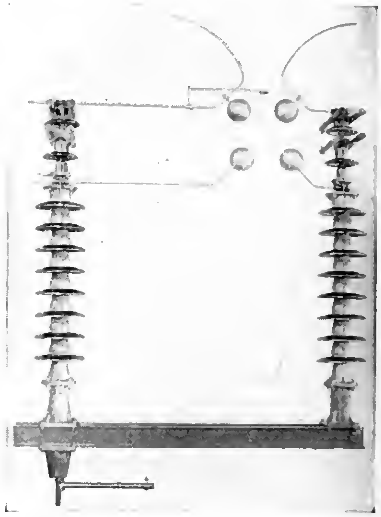

Fig. 6. Sphere-horn Gap for use with 115,000–135,000 Volt Aluminum Arrester

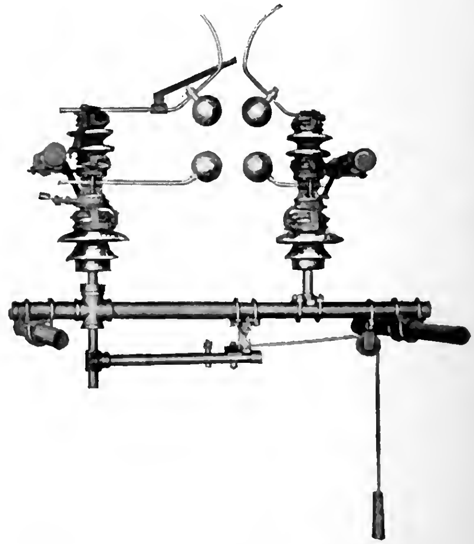

Fig. 7. Sphere-horn Gap for use with 20,000 Volt Aluminum Arrester

Applying the ideas developed these tests to the protection of apparatus, there are two natural conclusions: first, the time-lag of the insulation of the apparatus should be made as great as possible; second, the time-lag of the protective devices should be made as small as possible. In other words, the insulation of the apparatus should be designed to be as slow as practicable and the lightning arresters should be made as fast as possible. These aims can be attained by careful selection of insulating materials, and by proper shaping and spacing of conductors and electrodes.

These conclusions have naturally led to changes in gap constructions for various types of arresters. Fig. 5 shows the improved sphere-horn gap for a 70-kv. aluminum arrester. In this equipment there are three gaps, two of which are sphere-gaps and the third a horn-gap. The lower pair of spheres forms the main gap of the arrester, through which only the heaviest and most impulsive discharges pass. The upper pair of spheres forms the auxiliary gap which is connected through the charging resistances and which is so arranged as to discharge the remaining and greater part of the high frequency disturbances. The object of the auxiliary horn is three-fold. It serves first as a contact point for the charging operation; second, as a point of lowest spark potential for low-frequency sloping wave-front disturbances; third, as a guide and magnetic blowout for causing the final arc to rise and be extinguished.

This addition of spheres to the horn-gaps of lightning arresters marks a distinct advance in protective apparatus for it greatly reduces the time-lag of the arrester equipment and thus lessens the electrical stress on the insulation of the generating, transforming, and distributing apparatus on the system.

LIFE IN A LARGE MANUFACTURING PLANT

I. MEDICAL SERVICE AND HOSPITALS

This article is one of a series describing the systematic plans which have been developed for the selection of an efficient working force in a large manufacturing organization, and for the maintenance of its high physical, mental, and moral standard. New employees for all branches of the organization, offices and works pass the physical examination—no partiality is shown. When Mr. E. W. Rice, Jr., President of the General Electric Company was asked "Does welfare work pay?", he replied, "Yes we are sure that it pays, although we may not be able to show it on our books; but in any event we shall continue it because it is a service we owe to our fellowman and to the ideals of American industry."—EDITOR.

No one questions the wisdom of the medical examination when enlisting for military duty; and just so when enrolling with the armies of industry—the physical examination is becoming a matter of course. You, as an army recruit, do not feel insulted when Uncle Sam examines your teeth, and thumps your chest, and tests your vision; you do not feel that the army physician's services are to be classed as charity or philanthropy—you know it is efficiency, the greatest good for the greatest number, that dictates the policy of the physical examination. Therefore, to maintain the same high standard in the industrial army, every new employee must be examined—even consulting engineers. This has been the procedure in the General Electric Company's organization since 1914—without exception or favoritism.

It is for this good reason that we, in the great Industrials of to-day, welcome the plan and take a keen interest in the details of the maintenance of "*Health en masse*"—which is the big idea back of both armies and corporations.

The importance of preventing sickness is recognized by all; and how reasonable it is that the services of a medical staff maintained by the Company can carry out this important preventive work better and cheaper in the aggregate than curative work done by individual arrangement.

It is a great source of comfort to feel that there is no taint of tuberculosis or infectious disease among one's business associates. And from a more altruistic point of view, many of our less fortunate brothers have had the way pointed out to them for the complete recovery of their health—due to an expert's diagnosis at the time of the medical examination.

Free Diagnoses

In the year 1916, 13,716 examinations were made at the offices and works in Schenectady and each examination practically amounts to a free expert diagnosis. Many

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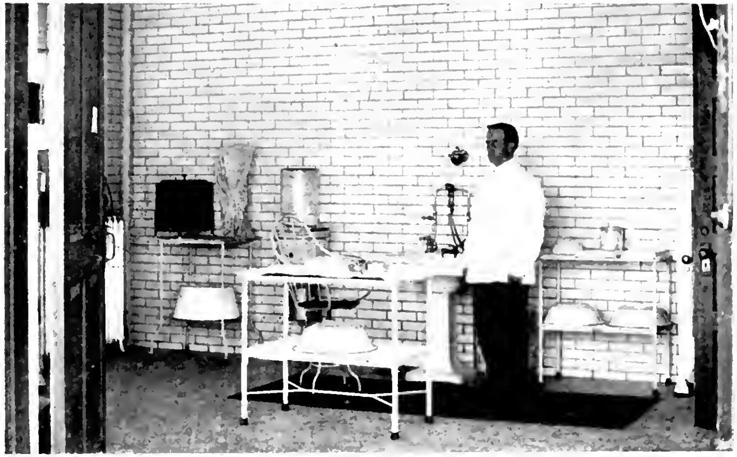

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1.—The Schenectady Hospital. 2 and 3.—The Man's Ward of the Emergency Hospital at the Pittsfield Works. 4.—The Erie Works Hospital.

Hospital facilities are provided at all of the numerous Works of the General Electric Company. Some of these hospitals are quite large, the number of employees in some of the plants equaling the population of a good sized city.

In the case of serious accidents, first treatment is given in the emergency hospital before the employee is sent home or to the hospital, and daily treatment or dressing is given as necessary. Employees are encouraged to report even the smallest injury, as this policy often prevents an insignificant scratch from developing into a serious case.

men and women have practically had their eyesight saved because they have taken the advice of the Company physician, and taken steps to correct the dangerous drift. In fact, many people have been found practically blind in one eye—not realizing the danger they were in until informed by the examining physician. A similar situation has arisen in regard to men either ruptured or on the verge of hernia.

Life Extension

In this connection, Mr. A. W. Clark in charge of the Welfare Department, recently remarked:

> "The day of preventive measures and medicines has dawned, and everyone is now thinking how disease can be prevented, instead of waiting until the disease has developed. Our medical examinations have revealed the beginnings of troubles unknown to the person examined; attention was called to them and advice given. In many cases the progress of the disease was checked. Everyone who has some reason to suspect that there is anything wrong, should get medical advice and get it early. The medical men who have studied the records agree that several years will be added to the average span of life by periodic medical examinations."

We are all appreciating more every year that the better suited we are *to* our work, the more suited we will be *with* our work. Now that these examinations have been started, we see that their object is not to keep us out of employment, but to direct us away from that kind of employment which may damage our health.

If a man had weak eyesight, the modern industrial company would never give him work near rapidly moving machinery; or, if his lungs were weak, he would not be permitted to do any work of a dusty nature which would soon aggravate the condition of his lungs.

In speaking of this dusty work, the fact should not pass unnoticed that there are periodical examinations of all those who are working in dusty rooms. Likewise anyone who has the appearance of lung trouble, or other disease, which may be aggravated by his occupation, is given a special additional examination in order to detect and therefore prevent any tendency toward disease. If such is discovered, necessary precautions to safeguard his health are advised, or the nature of his work is changed. Think of the sufferings of the past, when no such provisions were made! The expression, the scrap pile of humanity, formerly applied to the workers in large industrial plants, is no longer applicable.

Running the Gauntlet

In fact, by the time we have got fully into the swing of Life in a Large Manufacturing Plant, we realize that unwittingly we have "run the gauntlet"—mentally, physically, morally and industrially. This being the case, and all having passed the various tests of fitness, we find that our fellow-workers are anything but candidates for the scrap pile. The reverse is the case, and in the sense that each one of us has been selected for fitness, it can easily be seen that the organization amounts to a picked crew.

It is of interest to note that the rejections vary from $3\frac{1}{2}$ per cent to 6 per cent, the greater number being due to hernia and defective eyesight. Many cases of arrested development of the eye are noticed, and it is remarkable that so many applicants have not discovered prior to these examinations that they were practically blind in one eye. Frequently the sight can be immediately improved by proper glasses, this being particularly true in cases of short-sightedness. Many applicants have confessed that when standing on the curb they couldn't see a trolley car pass, and the simple expedient of providing proper glasses has surely saved many a life from street accidents.

All employees who are absent for two months or longer come back as new employees and have to pass a medical examination before re-employment.

Vital Statistics

There is another very important provision in which preventive measures are supplied for maintaining health *en masse*,—i.e. the Hospital—the ally of hygiene and enemy of suffering. Splendid records have been kept ever since the establishment of the hospitals. The history of the achievements of the medical men of this staff is written in the record; and some very striking facts stand out from among what some people might call plain statistics.

Most Accidents in Summer

Accidents unfortunately occur everywhere, on the street, in the home, and in the factory. Their number, by the law of chances, is likely to be in proportion to the population of a town or to the number of employees in a factory. So, as our organization grew and the number of employees increased from hundreds to thousands, facilities for taking

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All applicants for employment must pass a medical examination, which frequently results in the discovery and correction of unsuspected defective eye-sight and other ailments. 1.—Men's waiting room and dressing booths at Schenectady. 2.—An applicant taking the first test for eyesight in the examination room. Women applicants are examined by a woman physician. 3.—Doctor's office where these examinations are made. 4.—Women's medical room adjoining the doctor's office, where minor ailments and injuries are treated.

care of them became necessary. It has been the spirit of the Company to keep these facilities well abreast of the needs, and today our hospital facilities are larger than those of many towns, for the simple reason that our industrial army is larger than the populations of many towns. The presence of hospitals in a factory does not denote that the work is hazardous; indeed, the majority of accidents can be traced to carelessness, and no small part of the work in connection with factory hospitals is educational work—trying to teach the vital lesson of Safety First. Such educational work is made more difficult by the fact that many foreigners are employed who cannot speak English.

All of us are human and there is one characteristic which is particularly noticeable in us all; namely, our willingness to assume risks if we can save a little time. This trait is in daily evidence at all our busy street corners where pedestrians disregard the warnings and rules of traffic officers and persist in crossing the street or railway tracks at unsafe moments, being willing to risk injury for the saving of a fraction of a minute. In the same way it has been found that workmen in the shops will frequently assume risks in order to save a second or two; and therefore we shall always have accidents, and the larger the number of employees the larger the number of accidents.

One of the strange facts developed from a study of these records is:

Nearly 64 per cent of the major accidents of the year take place in the six warm months, May to October inclusive.

Medical men and executives and statisticians are all baffled by this mystery. Not one has been able to satisfactorily explain why 64 per cent of the accidents occur in warm weather and only 36 per cent occur in cold weather, year after year.

There is still another mystery:

Why do most of the major accidents take place either early in the morning or late in the afternoon. No one knows.

These two curious facts are undeniably true—they are medical history—and right here in these two unexplained facts lie some of the problems on which high type executives, engineers, and surgeons are devoting serious thought. They will clear up these mysteries in time, and their solution will probably result in some special instructions for us to follow at the beginning and close of the day; and we will be glad to do so, for all of us are anxious to avoid even a scratch.

What is An "Accident?"

An accident is an accident even if it is only a scratch. This may seem a cranky idea, but it is based on long study, experience, and observation. It is the positive conclusion of the physicians and surgeons that a wound, no matter how trifling—even if only a scratch—should be given a proper dressing immediately after the accident occurs; for it has been found that infection of a slight wound gives infinitely more pain and is more dangerous than the fracture of a bone.

In 1916, day and night, there were 13,190 accidents at the Schenectady Works, but only thirty-six were serious enough to be classed as bed cases, and only eleven were serious enough to require an ambulance call.

Out of practically 21,000 men working with steam and electricity, operating ponderous machinery weighing hundreds of tons, only two men died as the result of accidents. These include electric shock, scalding from steam, and fires and railroad accidents; for it should be understood that the great factory of today has indoor and outdoor railways, and streets the same as cities, with motor busses and trolleys. There are few cities of 21,000 population in which the accidental death statistics are so low. Automobiles alone killed 140 people in Philadelphia in 1916.

Diminishing Fatalities

Remarkably complete records are kept showing the history of every accident for the full decade, 1907 to 1916 inclusive. In the first half of the last decade, there were twelve fatal accidents at the Schenectady Works, an average of 2.4 per year.

In the last half of the past decade, the fatalities decreased to an average of only two per year—this for the years 1912 to 1916 inclusive. Another bit of history which makes the above achievement all the more remarkable is the fact that in the last five years there were 25 per cent more employees in Schenectady than in the first half of the decade. In other words, between 1907 and 1911, one man out of 6,100 met with a fatal accident, while in the past five years only one in every 9000 was so unfortunate. In 1916 it was only one man in 10,100.

Other interesting facts will be seen by studying the following figures; and the amount of effort and attention which they represent may be gathered from the fact that in the year of 1916 alone the hospital

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Everything possible is done for the comfort of the sick and injured at the various works. 1.—Ambulance at the Pittsfield Works. 2.—Closed automobiles are used for taking home sick or injured employees, who do not require the service of an ambulance. This illustration shows a car at the Schenectady Works used for this purpose. 3.—Doctor's office at the Schenectady Works' Hospital where all records are kept. 4.—Class for first aid instruction at the Pittsfield Works.

made 55,362 dressings and treatments. The average worker who meets with an accident receives three additional dressings.

Year	No of Employees on Schenectady Payroll	Total Accidents (including scratches)	Per Cent
1907	15,544	1832	1.18
1908	11,359	1229	1.08
1909	13,361	1706	1.27
1910	16,462	2729	1.66
1911	16.107	3075	1.91
1912	17,487	4174	2.39
1913	19,977	5670	2.84
1914	16,823	4261	2.54
1915	15,347	5476	3.69
1916	20,985	11,427*	5.69*

* In 1916 *all* injuries, including even slight scratches, were reported, whereas the record of previous years includes only the more serious accidents.

Eye Cases

Among the 1916 accidents, 5,575 pertained to the eye—cinders, saw-dust, chips, emery, dust, etc. It is to the credit of the hospital that the first treatments of these were made so successfully that only 171 of them were referred to an eye specialist in the city; one man lost the sight of one eye; and not a single man became blind. The Company has made it a practice in the past to pay the doctor's bill of all workers sent from the hospital to the City specialist.

Works Hospitals

It would be tedious to describe in detail all the hospitals in our many factories, but a brief review of hospital work at the Schenectady Works will give an idea of this necessary adjunct to modern manufacturing.

This work began with the employment of a medical student whose services were sought for first aid before sending the patient to the city hospital. Later it became essential to have some one in each department who understood first aid treatment, and a series of talks on "first aid", by a leading surgeon, with demonstrations on actual dressings, was given to a class made up of the foremen, assistant foremen, and shop clerks of each department.

In accordance with the recommendations of the Safety Committee co-operating with well-known surgeons, first aid chests containing the necessary materials were prepared and placed in each department. This outfit has been quite extensively adopted in manufacturing plants.

It was soon found that the treatment of accidents in the shops caused confusion and did not result in systematic treatment, so it was decided to establish a real emergency hospital, where a trained hospital steward could administer treatment and be responsible for the dressing of wounds under the best conditions. The hospital staff includes a steward and four assistants.

Careful records are kept of each case. The majority of treatments are of a very minor nature and any increase in the number of treatments bears testimony to a more rigid enforcement of the regulations on the part of the organizations, and a better spirit of co-operation on the part of the employees, in conforming to the general wish that the merest scratch shall receive proper treatment to avoid infection.

In the hospital work, emphasis has been placed upon the fact that efficiency in surgery depends upon the individual who applies the first dressing, and the stewards thoroughly understand that the aim of "first aid" is to apply an antiseptic dressing that will prevent infection of the wound.

No wounds are now dressed in the shops; all injured are immediately sent to the hospital, the major cases being transported on stretchers conveniently located in each department. All major eye cases are treated by one of the eye specialists of the city, the injured being conveyed by automobile.

Women and Girls

A woman physician devotes her entire time to the care of the women and girl employees. Her office is fitted with booths for medical examination, and connects with the women's rest room, which is equipped with cots, where the girls from the factory can be made comfortable. All women or girls who are too ill to work are sent by the foreman to this office by automobile. Many of them after an hour or two in the rest room feel able to return to their work. Those who are too ill to work are sent home by automobile, and those who remain in the rest room are given such simple treatment as will give them relief.

In one month, 155 girls came to this office for treatment, and 127 of them returned to work the same day. In addition to the treatments given, the doctor suggests preventive measures, such as diet, exercise, etc. At intervals, during the noon hour, the woman physician gives talks to the girls in the various departmental rest rooms in the shops.

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Rest rooms for women employees are provided at most of the district and local offices, as well as at the various works of the Company. In these rooms provision is frequently made for preparing simple lunches which avoids the necessity of going out in bad weather. 1 and 2.—Rest rooms of the New York District Office. 3.—The women's rest room of the Chicago District Office. 4.—The rest room at the Philadelphia Office. In this case the rest room is on the top of the building in which the office is located, and the roof has been made into a promenade where the girls can take fresh air and exercise.

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In addition to the medical services provided at all the Works, rest rooms for women are maintained throughout the organization, where simple remedies may be obtained in case of slight indisposition. 1.—Medical room at the Schenectady Works. This is under the care of a trained nurse and communicates with the rest room, 2, where short periods of rest may be taken. These rooms are under the charge of a matron who looks after the welfare of those using the rooms. 3.—One of the women's medical rooms at the Pittsfield Works. 4.—One of the rooms at the Erie Works.

Girls Rest Rooms

There are thirty-six rest rooms for girls at the Schenectady Works, classified as follows:

Twenty-two secondary rest rooms, seven in charge of matrons, four in charge of doctors, one in charge of a nurse, and one in the main office building.

In all of these the telephone is available for the purpose of summoning such additional assistance as may be required. Simple treatments are afforded which permit most of the girls to return to work after one or two hours of rest. Books are provided, as well as individual instruction, teaching how best to preserve their health. Those few who are not able to go back to work are taken to their homes in the Company's automobiles.

Red Cross Classes

Seven enthusiastic classes have been formed to teach the girls first aid; these are called "Schools for Red Cross Nurses." The girls attend these classes on their own time.

No Stools

Six or seven years ago all the girl workers sat on stools while they were working, but now all have chairs with backs.

Cold statistics cannot show the amount of suffering and disease which are prevented by welfare work, such as medical examinations when applying for work, educational work in personal hygiene, and other preventive measures.

It should be noted that a majority of the work prescribed above was undertaken and well under way before the New York State Workmen's Compensation Act was passed by the Legislature.

At the Company's Other Plants

The hospital and medical facilities and methods at the other works of the General Electric Company are similar to those at Schenectady, but certain modifications are made to suit different conditions. For example, at the Erie Works, which are comparatively new, hospital facilities were provided when manufacturing operations began. Any new works organization would now include a hospital unit, but it was especially necessary at the Erie Works, owing to the remoteness from the city. A centrally located and amply equipped building provides facilities for the treatment of all, as well as for the medical examination of applicants for employment.

The Lynn Works also has a "first aid corps," some 150 selected men and women being under periodical instruction by the Works' physician in order that they may be able to render quick and intelligent "first aid" to the slightly injured. Each member of this first aid corps is furnished with a first aid cabinet, and whenever a member of this corps uses the first aid equipment he promptly makes out a record card and sends it to the medical department. By this means the Works' physician keeps in close contact with the work of all members, and is in a position to follow up their cases, if necessary.

These first aid outfits consist of a glass jar in which the necessary medicants and other material are located in well arranged order. Inside the glass cover printed instructions on first aid treatment are given, which are sufficiently comprehensive so that in case no member of the corps is immediately present any employee can give intelligent aid when necessary.

In many of the larger buildings of the Lynn organization, special emergency rooms are maintained. They are equipped with running hot and cold water, stretchers, and such medicants and paraphernalia as are needed in cases of injury where the patient should not be removed from the building until he can be taken to the Works' ambulance by the Works' physician, or one of his assistants.

The hospital work in the lamp factories is of a somewhat different nature from that in the other factories owing to the difference in the work. There is little risk of serious personal injury in lamp making, but the fabrication of glass in any industry is always productive of a relatively large number of slight cuts and trivial burns. While most of these injuries would be unnoticed if they were to take place in the employee's home, it has been made a practice at the lamp factories to give prompt attention to all slight injuries, and as at the other works the necessity of having even the slightest injury promptly treated is fully realized.

THE PURPLE COLOR OF LAMP GLOBES

By M. Luckiesh

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The presence of the often noted purplish tint of lamp globes has been shown to be due to manganese. This article calls attention to the fact that the introducing of manganese to neutralize the greenish tint due to slight quantities of iron oxide, may reduce the light transmission factor from 10 to 25 and even 55 per cent, there having been found specimens having 85 per cent reduction. The recommendation is therefore made that in outdoor illumination glassware the manganese be omitted.—Editor.

The purplish tint of lamp globes is commonly observed. Glasses exposed to sunlight and to X-rays sometimes undergo a similar change. It has generally been assumed that this color is due to a change in the chemical or physical state of the manganese which is present in most clear glasses. This coloration of glasses under exposure of radiant energy is not alone confined to glasses containing manganese. Sometimes glasses containing potash but free from manganese gradually assume a bluish tinge and those containing sodium, a yellowish green tinge. The author has in his possession a specimen of lead glass which exhibits a muddy yellow color after exposure to X-rays. Many other effects have been observed, but the manganese coloration is the effect of chief interest from the standpoint of lighting.

This coloration has been investigated from the viewpoint of glass manufacture, but has yielded data pertinent to lighting. Many samples of glasses colored by radiant energy have been gathered and examined both for spectral and integral transmission of visible radiation. The spectral analyses show conclusively that the purple coloring is due to manganese. This color is quite unstable for it disappears under the moderate heat of the bunsen flame long before the glass is sufficiently hot to lose its rigidity.

There is no general agreement regarding the chemistry of glasses, especially of colored glasses. The colors of solutions of metallic salts and of colloidal metals are parallel to a degree to those obtained in glasses containing the same metals, although the whole at present must be considered only a rough analogy. This and other considerations have led to the assumption that the colors of glasses are due to two general states of the metals in the glasses. In one state, for example in copper blue-green glass, the metal is supposed on this assumption to be in combination similar to that in an ordinary solution such as copper sulphate in water; and in the other state, for example gold ruby glass, the metal is supposed to exist in a colloidal condition. The purple of manganese is supposed by some to be due to the existence of the manganese in chemical combination and this compound to be dissolved in a manner analogous to the solution of a metallic salt in a solvent. The radiant energy may be supposed to change the composition of this compound which results in the purple color. The metal under somewhat similar conditions has been spoken of as "crystallizing out." There are other opinions. However, it is the aim in the foregoing only to present a picture of what might be true.

Manganese in clear glass performs the primary function of neutralizing the greenish tint usually present owing to slight quantities of iron oxide in the ingredients of the mix. The spectral transmission of a glass containing a slight amount of iron is shown in curve *I*, Fig. 1; and that of a glass containing a slight amount of manganese is shown in curve *M*. It is seen that these two are approximately complementary to each other; that is, the purple of the manganese neutralizes the green of the iron. However, this is done at the expense of light transmission. Curves *ML* and *MX* are the spectral transmissions of ordinary glasses containing manganese after exposure to radiation from an arc-lamp and to X-rays respectively.

An example will make the process clear. Suppose the slight amount of iron present reduced the transmission factor by 5 per cent, and suppose that in order to neutralize this color a sufficient amount of manganese must be incorporated to reduce the transmission factor by 6 per cent. Without considering surface reflection, the total transmission has been reduced 11 per cent; and those who pay the lighting bills have received in return only a neutralization of the slightly greenish tint. However, besides this initial decrease there often is a gradual decrease in the transmission factor as the purple color is brought out by the intense radiation from the sun and from artificial light-sources. Measurements show that when this color is noticeable to casual observers the transmission factor has been reduced from 10 to 25 per cent. In the case of opal glasses, the decrease in the transmission factor is even more rapid owing to the diffusion and the consequent traversing of greater paths in the purple medium by the radiant energy.

The magnitude of the absorption of such glasses of a purple tint is surprising to those not especially acquainted with colored media. The writer has picked up pieces of arc lamp globes, only removed from use by accidental breakage, which had transmission factors slightly more than one-half that of clear uncolored glass. Measurements of transmission factors of specimens found in practise in which the purple color was quite pronounced varied from 85 to 55 per cent. That of the *MX* sample, Fig. 1, was only 40 per cent of clear uncolored glass.

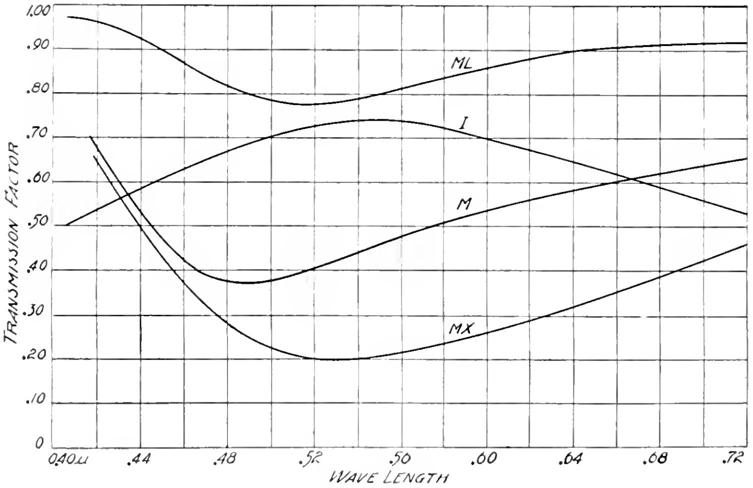

Fig. 1. Spectral Transmission of Different Kinds of Glasses

This is a serious matter in lighting and one which should receive attention inasmuch as the remedy is simple. Manganese need not be employed in clear and opal glassware for purposes of outdoor illumination. Of course in most cases the glasses will exhibit a slightly greenish tint but this should not be objectionable, especially in view of the decrease in transmission factor attending the use of manganese. Although there are no conclusive data on the subject, it appears that the ultra-violet rays are responsible for bringing out this manganese color because only glasses exposed to radiation from the sun and from some of the arc lamps extremely rich in ultra-violet rays exhibit this change very markedly. There is some evidence in street-lighting globes containing tungsten lamps that the coloration is due chiefly to solar radiation.

Window glasses are subject to the same consideration although the economic factors are not as urgent. Some uncolored glasses which are ordinarily known as clear glasses have been found to absorb more luminous flux than might be suspected. Some of these when new absorb as much as 7 per cent more than could be accounted for by surface reflections. This is largely due to the "smoke" resulting from the neutralization of the iron green by the manganese purple.

The conclusion from these observations is the suggestion to eliminate manganese from glasses for many illuminating purposes and to be content with the possible greenish tint and the higher transmission factor both when the glass is new and especially after prolonged subjection to powerful radiation. Furthermore, it is not always safe to assume that the only appreciable decrease in luminous flux which passes through a sheet of clear uncolored glass is that due to surface reflections. Some clear glasses are in reality very light shades of "smoke" glass.

DEVELOPMENTS IN SWITCHBOARD APPARATUS

New Back of Board Field Switches

In the starting of a synchronous motor from the alternating current source with the field open-circuited, which is the practice of the General Electric Company on all a-c. motors using 125-volt excitation, there is considerable induced voltage across the field terminals until the motor reaches synchronous speed. Under these conditions an exposed field switch on the front of a switchboard is more or less of a source of danger to the operator.

The most approved method of reducing this danger in connection with hand-operated field switches is by means of the back of board switch shown. This switch embodies all the essential features from a safety-first viewpoint. It consists of an operating handle similar to an oil circuit breaker lever mounted on the front of the board and the switch proper mounted on a slate base, which is supported on a framework back of the switchboard. The switch is connected mechanically to the operating handle by means of connecting rods and bell hangers. This locates all live parts on the back of the board and does away with danger of accidental contact to the operator from the front. This type of switch is used also in connection with alternating current generators when it is desired to reduce risk to a minimum.

Fig. 1. Operating Lever for Back-of-board Field Switch

Fig. 2. Back-of-board Field Switch. View from rear of Switchboard

When solenoid-operated field switches are used in the field circuits of synchronous motors started from the alternating current source, they are ordinarily made of two single-pole elements with independent closing and opening coils. Both poles are closed simultaneously, but in opening one pole precedes the other, connecting the discharge resistance across the field, the other pole opening immediately after and interrupting the discharge circuit, and entirely disconnecting the field circuit.

On synchronous motors utilizing 250-volt excitation it is the practice to start with the field short-circuited through the discharge resistance. In such cases a double-pole switch is provided to short-circuit the field through the discharge resistance during the period of starting.

Solenoid-operated field switches for synchronous motors started with the field short circuited are double-pole with common closing coil and common opening coil. No provision is made for automatically interrupting the discharge circuit after the switch is opened, although the discharge blade can be opened by hand.

Protection against Accidental Reversal of Motor Rotation

Reverse phase relays are being used more and more extensively with alternating current motors to prevent damage to life, machinery or manufactured product which might occur from a reversal of motor rotation caused by an accidental interchange of motor leads between the relay and the source of power supply. Such relays are particularly valuable in connection with elevators, hoists, conveyors, cranes, machine tools and textile machinery. Protection is required for two conditions: first, where the motor operates normally in one direction only, second, where the motor under normal conditions operates in both a forward and a reverse direction by changing the phase rotation with a controller. In the first case the relay is installed as near the motor as possible, so that when current is thrown on the motor under unintentional reversed phase conditions, the relay operates, opens up the motor switch and cuts out the motor from the circuit automatically. In the second case the relay is connected outside of the controlling apparatus of the motor and affords protection for reversals of phase between the controlling apparatus and the source of power supply.

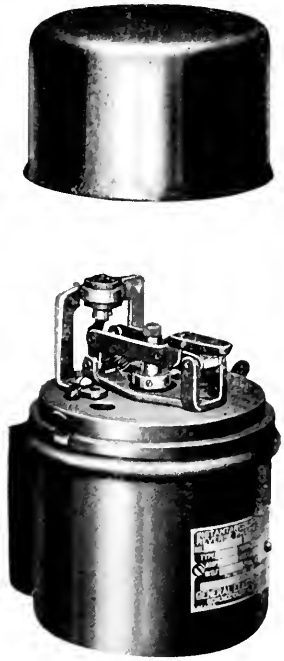
Fig. 3. Reverse Phase Relay

Among the common causes of accidental phase reversal are the interchanging of wires by power companies when repairs to cables are made involving a temporary discontinuing of the service mains. This may also happen when additional switching apparatus is installed or when additional service wires are connected.

The new reverse phase relay illustrated on this page is made in both circuit opening and circuit closing forms. Both types of contacts are equipped with toggles so arranged that there is no tendency for the contacts to open or close until the toggle has buckled, a small spring then throwing the contacts quickly to the desired position. The type of contacts required for any installation will depend on the method of tripping out the motor switch. When contactors alone are used, circuit opening contacts are recommended. The circuit opening contacts are hand reset. Circuit closing relays are used in connection with a shunt trip on a switch or circuit breaker. The contacts are of rugged construction protected by a dust proof cover. The relay operates on the same principle as a squirrel cage induction motor. The operating coils correspond to the stator, and a hollow aluminum cylinder connected to the contacts to the rotor. The cylinder (plunger) does not rotate, but moves in a straight line, either up or down depending upon phase rotation. When one of the phases of the line is reversed, the plunger moves and operates the circuit closing or circuit opening contacts, depending on the form of the relay.

These reverse phase relays are furnished with either current or potential windings for connection in the circuit as follows:—Current windings: In series with the circuit up to 100 amperes at 550 volts: in the secondaries of current transformers both above 100 amperes up to 550 volts and for all currents on voltages above 600. With current coils the relay will operate on phase reversal at 70 per cent of normal current. Potential windings: These are connected directly across the circuit up to 550 volts and to the secondaries of potential transformers above 550 volts. The potential coils are furnished with external resistance of proper value for the different voltages.

BIBLIOGRAPHY OF THE LITERATURE OF SUBMARINES, MINES AND TORPEDOES*

By David B. Rushmore

Assisted by

William H. Lanman and Eric A. Lof

At the present moment there is a wide-spread desire for knowledge on the subject of submarines, the information concerning which is widely diffused and is difficult of location and access. Up to the present time but little has been known by the public in general on this subject, partly because of its apparent relative unimportance, and partly because much of the activities concerning these boats has been regarded as confidential and the subject somewhat shrouded in secrecy.

At the present moment submarines have an interest paramount to all else. They represent an advance made in the methods of naval warfare which has not yet been met by the development of a proper defence. Like the old race between the development of armor which cannot be pierced by any projectile, and of projectiles which can pierce any armor, the development of methods of warfare has alternated between improvements in the offensive and defensive sides. Doubtless within a comparatively short period methods of defence against the submarine will be developed to such an extent as to render it comparatively harmless, but this has not as yet been attained.

A considerable effort has been made to gather together in one place the references on the subject of submarines to be found in books and periodicals, and while not absolutely complete may be considered as comparatively comprehensive.

It is hoped that the bibliography here published may be of some assistance in solving this important problem of the hour.

By far the best historical treatise to be had is the "Evolution of the Submarine Boat, Mine and Torpedo," by Commander Murray F. Suetter of the Royal Navy, published in 1908. A more recent book on the subject, of a somewhat "popular" nature, but containing much valuable information, is "Submarines, their Mechanism and Operation," by Frederick A. Talbot.

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* Mr. William H. Lanman, Engineer and Patent Attorney, 165 Broadway, New York City, has kindly offered to assist anyone who has difficulty in obtaining any desired book or article mentioned in this list, and it is suggested that those desiring further assistance on the subject correspond directly with him.

LIST OF BOOKS AND ARTICLES ON SUBMARINES AND ALLIED SUBJECTS

1917

- Ideal Submarine,
  - Sci. American, Jan. 13.
- Fresh Air for Submarines,
  - Heat. and Vent., Feb.
- American Built Submarine for Spain,
  - Sci. American, Feb. 3.
- Aboard the Merchant Submarine Deutschland,
  - Sci. American, Feb. 10.
- German Submarines and Our Harbors,
  - Sci. American, Feb. 10.
- On the Suitability of the Current Design of Submarines to the Needs of the U. S. Navy,
  - Soc. Naval Archts. and Marine Engrs., Feb. 16.
- Mr. Ford's Baby Submarine,
  - Sci. American, Feb. 24.
- Mines, in Coast Defense,
  - Information, March.
- Depth of Submergence of Torpedoes,
  - Information, Mar.
- Suitability of Current Design of Submarines, to the Needs of the U. S. Navy,
  - Capt. W. L. Rogers, Jour. U. S. Artillery, Mar.-Apr.
- Destroyer and the Torpedo,
  - Sci. American, Mar. 3.
- Notes on Our Inadequate Submarines,
  - John Shegog, Sci. American, Mar. 3.
- How Submarine Chasers Round Up Underwater Craft,
  - Sci. American, Mar. 3.
- Scout Patrols and the Navy Department,
  - Sci. American, Mar. 3.
- Anti-Submarine Patrol; How Submarine Chasers Round Up Underwater Craft,
  - Marion Eppley, Sci. American, Mar. 3.
- From the North Sea to the Atlantic,
  - Sci. American, Mar. 10.
- The Submarine as a Mother Ship for Seaplanes,
  - Sci. American, Mar. 10.
- Small Ships an Answer to the Submarine,
  - Sci. American, Mar. 17.
- Lassoing the Submarines,
  - Literary Digest, Mar. 17.
- Twenty Years' Development of the Holland Submarine,
  - Sci. American, Mar. 31.
- Swatting the Submarine,
  - Literary Digest, Mar. 31.
- The Submarine,
  - Am. Soc. M. E. T., Apr.
- Smoke-Gun Baffles U-Boat,
  - J. A. Massal, Illus. World, Apr.
- Strategic Value of Newfoundland in a Submarine War,
  - P. T. McGrath, Forum, Apr.
- Buoyancy and Stability of Submarines,
  - Wm. Hovgaard, London Engrg., Apr. 13.
- Smoke Protection Against the Submarine,
  - Sci. American, Apr. 21.
- The "Multi-Tubular" Submarine,
  - Sci. American, Edwin Cerio, Apr. 28.
- Various Types of Submarine Chasers,
  - Wm. W. Nutting, Sci. American, May 5.
- War Inventions and how they were Invented,
  - C. Gibson,—Seeley, Service & Co., Ltd., London, (book).

1916

- Submarine in War,
  - R. W. Neeser, Scribner's Mag., Jan.
- Motor Boats of the Volunteer Patrol Squadron,
  - Sci. American, Jan. 1.
- Submarine—Gun Mounting,
  - Jour. U. S. Artillery, Sept.-Oct.
- The Snare of the Nets,
  - Literary Digest, Jan. 8.
- Sketches Illustrating Underground Manocuvers in the War,
  - Sci. American Suppl., Jan. 22.
- Perils to Crews of Submarines Due to Internal Cause,
  - Sci. American, Jan. 29.
- Propulsive Machinery for Submarines,
  - G. Berling, Am. Soc. Naval Engrs, Jour., Feb.
- Inside a Submarine,
  - C. H. Claudy, McBride's Mag., Feb.
- Submarine Warfare; Early History of Underwater Craft and their Recent Uses in Naval Activities,
  - Sci. American, Feb. 5.
- Achievement of the Submarine,
  - D. Hannay, Living Age, Feb. 5.
- Spanish Torpedo Boat Destroyers of the "Bastamante" Class,
  - Engineer, London, Feb. 11.
- Present Condition of the Submarine,
  - Sci. American Suppl., Feb. 12.
- Stored Energy of the Submarine,
  - Sci. American, Feb. 12.
- Submarine Question,
  - R. L. Gordon, Sci. American, Feb. 19.
- Periscope of the Submarine,
  - Sci. American, Feb. 26.
- Torpedo Tubes; the Mechanisms Used Above and Below the Surface,
  - Sci. American Suppl., Mar. 4.
- Submarines as Commerce Destroyers,
  - New Republic, Mar. 4.
- Super-Submarine,
  - Engineer, London, Mar. 17.
- Ruthless U-Boat War,
  - Literary Digest, Mar. 25.
- Submarines that Sting Battleships,
  - George C. Denny, Illus. World, Apr.
- The Parodi Periscope,
  - Long, Engineering, London, Apr. 14.
- Rapid-Fire Revolver Principle Applied to the Submarine Torpedo Tube,
  - Cerio, E., Sci. American, Apr. 15.
- Sea-Going Submarines and their Torpedo Armament,
  - Sci. American, Apr. 15.
- Detonation of Submarine Mines by Electricity,
  - Sci. American Suppl., Apr. 15.
- U. S. S. Conyngham,
  - H. H. Norton, Am. Soc. Naval Engrs. Jour., May.
- Submarine Engines of the German Navy,
  - Lieut. C. W. Minitz, Am. Soc. Naval Engrs. Jour., May.
- U. S. S. Jacob Jones,
  - W. F. Sicard, Am. Soc. Naval Engrs. Jour., May.
- Need of an Efficient Mother Ship fo the Submarines of the U. S. Navy,
  - R. G. Skerrett, Int. Marine Eng., May.
- How the Submarine is Navigated,
  - Marine Rev., May.
- Submarine Nets for the Navy,
  - Sci. American, May 6.
- Submarine Propulsion,
  - Army and Navy Journal, May 6.
- Submarine Killer,
  - A. M. Rud, Illus. World, June.
  - Literary Digest, June 24.
- Combination Helmet and Suit Used in Escaping From Disabled Submarines,
  - Sci. American, June 17.
- Submarine "Curtain of Fire,"
  - Sci. American, June 22.
- Peril of the Submarine,
  - Sci. American, June 29.
- Mines, Planting from Scow. Raising from Scow,
  - Capt. E. A. Greenough, Jour, U. S. Artillery, July-Aug.
- Submarine Merchantmen,
  - Nation, July 13.
- Story of the War. The Merchant Submarine,
  - Outlook, July 19.
- Submarines in the Merchant Service,
  - Sci. American, July 22.
- German Submersible Blockade Runner—Deutschland,
  - Sci. American, July 22.
- Germany's Underwater Street to America,
  - Literary Digest, July 22.
- German Submarines C-5 and Deutschland,
  - Engineer, London, July 28.
- Mining by Submarines,
  - Army and Navy Gazette, July 29.
- Submarine Tender U. S. S. Bushnell,
  - Lieut. G. E. Davis, U. S. N.-Am. Soc. Naval Engrs. Jour., Aug.
- First Undersea Trader Reaches U. S.,
  - Marine Rev., Aug.
- The Electrical Equipment of a Modern Foreign Submarine Boat (Serial),
  - H. H. Wood, El. Rev., Aug. 4.
- Sub-Surface Blockade Running,
  - Sci. American, Aug. 12.
- Argument for the Big Submarines,
  - Sci. American, Aug. 19.
- Captured German Mine-Laying Submarine,
  - Sci. American, Aug. 19-Nov. 4.
- The Torpedo and Submarine Branches of the German Navy,
  - Reginald B. Belknap, U. S. Naval Inst. Jour., Sept.-Oct.
- The Log of the C. S. Submarine,
  - William E. Beard, U. S. Naval Inst. Jour., Sept.-Oct.
- Resistance of Submarines and Airships,
  - Engineer, London, Sept. 15.
- Signaling to Submarines,
  - Elec. World, Sept. 16.
- Rights and Privileges of Submarine in War,
  - Riv. Marit., Oct.
- Signaling to Submarines,
  - Literary Digest, Oct. 14.

Requirements of the Ideal Submarine Engine,
Army and Navy Journal, Oct. 14.
Two Years of Submarine Warfare (Serial),
Engineer, London, Oct. 20 and Nov. 3.
What I Saw of the German Submarine,
V. Frissell, Outlook, Oct. 25.
Submarine Mine-Layer,
Literary Digest, Oct. 28.
Problems of the Submarine,
(Abstract) Jour. Fr. Inst., Nov.
Consideration of the Best Kind of Motor for Submarines,
Riv. Marit., Nov.
The Fleet Submarine,
Proc. U. S. Naval Inst., Nov.-Dec.
Torpedo Screen for Ships Under Way,
Sci. American, Nov. 4.
When Fulton Suggested Submarine Warfare,
Sci. American, Nov. 18.
How Koenig Dodged the British,
Literary Digest, Nov. 18.
Suitability of Current Design of Submarines to the Needs of the U. S. Navy,
Int. Marine Engrg., Dec.
Accomplishments of Submarines,
Riv. Marit., Dec.
Etiquette of Submarining,
D. Wilhelm, Illus. World, Dec.
Uncle Sam's Submarine Supremacy,
H. T. Rich, Forum, Dec.
Resistance of Submarines,
Genie Civil, Dec. 16.
The Submarine of Tomorrow,
Am. Soc. Naval Engrs. Jour., p. 278.
The Submarine Power Plant,
Am. Soc. Naval Engrs. Jour., p. 286.
Present Condition of Submarines,
Am. Soc. Naval Engrs. Jour., p. 272.
Submarine Propulsion,
Am. Soc. Naval Engrs. Jour., p. 292.
The Development of the Submarine,
L. Y. Spear, Soc. Naval Archts. and Marine Engrs, p. 141.
Accurate Measurement of Torpedo Ranges,
Lieut. F. S. Craven, U. S. Naval Inst. Jour., p. 1225.
Some Notes on Torpedo Gyroscopes and their Adjustment in Service,
Lieut. W. P. Willianson, U. S. Naval Inst. Jour., p. 157.
Submarines or Battleships?
United Service Magazine, London, p. 166.
La Nove da Battalgia In Sommergible,
M. Monticelli, Revista Marittina, Rome, p. 271.
Les Sous-Marin Allemand de Blatimore,
Degony, Rev. des deux. Mondes, Paris, p. 888.
Los Grandes Conquistas Cientificas Como Nacio El Submarine,
R. D. Cortes, Por Esos Mundos, Madrid, p. 74.
The Submarine,
National Review, London, p. 445.
Les tendances actuelles dans la construction des sous-marins,
Genie Civil, Paris, p. 50.
La Nove Sommergible,
L. Gaia, Civilta Cattalica, Rome, Vol. 1 and 2, pp. 962 and 311.
Submarines as Merchantmen,
H. D. Jacob,—Case and Conant, Rochester, p. 277.
Flying, Submarining and Mine Sweeping (book),
Jane Anderson and Gordon Bruce, Sir. J. Causton & Sons, London, 36 p.
The Story of the Submarine (book),
Parnham Bishop, The Century Co., New York.
Dreadnought or Submersible (book),
O. Guiheneue, Perrin & Cie., Paris.
The Submarine Torpedo Boat, Its Characteristics and Modern Development,
Allan Hoar,—D. Van Nostrand Co., New York.
Radiodynamics, the Wireless Control of Torpedoes and other Mechanisms (book),
B. F. Miessner,—D. Van Nostrand Co., New York.
Fleet Submarines—Report,
U. S. Congress—Senate Com. on Naval Affairs, 64th Cong., 1st session—Senate Rept. No. 526.
Submarine Holland "9" Becomes Junk,
The Marine Review, Apr.
Instruments Used in Navigating Submarines,
The Marine Review, May.
Submarine L-6 Launched by California Shipbuilding Co.,
The Marine Review, Dec.

1915

The Submarine and the Puture,
V. N. Bieg, Proc. U. S. Nav. Inst., Jan.-Peb.
Mr. Hammond's Torpedo,
Jour. U. S. Artillery, Jan.-Feb., p. 141.
Submarines that are Strictly Invisible,
S. Lake, Sci. American, Jan. 16.
The Periscope,
Sci. American, Jan. 30.
Terrible Submarine,
B. J. Hendrick, McClure's Mag. Vol. 44, Feb.
Launching a Torpedo on the Wing,
R. Bache, Technical World Mag., Feb.
Submarines—Improvements,
C. N. Hinkamp, Am. Soc. Naval Engrs. Jour., Feb.
Engineer, Mar. 19.
Additional Notes on Submarines,
G. W. Baird, Am. Soc. Naval Engrs, Jour., Feb.
Trials of the Submarine Tender Fulton; First U. S. Naval Vessel to be Fitted with Diesel Engines,
Int. Marine Engrg., Feb.
Present Conditions of the Submarine,
A. M. Laubeuf, Int. Eng. Cong., San Francisco, Sci. Am., Feb. 12, 1916.
Is There Any Defense Against the Submarine?
Sci. American, Feb. 13.
Exploding Torpedo by Gun Fire,
Sci. American Suppl., Feb. 13.
The Modern Submarine in Naval Warfare,
R. H. M. Robinson, Jour. Fr. Inst., Mar.
Sci. American, May 8-15.
German Submarines U-8 and U-12,
Engineer, London, Mar. 12.
Making the Ocean Warn of its Perils,
C. Carton, Technical World, Apr.
Modern Submarine; Features of the Holland, Laubeuf, Krupp and Laurenti Types,
Eng. Mag.—C. A. Ward, (abstracts), Apr.
Int. Marine Engrg., June.
New Defense Against the Submarine,
C. Moffett, American Mag., Apr.
The Submarine,
Marine Engr. and Nav. Archts., Apr.
Submarine at Sea,
Sci. American, Apr. 3.
Submarine Disaster at Honolulu,
Sci. American, Apr. 10.
Submarine to Salve a Submarine,
R. G. Skerrett, Sci. American, Apr. 10.
Fessenden Oscillator to Detect Submarines,
C. Moffett, Elec. Rev. & West. Elec'n, Arp. 17.
Blockade by Submarine,
Sci. American, Apr. 24.
Submarine Boat Strength and Speed,
E. Bertin, Engineering, London, Apr. 30.
The Immersion of Submersibles,
A. Belloni, Revista Marittina, May.
Applications of Electricity in Naval Warfare,
H. L. Hibbard, Sibley Jour. of Eng., May.
Submarines and Torpedoes,
C. N. Hinkamp, Am. Soc. Nav. Engrs. Jour., May.
Sci. American, Aug. 28.
The German Offensive and Defensive Mine,
Lt. O. C. Warner, Jour. U. S. Artillery, May-June.
Submarine as a Commerce Destroyer,
Sci. American, May.
Submarine Signaling,
Engineer, May 7.
Sci. American, Sept. 11.
The Submarine in Naval Warfare,
Sci. American Suppl., May 8-15.
Mother Ship for Submarines; a Combined Salvage and Drydock Vessel,
R. G. Skerrett, Sci. American, May 8.
Submarine Torpedo Boat and Its Results,
Eng. News, May 13.
Edison Submarine Boat Storage Battery,
H. T. Wade, Sci. American, May 15.
First American Submarine,
C. Griswold, Sci. American, May 22.
Loading and Firing Submarine Torpedoes,
Sci. American, May 29.
Submarine Signalling and Proposed Method of Safe Navigation in Fog,
F. L. Sawyer, Int. Marine Eng, (abstract), June.
Mine Planting—Forms for Records of,
Jour. U. S. Artillery, May-June.
Protection Against Torpedoes,
Engineer, June 8.
Sci. American, Feb. 13.
Torpedoes, the Lusitania and Naval Architecture,
W. Kaempffert, Am. Review of Reviews, June.
Germany's Submarines,
H. T. Wade, Am. Review of Reviews, June.
The Modern Terror of the Deep,
Ap. Sci., June-July.
Submarine for the Austro-Hungarian Navy,
Sci. American, F. C. Coleman, June 23.
Modern Submarine Torpedo Boats of the United States and Other Navies,
Eng. News, June 24.
Logical Results of the Submarine Torpedo Boat,
Eng. News, June 24.
The Submarine Campaign,
A. H. Pollen, Dublin Review, July.

Submarines,
H. S. Howard, Am. Soc. Marine Draftsmen Jour., July.
Inventor of the Modern Submarine
John P. Holland, the Irish Patriot,
J. B. Hendrick, World's Work, July.
The Electrical Equipment of Submarines,
W. D. Horsnaill, Elec. Rev., London, July 2.
Superheated Steam in Torpedo Boat Engines,
W. H. Miller, Sci. American, July 3.
Modern Submarine; Methods of Control,
Sci. American, July 3.
Machinery of Modern Submarine,
A. P. Chalkley, Sci. American, July 3.
The French Laubeuf Submarine Boats,
Engineering, London, July 9.
Submarine Catcher,
Sci. American, July 24.
New Tygard Engines for Improving Submarine Service,
J. W. Tygard, Ap. Sci., Aug.
First Electrically Propelled Submarine Vessel,
J. F. Waddington, Int. Marine Engrg., Aug.
The Leon Torpedo,
Engineer, London, Aug. 27.
An Automatic Mine,
Jour. U. S. Artillery, Sept.-Oct.
Stitch in Time Saves Nine; Defense Against Submarines,
Sci. American, Sept. 4.
Austrian Submarines
Sci. American, Sept. 18.
Submarine for Hydrographic Work,
Sci. American, Sept. 25.
Future of the Submarine,
F. D. Roosevelt, North Am. Review, Oct.
Submarine Signaling; the Protection of Shipping by a Wall of Sound and Other Uses of the Submarine Telegraph Oscillator,
R. F. Blake, A.I.E.E. Proc., Oct., 1914.
U. S. Smithsonian Inst. Report, 1915, p. 203.
Boat Design that Eliminates Bow Waves and Wake,
C. Herin, Sci. American, Oct. 9.
(Discussion, Waveless Boat), Nov. 20.
First Spanish Submarine,
Sci. American, Oct. 9.
Baby Submarine,
Sci. American, Oct. 9.
Submarines Betrayed by Sound Waves,
Sci. American, Oct. 16.
Von Tirpitz and His Navy,
Sci. American, Oct. 16.
Salvage of the Submarine,
J. A. Furer, Sci. American, Oct. 16.
Abstract—Int. Marine Engrg., June, 1916.
Submarine Periscopes,
E. Coustet, Sci. American, Oct. 23.
Submarine Tender,
C. N. Hinkamp, Am. Soc. Naval Engrs. Jour., Nov.
Motive Power for Submerged Operation of Submarines,
Int. Marine Engrg., Nov.
The Submarines of Today and Tomorrow,
L. Y. Spear, Soc. Nav. Archts. and Marine Engrs., Nov.
Int. Marine Engrg., Dec.
Torpedo—Mine which Floats Freely at Predetermined Depth.
From Le Genie Civil—Jour. U. S. Artillery, Nov.-Dec.
Raising the Submarine F-4,
J. A. Furer, Eng. News, Nov. 4.
Submarines that Crossed the Ocean,
Sci. American, Nov. 6.
Look-out for Submarines,
Sci. American, Nov. 13.
Submarine Chasers for the British Navy,
Sci. American, Nov. 13.
The Submarine Power Plant,
Sibley Jour. of Engrg.—A. Hoar, Nov.
Submarine Propulsion,
P. H. Berggeen, Sibley—Jour. of Engrg., Nov.
General Review of Submarine Design, Machinery, and Handling,
W. F. Pot, Ingenieur, Nov. 6.
Mines,
Sci. American, Suppl., Dec. 18.
Submarine or Battleship—Which?
Sci. American, Dec. 18.
Listening for the Submarine,
Literary Digest, Dec. 25.
German Submarines,
Am. Soc. Naval Engrs. Jour., p. 487.
Submarine Engines,
Am. Soc. Naval Engrs. Jour., p. 471.
Modern Torpedo Boats of the U. S. and Other Navies,
Am. Soc. Naval Engrs. Jour., p. 689.
Salvage of the F-4 Submarine,
Am. Soc. Naval Engrs. Jour., p. 1041.
Adopting Submarine Transporters for General Cargo,
Am. Soc. Naval Engrs. Jour., p. 698.
Submarine of Today and Tomorrow,
Int. Marine Engrg., p. 549.
Recent Development in Submarine Signaling,
Millet, Int. Marine Engrg., p. 16.
Modern Submarines in War and Peace (serial),
Int. Marine Engrg., 1915–1916.
Submarine Disappearing Guns,
U. S. Naval Inst. Jour., p. 940.
Krupp Guns for Submarines,
From Engineer—U. S. Naval Inst. Jour., p. 206.
The Submarine—Its Purpose and Development,
Thos. A. Kearney, U. S. Naval Inst. Proc., p. 1239.
Submarine Torpedo Boats,
L. Y. Spear, Int. Eng. Congress, San Francisco.
The Submarine,
R. H. M. Robinson, Int. Eng. Congr., San Francisco.
L'Artillerie des Bateaux Sous-Marines,
D. Bellet, Revue du Mois., Paris, Tome 19, p. 99.
Le Role et L'Avenir des Bateaux Sous-Marines,
D. Bellet, Rev. Politique and Parlementaire, p. 145.
Submergibles,
Claudio Alderguia, Rev. Gen. de Marina, Madrid, p. 395.
La Variete des Types de Sous-Marines,
Degony. Rev. des deux mondes, Paris, p. 347.
Submarine Boats,
W. Hovgaard, Roy. Canadian Inst. Trans., Vol. 11, p. 119.
Le Probleme Sous-Marin,
Rene Milan, Nouvelle Serie Tome 225, Paris, p. 665.
Automatic Submarine Contact Mines,
Wash., D. C., Carnegie Endowment for International Peace
Submarines vs. Surface Craft for Future Navies,
W. O. Horsnaill, Fortnightly Rev., N. Y., Vol. 98, p. 659.
Submarines and Aircraft,
F. T. Jane, Edinburgh Rev., Vol. 221, p. 140.
The Submarine Myth,
A. H. Pollen, Dublin Review, London, Vol. 156, p. 326.
Peut-On se Defendre Contre les Sous-Marins?
O. Guiheneuc, Correspondant, Paris, p. 516.
La Nave Subacquea; Sattomarine e Sommergibili,
Enzo Campagna, Milano—U. Haupli.
Sottomarini, Sommergibili e Torpediut (book),
E. Bravetta, Milan, Fratelli Treves, p. 230
Les Sous-Marins et la Cuerre Actuelle,
Genzes Blanchon, Paris—Blond et Gag.
War's New Weapons (book),
H. Dewits, Dodd, Mead & Co., New York.
Submarine Vessels, Including Mines, Torpedoes, Guns, Steering, Propelling, etc.,
W. E. Dommett, McDevitt-Wilson's, New York.
Narciso Monturial Y la Navegacion Submarina (book),
J. Estrany—Barcelona: G. Gelli.
Otto Weddingen und Seine Waffe (book),
H. Kirchhoff, Berlin–Marinedank Verlag.
Sous-Marins et Submersibles, leur Development, leur Role dans la Guerre, leur Role dans L'Avenir, les Sous-Marins Allemand (book).
A. M. Laubeuf, Paris: Delagrove, 100 p.
Das Uterseeboot (book),
K. Neureuther, Meunchen: A. Hertz.
Das Uterseeboot im Kampfe (book),
F. Otto, Leipzig, C. F. Amelang.
Submarine Problems and Torpedo Defense,
Joseph A. Steinmetz, Philadelphia, 96 p.
Submarines, their Mechanism and Operation (book),
Frederick A. Talbot, McDevitt–Wilson's, New York.
De Duikboot en Haar Rol in den Europeeschen Oorlog,
W. P. DeVries, Amsterdam, Gebr. Graav.
Du Role de la Physique a la Guerre,
J. Violle, Paris: Berger Levrault 91 pp.
Submarine Attack Described by an Officer in the British Merchant Marine Service,
The Marine Review, Sept.
Submarine Warning Flag, Use of Same,
The Marine Review, Dec.

1914

The Mine Defense of Harbors,
P. D. Bunker, Jour. U. S. Art., Mar.–Apr.-July-Aug.
The Stability of Submarines while Filling Ballast Tanks,
Int. Marine Engrg., Apr.
Drydocking in Canal Locks,
C. W. Fisher, Sci. Am., Apr. 18.
Submarine Signalling, (serial),
Marine Engr. and Naval Architect, May.
The Propulsion of Submarines,
M. Poincet, Tech. Mod. (Suppl.), May 15.
Seaplane, Submarine and Ship,
Engineer, London, June 12.
The Future of the Submarine Boat,
Engineering, London, June 12.
How Inventors Propose to Save Men from Sunken Submarines,
H. Bannerman and Phillips, Sci. Am., June 27.
Submarine Tender Fulton; Diesel Engines Installed,
Int. Marine Engrg., July.
Battleships and Submarine Attack,
Eng., July 17.
Sci. American, Aug. 15.
Submarine Bell—Plans,
Eng. Mag., July.

Future of the Submarine,
Sci. American, July 4.
Underwater Siren to Prevent Collisions at Sea,
(R. C. Fessenden's latest invention)
P. H. Middleton, Sci. American, July 4, 1914.
Submarine and Dreadnought,
W. F. Johnson, Sci Amercian, July 22.
Limitations of the Submarine,
Engineer, July 31.
Sci. American, Sept. 5.
Protection of Battleships Against Submarine Attack,
Sci. American, Aug. 22.
Engineer, London, (with discussion), July 10.
Eng. Mag., (abstract), Sept.
German Submarine Boats,
Sci. American Suppl., Sept. 5.
The Automobile Torpedo,
Sci. American Suppl., Oct. 3.
Attack and Defense by Submarines,
Sci. American, Oct. 3.
Submarine Vindicated,
Sci. American, Oct. 3.
Battleship vs. the Submarine,
Sci. American, Oct. 10.
The Use of Submarine Mines as Effected by the VIII Hague Convention,
P. K. Kekewitch, Jour. Roy. Serv. Inst., Nov.
The Submarine Mine,
J. N. Ferguson, Proc. U. S. Naval Inst., Nov.–Dec.
Modern Submarine Warfare,
Sci. American, Nov. 7.
Propulsion of Submarines,
Sci. American Suppl., Nov. 14.
Submarine Signaling Device,
Elec. World, Nov. 14.
Propulsion of Submarines; Germany and French Practice,
Sci. American, Nov. 14.
Submarines in War,
Engineer, London, Nov. 20.
Reference List of Parts of Submarines,
Sci. American, Dec. 5.
Sectionalizing View of a Modern Submarine,
Sci. American, Dec. 5.
First German Submarine,
Sci. American, Dec. 12.
Submarines Attack Battleships,
Am. Soc. Naval Engrs. Jour., p. 1401.
Future of the Submarine Boat,
Am. Soc. Naval Engrs. Jour., p. 923.
Submarine Repairs and Operation,
C. N. Hinkamp, Lieut. U. S. N., Am. Soc. Naval Engrs. Jour., p. 886.
Submarine Signaling,
W. R. Carter, Lieut. U. S. N., Am. Soc. Naval Engrs. Jour., p. 832.
Submarine Signaling—Inter-Ship Communication,
W. L. Cathcart, Am. Soc. Naval Engrs. Jour., p. 889.
Submarine Tender Fulton,
Am. Soc. Naval Engrs. Jour., p. 1022.
Submarines,
Am. Soc. Naval Engrs. Jour., p. 1400.
Australian Submarines,
Am. Soc. Naval Engrs. Jour., p. 1207.
Austro-Hungary Submarines,
Am. Soc. Naval Engrs. Jour., p. 1407.
Brazilian Submarines,
Am. Soc. Naval Engrs. Jour., p. 1029.
Diesel Motors in Submarines,
Am. Soc. Naval Engrs. Jour., p. 255.
Dutch Submarines,
Am. Soc. Naval Engrs. Jour., p. 1032.
Protection Against Submarine Attack,
Int. Marine Engrg., p. 393.
Submarines and Their Propulsion,
Sibley Jour. of Engrg., Vol. 29 p. 41.
The Blindfolded Game—Submarines, their Duties and Dangers,
G. Fiennes, Living Age, Boston, p. 268.
The Submarine in War; Its Menace and Achievements,
A. Hurd, Fortnightly Rev., Vol. 96, p. 928.
Living Age, Vol. 66, p. 515.
Submarine Engineering of Today (book),
Charles W. Domville-Fife, J. B. Lippincott Co., Phila.
Submarine Boats K-5 and K-6,
The Marine Review, Apr.
Submarine Intership Communication, Fessenden Oscillator,
The Marine Review, Sept.
Mines, Floating and Anchored: How they are Laid and Removed,
The Marine Review, Oct.
New Type of Submersible (Kabben for Norwegian Navy),
The Marine Review, Dec.

1913

The Elia System of Construction and Placing Submarine Mines,
Genie Civil, Jan. 4.
Development of the Submarine Mine in the U. S. Service,
Jour. U. S. Art., R. P. Davis, Jan.–Feb.
New Russian Submarine Karas,
F. C. Coleman, Int. Marine Engrg., Mar.
Guns for Submarines; a Weapon that Swings Below Decks During Submergence,
A. Gradenwitz, Sci. American, Mar. 8.
Rudiments of the Dynamics of Submarine Propulsion (serial),
M. Klein, Schiffbau, Mar. 12.
Submarine Violin,
Sci. American, June 7.
Thirty-six Hours Under Water,
C. L. Edholm, Sci. American, June 21.
Russia's Submarine Cruiser,
Sci. Am., R. G. Skerrett, Apr. 26.
The Ships "Pluton" and "Cerbere" for Anchoring Submarine Mines,
M. Gouriet, Genie, Civil, Apr. 26.
New Type of Submarine Boat,
Int. Marine Engrg, July.
Wireless and Sound Signals as Aids to Navigation,
Sci. American, L. E. Browne, July 19.
Submarine Ship Construction,
Aarestrup, Schiffbau, July 23.
The Visibility of Submarines,
W. L. Cathcart, Sci. American, Aug. 16.
Ocean-going Submarine,
Sci. American, Oct. 11.
The French Mine Layers Cerbere and Pluton,
Engr., London—Int. Marine Engrg., Nov. 14, p. 375.
Rescue Apparatus for the Crew of a Wrecked Submarine,
A. Gradenwitz, Sci. American, Nov. 22.
"Kangaroo," Transport Ship for Submarines,
Sci. American, Dec. 6.
Speed and Resistance of Submarines,
Am. Soc. Naval Engrs., Jour., p. 307.
Submarine Iquique, Launch of Chilian,
Int. Marine Engrg., p. 295.
Problem of Submarine Signaling,
Extract from an article in National Magazine, Oct., 1912—Submarine Signal Co., Boston.
Reducing the Toll of the Sea,
W. Packard, Submarine Signal Co., Boston.
The Romance of Submarine Engineering (containing interesting descriptions in non-technical language of the construction of submarine boats, etc.) (book),
Thomas W. Corbin, J. B. Lippincott Co., Phila.
Chilean Submarine Iquique Launched,
The Marine Review, July.

1912

Submersible Boat for the Dutch Navy,
Engineering, London, Jan. 5.
Evolution of the Submarine,
H. C. O'Neill, Windsor Mag., Mar.
The Use of Electricity in Submarines,
A. Bezzi, L'Electrician, Apr. 13.
Automatic Submarine Mines,
Engineering, London, (serial), Apr. 19
The Use of Electricity in Submarines,
Arnold, Schiffbau, June 12.
Modern Submarine Boats for U. S. Navy,
Marine Engrg., July.
The Question of the Submarine Type,
Marcel Klein, Schiffbau, July 24.
Submarines Up-to-Date,
Chas. F. Carter, Tech. World Mag., Aug.
An Auxiliary for Submarine Service,
Engineer, London, Sept. 27.
To Make the Submarine Safer,
Technical World Magazine, Nov.
Salvage and Testing Facilities for Submarines,
R. G. Skerrett, Sci. American, Nov. 23.
Military Value and Tactics of Modern Submarines,
Proc. U. S. Naval Inst., Dec.
Improvements in Submarines,
Henry Bernay, Am. Soc. Naval Engrs. Jour., p. 273.
Results Obtained in Submarine Navigation in the French Navy,
Am. Soc. Naval Engrs. Jour., p. 312.
Submersible Boat for Dutch Navy (description and trials),
Am. Soc. Naval Engrs. Jour., p. 348.
Italian Submersibles,
Am. Soc. Naval Engrs. Jour., p. 1103.
New Type of Submersibles for the British Navy,
Am. Soc. Naval Engrs. Jour., p. 338
Transport Ship for Submarines,
Int. Marine Engrg., p. 495.
Submarine Transport Ship,
Int. Marine Engrg., p. 353.
Salvage Dock for Submarines,
Int. Marine Engrg., p. 502.
Salvage and Testing Docks for Submarines,
Int. Marine Engrg., p. 310.
L'Air Dans les Submersibles Plonges,
C. M. Belli and G. Ollivi, Int. Congress on Hygiene and Demography, Washington, Trans., Vol. 5, p. 827.

A Modern Submarine Boat (book),
C. Teitch, N. W. Henley Pub. Co., N. Y.
Description of Engine Installations of Submarine Boats, E-1 and E-2,
The Marine Review, May.
Trials of Submarine F-3,
The Marine Review, July.
Submarine Torpedo Boat Seal,
The Marine Review, Oct.

1911

The Development of Submarine Boats,
S. Lake, Sci. American Suppl., Vol. 71, Jan. 14.
The Modern Submarine (serial),
H. Vogel, Zeitschr. d. Ver. Deutscher, Ing., Feb. 18.
The Submersible "Kabben" for the Norwegian Navy.
Sci. American, Mar. 25.
The Construction and Testing of Schneider Torpedoes,
Genie Civil, A. Vergnier., Apr. 8.
Tank Tests on Models of Submarines,
M. S. Chace, Engineering, London, July 14.
The Laubeuf Submersible Boat,
Engineering, London, Aug. 18.
The Submarine Vessel (serial),
K. Dietze, Int. Marine Engrg., Sept.
Submarines—Defensive and Offensive,
Quarterly Review, Vol. 215, Oct.
The Development of the "Holland" Submarine,
Engineering, London, Nov. 17.
The Modern Submarine,
D. C. Bingham, Sci. American, Dec. 9.
Results Obtained by the French Navy in Submarine Navigation,
Jour. Roy. United Service Inst., Dec.
The Submarine "Holland,"
Gouriet, M.—Genie Civil, Dec. 16.
Storage Batteries for Submarines,
Ensign J. B. Howell, U. S. N., Am. Soc. Naval Engrs. Jour., 19, p. 186.
U. S. Submarines No. 28 to 35
Am. Soc. Naval Engrs. Jour., p. 329.
Submarine Signaling,
Int. Marine Engrg., p. 269.
Submarine Boat Wrecker,
Int. Marine Engrg., p. 362.
La Navigation Sous-Marine, (book)
Ch. Radiquer, Paris, O. Doin & fils.
Das Moderne Unterseeboot,
H. Vogel, Verein Deut. Ing. Zeitschr., Vol. 55, p. 241, 298, 389.
Wilhelm Bauer, Der Erfinder des Unabhaengigen Unterseeboots,
O. Gluth. Muenchen, Hans Sachs Verlag.
Submarine Sound Signaling,
The Marine Review, June.
Submarine Boat Skipjack Launched,
The Marine Review, June.
Launching Submarine Torpedo Boat Carp,
The Marine Review, Oct.

1910

Submarine Sound Signals,
Sci. American Suppl., Jan. 8.
Suggested Methods of Escape Out of Sunken Submarines,
F. G. Zimmer, Cassiers Mag., Feb.
The First Submarine Boats for Austria-Hungary,
Engineer, London, Feb. 11.
Characteristics of Submarines,
K. Dietze, Schiffbau, M., Mar. 9.
The Stability of Submarines,
B. C. Laws, Cassiers Mag., Apr.
How the Submarine is Navigated,
Marine Rev., May.
Submersibles,
R. G. Skerrett, Am. Soc. Naval Engrs. Jour., May.
New Wars for Old,
Blackwood's Mag., C. A. Repington, June, p. 893.
Ballast and Diving Arrangements in Submarine Design.
Schiffbau, June 22.
A New Type of Submarine Boat,
Sci. American Suppl., July 9, p. 21.
Stability and Strength in Submarine Design,
Schiffbau, July 13.
French Submarines and Submersibles,
M. Laubeuf, Engineer, London, Aug. 26.
The Electrical Propulsion of French Submarines,
J. Brequet, Electrician, London, Aug. 26.
The New U. S. Submarine Boat "Salmon,"
W. Fawcett, Elec. Rev., Sept. 17.
Submarines,
S. Lake, Pro. Engrs. Club, Phila., Oct.
Early Days of Submarine Warfare,
Sci. American, Oct. 8, p. 277.
The Cruise of the Submarine Torpedo Boat Salmon from Quincy, Mass., to Bermuda and Return,
D. A. Weaver, Am. Soc. Naval Engrs. Jour., Nov.
The Submersible,
Reprinted from Am. Soc. Naval Engrs. Jour., May, p. 465.
Gen. E. O. C. Ord. Twin-screw Steamer for Submarine Mine Service,
Fuller and Marsden, Int. Marine Engrg., p. 16.
Modern Submarine Torpedo Boats,
R. S. Bayard, Am. Machinist, Vol. 33, p. 163.
Hearings on H. R. 19617 and H. R. 19618, Providing an Increase of the Navy by Purchase of Ten Submarine Boats, etc.,
U. S. Congress—House, Com. on Naval Affairs, Wash., Govt. Print. Off., Feb., 19 p.
L'Etat Actual de la Construction des Sous-Marines and Submersibles,
Soc. des ingenieurs civils de France, Annee 63, p. 81, Labuef.
Die Internationale Abschaffung der Unterseeboote,
H. von Kalan, Deut. Rev. Stuttgart, p. 4.
Submarines of the World's Navies,
Chas. W. Domville-Fife, London, F. Griffiths, p. 150
Navigation Aerienne et Navigation, Sous-Marine (book),
H. Noalhat, Paris, L. Geisler.
Les Sous-Marins et Leur Role Dans Natre Flatte Militaire, A Propos Dune Recente Castastrophe,
Seaman, Correspondant, Vol. 239, p. 1071.
Bateaux Sous-Marins A Grande Vitesse Sous L'Eau (book),
C. del Proporto, Bruselle, E. and H. Mertens.
Description of Submersible Boat Hvalen,
The Marine Review, Feb.
Design of Submarines,
The Marine Review, Apr.
Sub-Surface Torpedo Boat—Invention of Clarence L. Burger,
The Marine Review, May.
Submarine Signaling,
The Marine Review, July.
Mine Laying and Torpedo Regulating Vessel,
The Marine Review, Oct.

1909

Submarine Experiments of the Past,
Sci. American Suppl., F. M. Feldhaus, Mar. 20, p. 174.
New Class of Submarines for the U. S. Navy,
Sci. American, May 1, p. 332.
The Development of the Submarine,
Paulus, Zeitschr. d. Ver. Deutscher Ing., Nov. 6.
New Swedish and Danish Submersibles,
R. G. Skerrett, Int. Marine Engrg., Dec. 1909.
Life Saving Devices in Submarine Boats,
Engineer, London, Dec. 10.
Submarines,
Am. Soc. Naval Engrs. Jour., p. 390.
Italian Submarine Foca,
Am. Soc. Naval Engrs. Jour., p. 347.
Italian Submarine Otaria,
Am. Soc. Naval Engrs. Jour., p. 716.
Trials of Submarines,
Am. Soc. Naval Engrs, Jour., p. 674.
Submarine or Surfaee Torpedo Boats,
Am. Soc. Naval Engrs. Jour., p. 598.
Submarine Signaling,
Am. Soc. Naval Engrs. Jour., p. 453.
The Design of Submarines,
M. T. Hay, Soc. Naval Archts. and Marine Engrs., Vol. 17.
Underwater Torpedo Boats,
L. Spear, Am. Soc. Naval Engrs. Jour., Vol. 21, p. 353.
Austrian Submarines,
Perkins, Int. Marine Engrg., p. 398.
Submarine Torpedo Boat Foca,
Int. Marine Engrg., p. 109.
The Automobile Torpedo in Coast Defense,
Jour. of U. S. Artillery, Ft. Munroe, Vol. 31., p. 138.
Internal Combustion Engines for Submarines,
Bircham, T. R. S., Eng., London, Vol. 107, p. 379.
Int. Naval Architects, London, Vol. 51, p. 55.
Allgemeine Gesichtspunkte fuer den Entwurf von Unterseebooten,
Schiffbau, Berlin, K. Dietze, Jahrg. 10, p. 725.
The Present Conditions of Submarine Boats,
Roy. United Service Inst. Jour., London, Vol. 53, p. 1271.
Good Test of Submarine Bell,
The Marine Review, Feb. 25.
Explosion on Italian Submarine Foca,
The Marine Review, June.
Launching of Submarine Torpedo Boats Bonito, Snapper and Grayling,
The Marine Review, July.

1908

The Relation of the Government to the Development of Submarine Vessels,
Sci. American Suppl., Mar. 21-28.
Italian Submarines,
Sci. American Suppl., May 23, p. 329.
The Story of the Submarine,
Wm. O. Stevens, St. Nicholas, July, p. 795.

Submarine Successes,
Sci. American, Sept. 26, p. 202.
Robert Fulton in France,
A. C. Sutcliffe, Century Mag., Oct., p. 935.
Submarnne C-17,
Am. Soc. Naval Engrs. Jour., p. 1003.
German Submarines,
Am. Soc. Naval Engrs. Jour., p. 539.
Submarine Mines and Mining,
Maj. R. P. Davis, Coast Artillery; Am. Soc. Naval Engrs. Jour., p. 674.
Italy's Progress in Submarine Navigation,
Am. Soc. Naval Engrs. Jour., p. 236.
Submarine Naval Warfare,
G. Laurenti, Cassier's Mag., Nov., p. 241.
Am. Soc. Naval Engrs. Jour., Vol. 20, p. 930.
Submarines of Battleship Speed,
Chace, Int. Marine Engrg., p. 14.
A Propos de Sous-Marins; Quelques Erreurs Valontairs,
Marine Francaise, Memor.—Annee 21, p. 623.
La Verite sur la Construction des Sous-Marins,
L. Marcellin, Marine Francaise, Annee 21, p. 129.
Submarines and Submersibles,
E. C. Given, Liverpool Eng., Soc. Trans., Vol. 29, p. 129.
The Story of the Submarine from the Earliest Ages to the Present Day (book),
Cyril Field, London-Sampson, Low, Marston & Co., 304 p.
Select Committee Under House Resolution 288,
U. S. Congress—House, Wash., Govt. Print. Office, 87 p.
Select Committee Under House Resolution 288 (Hearings Beginning Mar. 9, April 30, 1908),
U. S. Congress—House, Wash., Govt. Print. Office, 2 Vol.
Submarine Boat, Novel Features of New Type,
The Marine Review, Feb. 27.
Submarine Boat, Twin-screw,
The Marine Review, Apr. 2.
Submarine Navigation, Present and Future,
Labeuf, The Marine Review, Mar. 12.
Submarine Signaling,
The Marine Review, Feb. 27.
Submersible Torpedo Boat,
The Marine Review, Mar. 5.
Novel Type of Submarine Boat,
The Marine Review, Sept. 17.
Anchor for Submarine or Submersible Boat,
The Marine Review, Oct. 1.
Description of Internal Works of Submarine,
The Marine Review, Oct. 29.
Submarines—Description of Craft for Transporting Them,
The Marine Review, Nov. 5.

1907

The First German Submarine,
Sci. American Suppl., Aug. 10, p. 84.
The Development of Our Submarine Fleet,
Sci. American, Aug. 5, 1913 and Dec. 7, p. 420.
Austrian Submarines (two ordered in Germany),
Am. Soc. Naval Engrs. Jour., p. 858.
Submarines for Italy,
Am. Soc. Naval Engrs. Jour., p. 261.
French Submarines Propelled by Electricity,
Am. Soc. Naval Engrs. Jour., p. 847.
Increase of Submarines in French Navy,
Am. Soc. Naval Engrs. Jour., p. 574.
Tests of Submarines Octopus and Lake,
Am. Soc. Naval Engrs. Jour., p. 551.
The Position of the Submarine,
Am. Soc. Naval Engrs. Jour., p. 214.
The Subsurface Torpedo Boat,
W. I. Babcock, Soc. Naval Archts. and Marine Engrs., p. 243.
Mine Laying Steamer Wetherill,
Int. Marine Engrg., p. 502.
English and French Submarines,
Int. Marine Engrg., p. 229.
Development of Submarine,
L. Y. Spear, Int. Marine Engrg., p. 16.
Submarine Boat Lake,
Int. Marine Engrg., p. 230.
Submarines of Battleship speeds,
M. S. Chase, Soc. Nav. Archts. and Marine Engrs., p. 43.
Progress of the Submarine Boat,
Sci. Am. Suppl, p. 167.
Torpilles, Torpilleurs et Sous-Marins,
Ch. Perrand, Rev. Sci., Vol. 8, Paris, p. 385.
Comment d'Etruire le Sous-Marin,
H. Michel, Marine Francaise, Vol. 20, p. 433.
Influence des Sous-Marins sur la Politique Navale des Divers Etats,
Labeuf, Marine Francaise, Annee 20, p. 67.
Ueber Luftverhaeltnisse und Luftverbrauch in Unterseebooten in Getauchtem Zustande,
Chladek, Franz, Mitteil a.d. Gebiete d. Seewesens, Vol. 35, p. 897.
Safe Submarine Vessels and the Future of the Art,
S. Lake, Lond. Inst. of Naval Archts., Vol. 49, p. 37.
Sci. American Suppl., May 18, p. 26222.
Der Gegenwaertige Stand der Unterwasserbootfrage,
Grenzboten, Jahrg. 66, Leipzig, p. 416.
Der Nutzen der Unterseeboote—Ihr Einfluss auf die Flattenpolitik der Einzelnen Staten,
Deut. Rev., Vol. 32, Stuttgart, p. 170.
Der Wert des Unterseeboots,
Deut. Rev., Vol. 32, Stuttgart, p. 163.
Unterseeboote,
Holzhauer, Berlin, E. S. Mittler.
The Evolution of the Submarine Boat, Mine and Torpedo, from the 16th Century to the Present Time,
M. F. Sueter, Portsmouth, Eng., J. Griffin & Co., p. 384
Capt. James Stone's Communication on Submarine Sound Signals,
The Marine Review, Jan. 3.
Submarine Signaling—Lightships Equipped with Device,
The Marine Review, Mar. 14.
A Few Facts About Submarine Signaling,
The Marine Review, Mar. 21.
Submarine Signaling on the Lakes,
The Marine Review, Mar. 21.
Submarine Signals on Lake Steamers,
The Marine Review, Mar. 28.
Submarine Signal Notes,
The Marine Review, Mar. 28.
French Submarine Boat Lutin Raised,
The Marine Review, Apr. 4.
Paper on the Development of Submarines,
Lawrence Y. Spear, The Marine Review, Apr. 11.
Submarine Signals on the Lakes,
The Marine Review, Apr. 18.
Increase in French Submarines,
The Marine Review, May 2.
Admiralty Tests of Submarine Signaling,
The Marine Review, May 23.
Interesting Experiments in Submarine Signaling,
The Marine Review, May 23.
Trial of Submarine Boat Octopus,
The Marine Review, May 23 and June 13.
North German Lloyd Comments Upon Submarine Signals,
The Marine Review, May 30.
Description of Receiver for Systems of Submarine Signaling,
The Marine Review, July 4.
Submarine Boat Equipped with Koerting six-cylinder Oil Engines,
The Marine Review, Aug. 1.
Submarine Signaling to be Installed on the Lakes,
The Marine Review, Aug. 15.
Submarine Signaling—Further Results Obtained on it by Means of Sound,
The Marine Review, Aug. 15.
Submarine Bell Signals Adopted by Trinity House Brethren,
The Marine Review, Aug. 29.
Submarine Boats Octopus, Viper, Cuttlefish and Tarantula Prove Good Sea Boats in Trials,
The Marine Review, Aug. 29.
John M. Gage—Description of Submarine Boat Invented by Him,
The Marine Review, Sept. 5.
Submarine Signal Installations to be Made in Britain,
The Marine Review, Sept. 5.
Commendation for Submarine Signals,
The Marine Review, Sept. 12.
Submarine Signal Equipment to be Installed,
The Marine Review, Oct. 24.
Submarine Signals—Installations to be Made on Numerous Ocean Liners,
The Marine Review, Oct. 31.
Submarine—Need of Them,
The Marine Review, Oct. 31.
Advantages of Submarine Signaling,
The Marine Review, Dec. 5.
Submarine Signals and Marine Underwriters,
The Marine Review, Dec. 12.

1906

Organization of the Submarine Flotilla of the British Fleet,
Sci. American, Apr. 14, p. 302.
L'Engin Porte-Torpilles Sous-Marin,
L. Lalande, Soc. d'anciens elives, Bull. Technique, Paris, Nov.
Supplying Submarines for the Russian Navy,
A. C. Johnson, World Today, Dec., p. 1316.
British Submarine Ordered,
Am. Soc. Naval Engrs. Jour., p. 644.
Conclusions as to Submarines,
Am. Soc. Naval Engrs. Jour., p. 266.
French Submarines,
Am. Soc. Naval Engrs. Jour., p. 1287.
The Stability of Submarines,
Am. Soc. Naval Engrs. Jour., p. 948.
The Submarine vs. the Submersible,
S. Lake, Jour. Am. Soc. Naval Engrs., p. 533.

The Limitations of the Diving Submarine,
R. G. Skerrett, U. S. Artillery Jour., Ft. Munroe, p. 221.
La Navigation Sous-Marins,
G. DeLaSalle, Rev. Francaise de L'etranger et. d. Colonies, Vol. 31, p. 384.
The Dangers of the Submarine, Real and Imaginary,
L. Spear, Harpers Weekly, Vol. 50, p. 1596.
Underwater Torpedo Boats,
Lake Torpedo Boat Co., Bridgeport, p. 116
La Navigation Sous-Marins,
G. Pesce, Paris, Vuibert & Nony, p. 498
Submarines—Divisions Into Classes,
The Marine Review, Apr. 5.
Efficiency of Submarine Signals,
The Marine Review, May 10.
Lecture on Submarine Signaling,
J. B. Millet, The Marine Review, May 17.
Submarine Signals—Government to Operate Them,
The Marine Review, May 31.
Submarine Sound Signaling,
Ferdinand Hefele, The Marine Review, July 12.
Haslar Floating Docks for Submarine Boats,
The Marine Review, Aug. 9.
Efficiency of Submarine Sound Signaling,
The Marine Review, Aug. 9.
Submarine Signals on Lightship Kewaunee,
The Marine Review, Dec. 20.
Captain O. Capper's Letter About Submarine Signals,
The Marine Review, Aug. 16.
Submarine Signals,
The Marine Review, Aug. 30.
Stability of Submarine Boats,
The Marine Review, Nov. 1.
Submarine Signals—Important Results Reported by British Admiralty,
The Marine Review, Nov. 15.

1905

Test of "Simon Lake X" (note),,
Am. Soc. Naval Engrs. Jour., Feb., p. 186.
Italian Submarine Delfino (description, note),
Am. Soc. Naval Engrs. Jour., Feb., p. 219.
Explosion Aboard British Submarine A-5,
Am. Soc. Naval Engrs. Jour., Feb., p. 215.
Submarines,
Sir Wm. White, Am. Soc. Naval Engrs. Jour., May, p. 530.
U. S. Submarines 9, 10, 11, 12 (contract and short description),
Am. Soc. Naval Engrs. Jour., May, p. 543.
French Submarines Q-59 and Q-60 (note),
Am. Soc. Naval Engrs. Jour., May, p. 563.
Cause of Explosion Aboard British Submarine A-5,
Am. Soc. Naval Engrs. Jour., May, p. 555.
New Submarines for the British Navy,
Sci. American, June 17, p. 481.
French Submarine,
Am. Soc. Naval Engrs. Jour., Aug., p. 907.
Accident to French Submarine Farfadet,
Am. Soc. Naval Engrs. Jour., Aug., p. 909.
Submarine Boats and Their Salvage,
Am. Soc. Naval Engrs., Aug., p. 851.
Accident to British Submarine A-8,
Am. Soc. Naval Engrs., Aug. Jour., p. 907.
French Submarine Boat Y, Launch,
Am. Soc. Naval Engrs. Jour., Nov., p. 1200.
Italian Submarine Glauco,
Am. Soc. Naval Engrs. Jour., Nov., p. 1203.
The Submarine as an Enemy,
F. B. Hoff, Proc. U. S. Naval Inst., Vol. 31, p. 383.
Submarine Navigation,
Sir Wm. White, Smithsonian Am. Report, p. 235.
The Submarine, Real and Imaginary,
W. R. Stewart, Tech. World, Vol. 3, p. 734.
Submarine Navigation,
Sir Wm. White, Technics, London, p. 12.
Ueber Unterseeboote,
C. Stainer, Stahl and Eisen, Dusseldorf, p. 1234.
En Sous-Marin,
Rev. de Paris, p. 587.
Les Submersibles et le Sous-Marins. Leur Utilization dans les Guerras Modernes,
d'Armor, Paris, A. Challamel.
Submarine Bells,
The Review, June 8.
Mr. Rabien Explains Submarine Signaling on Kaiser Wilhelm der Grosse,
The Marine Review, June 15.
Submarine Signaling,
The Marine Review, June 22.
Submarine Navigation—Article by Sir Wm. White,
The Marine Review, June 29.
Submarines,
Sir Wm. White, The Marine Review, July 20.
Cunard Line and Submarine Signaling,
The Marine Review, Oct. 5.

1904

Early Attempts at Submarine Navigation,
Sci. American Suppl., Vol. 57, Jan. 9, p. 23422.
Extensive Submarine Construction Programme for Great Britian,
Sci. American, Vol. 90, Feb. 20, p. 151.
Submarine Navigation Past and Present,
Sci. American Suppl., May 21 p. 23729.
Simon Lake and His Wonderful Submarine,
S. Mornington, Cosmopolitan Mag., Aug., p. 365.
The Evolution of the Submarine and How Far the Lake Type Solves the Problem,
U. S. Artillery Jour., Washington, Sept.–Oct.
Submarines "Lake" and "Holland,"
L. Lan, (Navy Dept. Rev. of Naval Publications, No. 87).
Will Battleships be Obsolete?
Morgan A. Robertson, World's Work, Nov., p. 5515.
War Department Report on Submarines,
Am. Soc. Naval Engrs. Jour., p. 1304.
Six Submarines for France,
Am. Soc. Naval Engrs. Jour., p. 667.
French Submarines and Submersibles,
Am. Soc. Naval Engrs. Jour., 1904, p. 355.
New British Submarines,
Am. Soc. Naval Engrs. Jour., p. 1328.
Refloating of Submarines,
Am. Soc. Naval Engrs. Jour., p. 1008.
Foundering of Submarine A-1,
Am. Soc. Naval Engrs. Jour., p. 691.
New Submarine Launch,
Am. Soc. Naval Engrs. Jour., p. 691.
Submarines in Various Navies,
Am. Soc. Naval Engrs. Jour., p. 669.
Test of Submarine Boat Fulton,
Int. Marine Engrg., p. 300.
Submarine Bell Signaling,
Int. Marine Engrg., p. 331.
The Problem of the Submarine,
R. G. Skerrett, Tech. World, p. 107.
Torpilleurs and Sous-Marins,
H. Pouleur, Rev. Univers. de Mines., Vol. 7, p. 131.
Torpilles, Torpilleurs et Sous-Marins,
H. Tanif, Questions diplomat et coloniales, p. 577.
War Under Water,
L. G. Laughton, Monthly Rev., London, Vol. 16, p. 60.
The Future of the Submarine Boat,
A. H. Burgoyne, Jour. Roy. United Service Inst., p. 1288.
Torpilleurs and Sous-Marins—La Tactique Naval et des Ensignements de la Guerra Russo-Japonaise,
H. Pouleur, Liege, C. Desoer (book).
Test of Submarine "Protector,"
The Marine Review, Jan. 7.
Submarine Building in England,
The Marine Review, Jan. 28.
Submarines of Protector Type Favored by War Dept.,
The Marine Review, Apr. 14.
Limitations of Submarine Craft,
The Marine Review, July 21.

1903

British and French Submarines,
A. C. Hurd, Forum, Oct., p. 315.
Submarine Work,
Contemporary Review, Nov., p. 696.
Submarine Shark Contract Trials,
Am. Soc. Naval Engrs. Jour., p. 859.
Submarine Protector, Des.,
Am. Soc. Naval Engrs. Jour., p. 1211.
Contract Trials of Submarine Porpoise,
Am. Soc. Naval Engrs. Jour., p. 859.
Contract Trials of Submarine Scott,
Am. Soc. Naval Engrs, Jour. p. 859.
Contract and Standardization Trial of Submarine Pike,
Am. Soc. Naval Engrs. Jour., p. 584.
Contract Trials of Submarine Moccasin,
Am. Soc. Naval Engrs. Jour., p. 39.
Contract and Standardization Trial of Submarine Grampus,
Am. Soc. Naval Engrs. Jour., p. 584.
Contract Trials of Submarine Adder,
Am. Soc. Naval Engrs. Jour., p. 39.
Submarines—Progress,
Am. Soc. Naval Engrs. Jour., 1903-1904, p. 666.
Submarine Development in the Direction of Increased Scope,
Am. Soc. Naval Engrs. Jour., p. 1211.
Trials of Submarine Boats Grampus and Pike,
Int. Marine Engrg., p. 368.
Les Sous-Marines et Leur Role,
H. de. Graffigny, Rev. Scientif. Ser. 4, Vol. 19, Paris, p. 15.
The Submarine,
Quarterly Rev., Vol. 198, London, p. 105.
Sull' Impiego dei Sottomarine,
F. Marulli, Revista Marittina, Vol. 36, p. 5.
The Success of the Submarine,
Nineteenth Century and After, A. C. Hurd, Vol. 54, p. 711

A Rambling Discourse on Submarine Navigation,
Forum, F. M. Barber. Vol. 34, p. 625.
La Navigation Sous-Marins a Traven les Sieles,
M. Delpeuch. Autorage illustre, Paris, T. Juven.
Les Sous-Marins et la Prochaine Guerra Novalle,
H. Noalhat, Berger-Levrault & Co.
Lake Submarine Boat Protector,
The Marine Review, Sept. 3.
Victory for Submarines,
The Marine Review, Sept. 24.
Submarine Torpedo Boat "Protector,"
The Marine Review, Jan. 15.
Submarine—Recent Inventions,
The Marine Review, Feb. 5.
Fulton's Submarine,
The Marine Review, Mar. 12.
Submarine is Only Toy,
The Marine Review, Apr. 2.
Submarine to Travel Under the Ice,
The Marine Review.
Submarines—Peace, War and Exploration,
The Marine Review, May 21.
Test of Submarines,
The Marine Review, May 21.
Submarine Boats—Steering,
The Marine Review, May 28.

1902

New British Boats,
Hurd, A. C., Nineteenth Century and After, Feb.
Le Armi Subaques Ael Secolo XIX,
Rivista Marittina, June, p. 437.
Submarine Boats,
L. Y. Spear, Int. Marine Engrg., p. 628.
Submarine Grampus, Launch,
Am. Soc. Naval Engrs. Jour., p. 947.
Gasolene Explosion,
Am. Soc. Naval Engrs. Jour., p. 614.
Test of Submarine Fulton,
Am. Soc. Naval Engrs. Jour., p. 298.
Submarine Fulton, Launch,
Am. Soc. Naval Engrs. Jour., p. 767.
Submarine Adder, Launch,
Am. Soc. Naval Engrs. Jour., p. 767.
Data on Submarine Adder,
Am. Soc. Naval Engrs. Jour., p. 475.
Submarines—Norway,
Am. Soc. Naval Engrs. Jour., p. 509.
Trials of Italian Submarine Delfino,
Am. Soc. Naval Engrs. Jour., p. 1117.
Trials of Submarines No. 3-8,
Am. Soc. Naval Engrs. Jour., p. 243.
Gasolene Engines for Submarines No. 3-8,
Am. Soc. Naval Engrs. Jour., p. 144.
Germany's Submarines,
Am. Soc. Naval Engrs. Jour., p. 578.
Submarine Boiler Accidents,
Am. Soc. Naval Engrs. Jour., p. 968.
Submarines Sirene, Triton, Espadon and Silure (data),
Am. Soc. Naval Engrs. Jour., p. 330.
Submarine Mishap,
Am. Soc. Naval Engrs. Jour., p. 968.
Submarine Silure, Submerged 140 feet,
Am. Soc. Naval Engrs. Jour., p. 609.
Note on Submarines,
Am. Soc. Naval Engrs. Jour., p. 1231.
Submarine No. 5 Launch,
Am. Soc. Naval Engrs. Jour., p. 966.
Tests of Submarine No. 2,
Am. Soc. Naval Engrs. Jour., p. 966.
Koehl's Submarine Explorer,
Am. Soc. Naval Engrs. Jour., p. 852.
Opinion of the Submarine,
M. Lockroy, Am. Soc. Naval Engrs. Jour., p. 608.
Submarines—Requirements,
Am. Soc. Naval Engrs. Jour., p. 304.
Future of Submarines,
Am. Soc. Naval Engrs. Jour., p. 1207.
Submarine Torpedo Boats, Past, Present and Future (discussion),
L. Spear, Soc. Naval Archts. and Marine Engrs. Trans., Vol. 10, p. 323.
Submarine Torpedo Boats,
G. W. Baird, Jour. Am. Soc. Naval Engrs., p. 845.
Submarine Boat,
Engineering, London, Vol. 74, p. 733.
Vol. 91, pp. 67, 86, 146, 166.
Submarines,
Ch. W. Robins, Naval Annual, Portsmouth, Eng., p. 144.
La Navigation Sous-Marine a Traverse les Siecles, d'Apres de Nombreux Documents Inedits,
Maurice Delpeuch, Paris, F. Juven, 450 pp. Bibliographie, p. 449.
Les Bateaux Sous-Marins et les Submersibles,
Equevilley, R., Paris, Gauthier-Willars.
Submarine Warfare, Past, Present and Future (book),
By H. C. Fyfe, McDevitt-Wilson's, New York City; $3.00
Hearings Before the Committee on Naval Affairs, House of Rep., on Submarine Boats,
U. S. Congress—House Com. on Nav. Affairs, Wash., Govt. Print. Office, p. 314
Moriarty Submarine Boat,
U. S. Congress, Senate—Com. on Naval Affairs, Wash., Govt. Print. Office, p. 49
Staff Corps Increase—Submarine Boats,
U. S. Congress—Senate, Com. on Naval Affairs, Wash., Govt. Print. Office, p. 103
Successful Test of Submarine Bell,
The Marine Review, Jan. 23.
Launching of Holland Submarine Torpedo Boat Plunger,
The Marine Review, Feb. 6.
Submarine Boat and Its Value,
The Marine Review, Feb. 13.
An Advocate of the Submarine,
The Marine Review, Mar. 6.
Value of Submarine Boats,
The Marine Review, May 29.
British Submarines,
The Marine Review, May 29.
Value of Submarine Boats,
The Marine Review, June 5.
Admiral O'Neill on Submarines,
The Marine Review, Aug. 21.
Submarine Boat Improved,
The Marine Review, Aug. 28.
Value of Submarines,
The Marine Review, Oct. 30.
Submarine Warfare,
The Marine Review, Nov. 6.
Submarine Boats Ready for Trial (Adder and Mocassin),
The Marine Review, Nov. 13.
Test of Submarine Boat Adder,
The Marine Review, Nov. 20.
Submarine an Adjunct to a Warship,
The Marine Review, Dec. 11.

1901

Admiralty and Submarine Boats,
E. Robertson, Nineteenth Century and After, Jan.
Early Submarine Warfare,
Engineer, London, Feb. 1.
The Turkish Submarine Boat of the Nordenfeldt Type,
Sci. American, May 4.
The First Submarine Boat,
Sci. American Suppl., Oct. 12.
Data on Submarine Shark,
Am. Soc. Naval Engrs. Jour., p. 476.
Submarine Porpoise Launch,
Am. Soc. Naval Engrs. Jour., p. 1085.
Data on Submarine Porpoise,
Am. Soc. Naval Engrs. Jour., p. 476.
Submarine Moccasin Launch,
Am. Soc. Naval Engrs. Jour., p. 767.
Data on Submarine Moccasin,
Am. Soc. Naval Engrs. Jour., p. 476.
Data on Submarine Triton,
Am. Soc. Naval Engrs. Jour., p. 1094.
Trials of Submarine Sirene,
Am. Soc. Naval Engrs. Jour. p. 1094.
Submarine Protee, (data),
Am. Soc. Naval Engrs. Jour., p. 781.
Submarine Narval (data),
Am. Soc. Naval Engrs. Jour., p. 291.
Submarine Naiade (data),
Am. Soc. Naval Engrs. Jour., p. 781.
Submarine Lynx (data),
Am. Soc. Naval Engrs. Jour., p. 781.
Submarine Ludion (data),
Am. Soc. Naval Engrs. Jour., p. 781.
Submarine Gustave Zede (note),
Am. Soc. Naval Engrs. Jour., p. 289.
Submarine Launch Espadon,
Am. Soc. Naval Engrs. Jour., p. 1095.
Submarine Names,
Am. Soc. Naval Engrs. Jour., p. 293.
Performance of Submarines,
Am. Soc. Naval Engrs. Jour., p. 730.
Submarine Launch,
Am. Soc. Naval Engrs. Jour., p. 1113.
British Submarine Destroyer,
Am. Soc. Naval Engrs. Jour., p. 492.
Submarine Destroyers,
Am. Soc. Naval Engrs. Jour., p. 731.
The Submarine,
Am. Soc. Naval Engrs. Jour., p. 1056.
Submarine Signaling,
Am. Soc. Naval Engrs. Jour., p. 212.
The Submarine Boat; Its Value as a Weapon of Naval Warfare,
Geo. Melville, Smithsonian Inst. Annual Report, p. 717-738.

Submarine (Arctic Boat),
Nat. Geogr. Mag., p. 201-202.
The Submarine Boat, Its Promises and Performances,
Melville, Geo., North Am. Rev., p. 584-598.
Am. Review of Reviews, May, 1902.
La Navigation Sous-Marine et les Torpilleurs Submersibles,
P. de LaRouveraye, Marine Francaise, Annee 14-p, 122.
La Navigation Sous-Marins—An Jourd Hui,
N. Noalhat, Marine Francaise, Vol. 14, p. 160.
Die Frage der Unterseeischen Boote,
Bebicte d. Seewesens, A. Leugnick, Mitthcil a.d. Vol. 29, p. 365.
The Tactics of the Submarine,
A. Atteridge, Monthly Rev., Vol. 4, p. 42.
The Motion of the Submarine Boat in the Vertical Plane,
Hovgaard, W., Trans. Inst. Naval Archts., London, Vol. 43, p. 143.
Entwixklung des Unterseebootwesens in den Jahren 1900-1901,
Dinglers Polytech. Jour., Vol. 316, p. 821.
La Navigation Sous-Marine,
Gaget, M., C. Beranger, Paris.
Submarine Boat—Its Future,
J. P. Holland, The Marine Review, Jan. 10.
Early Submarine Warfare,
The Marine Review, Feb. 21.
Submarine Boat Holland's Trial,
The Marine Review, Mar. 7.
Submarine Boats,
The Marine Review, Apr. 18.
Submarine Boat—New,
The Marine Review, Apr. 18.
Submarine Mines—Destructive Qualities,
The Marine Review, July 4.
Submarine Destroyer for England,
The Marine Review, July 11.
Submarine Boats—New Types,
The Marine Review, Sept. 5.
Submarines—Melville on French Marine,
The Marine Review, Sept. 5.
English Submarines Launched,
The Marine Review, Sept. 19.
Submarine Boat Fulton, Tests,
The Marine Review, Nov. 28.

1900

The Question of Submarine Boats,
Nineteenth Century and After, May.
The Merits and Failings of Submarine Boats,
Engineering Mag., June.
Submarine Boats from the Earliest Down to the Present Time,
Carl Busley, Marine Engrg., Oct. 1900-May, 1901.
La Naviguzione Subaqua a Scopo di Guerra,
Revista Marittina, Rome, Vol. 33, pp. 379-406.
La Navigation Sous-Marine—Etude sur les Governails d'Immersion,
H. Noalhat, Rev. Tech., Vol. 21, 1900, Vol. 32, 1901.
Submarine Navigation,
W. P. Bradley, Pop. Sci. Monthly, N. Y., pp. 156-175.
The Question of Submarine Boats,
E. Robertson, Nineteenth Century, London, pp. 713-722.
The Submarine Boat and Its Future,
North Am. Rev., J. P. Holland, Vol. 171, pp. 874-903.
Submarine Torpedo Boats,
W. W. Kimball, Harpers Monthly Mag., Vol. 110.
Untersee Boote,
Dinglers Polytech. Jour., Vol. 315, p. 32-34, Stuttgart.
Stand der Unterseebootfrage zu Beginn des zwanzigsten Jahrhunderts,
Dinglers Polytech. Jour., Vol. 315, pp. 277-281.
Le Probleme de la Navigation Sous-Marine,
Noalhat, H., Bull. Tech., Vol. 1, pp. 135-150.
Submarine Shark (name),
Am. Soc. Naval Engrs. Jour., p. 825.
Submarine Porpoise (name),
Am. Soc. Naval Engrs. Jour., p. 825.
Submarine Pike (name),
Am. Soc. Naval Engrs. Jour., p. 825.
Submarine Moccasin (name),
Am. Soc. Naval Engrs. Jour., p. 825.
Submarine Grampus (name),
Am. Soc. Naval Engrs. Jour., p. 825.
Submarine Adder (name),
Am. Soc. Naval Engrs. Jour., p. 825.
Contracts for Six U. S. Submarines Placed,
Am. Soc. Naval Engrs. Jour., p. 1096.
Submarine Purchase,
Am. Soc. Naval Engrs. Jour., p. 556.
Submarine Morse (data),
Am. Soc. Naval Engrs. Jour , 1900, p. 568; 1901, p. 291.
Submarine Flamberge (data),
Am. Soc. Naval Engrs. Jour., p. 800.
The Demonstrated Success of the Submarine Boat,
Ph. Hichborn, Eng. Mag., Vol. 19, pp. 321-241.

Construction and Tests of Submarine Boats for the U. S. Navy,
Int. Marine Engrg., p. 138.
Argonaut, Submarine Boat Nearing Completion,
The Marine Review, Jan. 11.
John P. Holland—Interview on Submarine Boats,
The Marine Review, Jan. 4.
Holland Submarine Boat—Secretary Long's Proposition,
The Marine Review, Feb. 15.
Holland Submarine Torpedo Boat,
The Marine Review, Mar. 29.
Holland Submarine Boat—Navy to Buy It,
The Marine Review, Apr. 12.
Submarine Boats,
The Marine Review, May 10.
John P. Holland on Submarine Boats,
The Marine Review, May 24.
Holland, Submarine Boat, Seaworthy,
The Marine Review, June 28.
Submarine Boat at Stamford Harbor,
The Marine Review, Aug. 16.
Submarine Boat Holland Could Not Be Located,
The Marine Review, Sept. 6.
Torpedo in War,
The Marine Review, Sept 6.

1899

Submarine Goubet,
Am. Soc. Naval Engrs. Jour., p. 254.
Submarine Pertuisane (data),
Am. Soc. Naval Engrs. Jour., p. 800.
Submarine Rapiere (data),
Am. Soc. Naval Engrs. Jour., p. 800.
Test of Submarine Holland,
Am. Soc. Naval Engrs. Jour., p. 1089.
Submarine Escopette (data),
Am. Soc. Naval Engrs. Jour., p. 800.
La Navigation Sous-Marine,
H. Noalhat, Bull. Technique, Vol. 1, pp. 52-78.
French Submarine Boats,
The Marine Review, Jan. 26.
Holland Submarine Boat,
The Marine Review, Feb. 16.
Holland Submarine Boat in England,
The Marine Review, Apr. 6.
A Submarine Problem (Difficulties with Plunger),
The Marine Review, May 18.
Interview with Inventor of Holland Submarine, Torpedo Boat, Plunger,
The Marine Review, June 1.
Submarine Boats,
L. Irwell, The Marine Review, June 1.
The New Submarine Boat Argonaut,
The Marine Review, June 29.
Submarine Torpedo Boats,
The Marine Review, Aug. 3.
Accident on Submarine Torpedo Boat Argonaut,
The Marine Review, Aug. 10.
Trial of Submarine Torpedo Boat Holland,
The Marine Review, Nov. 9.
Submarine Boats Abroad,
The Marine Review, Nov. 9.
Holland Boat and Her Tests,
The Marine Review, Nov. 16.
Interest in the Holland,
The Marine Review, Nov. 30.
Submarine Warfare,
The Marine Review, Dec. 28.

1898

Submarine Boat Argonaut,
Int. Marine Engrg., July, p. 7.
The Submarine Scott,
Am. Soc. Naval Engrs. Jour., p. 366.
The Submarine Scott, Launch and Destroyer,
Am. Soc. Naval Engrs. Jour., p. 366.
Submarine Torpedo Boats; Their Influence on Torpedo Boat Architecture and Value in Warfare, Marine Engrg., W. H. Jaques.
All the World's Fighting Ships,
S. Low, Marston & Co., Ltd., 1898–1910.
Has the Submarine Boat a Place?
W. W. Kimball, Soc. Naval Archts. and Marine Engrs. Trans., Vol. 6, pp. 61-74.
A Voyage on the Bottom of the Sea,
R. S. Baker, McClures Mag., pp. 203-209.
Holland Submarine Boat,
The Marine Review, Nov. 17.
The Submarine Boat,
The Marine Review, Nov. 17.
A Place all to Itself—Submarines in War,
The Marine Review, Nov. 17.

1897

Holland Submarine Boat "Plunger,"
Int. Marine Engrg., Sept., p. 20.
Submarine Plunger, Launch,
Am. Soc. Naval Engrs. Jour., p. 794.
La Navigation Sous-Marine,
H. Becus, Paris, p. 147

1896

New Goubet,
Am. Soc. Naval Engrs. Jour., p. 158.

1894

Submarine Accumulator Accident,
Am. Soc. Naval Engrs. Jour., p. 619.

1892

Note Marinare; Letture Pei Marini,
Nemo., Venuzia, F. Ongania.

1885

U. S. Report of Committee on Torpedoes, Stationary and Movable and Torpedo Boats,
Washington, Govt. Printing Office.

1887

Submarine Boats,
G. W. Hovgaard, McDevitt-Wilson's, New York City, p. 98

1875

Lecture on Submarine Boats and Their Application to Torpedo Operation,
F. M. Barber, U. S. Ordnance Bureau, Navy Dept.

1873

Movable Torpedoes,
John Ericson, New York, p. 14

LIST OF SUBMARINE AND ALLIED PATENTS

I. SUBMARINE VESSELS

Subject	Patentee	Patent No.	Date Issued
Submarine Boat	L. Alexander	7,609	Sept. 3, 1850
Submarine Vessel	L. D. Phillips	9,389	Nov. 9, 1852
Submarine Battery	J. Carver	41,365	Jan. 26, 1864
Submarine Vessel	J. Bachmann	44,380	Sept. 27, 1864
Submarine Torpedo Boat	S. S. Merriam	58,661	Oct. 9, 1866
Submarine Vessel	E. C. B. Rick	69,940	Oct. 15, 1867
Submarine Torpedo Boat	J. Jopling	173,018	Feb. 1, 1876
Torpedo Guards for Vessels	B. A. Richardson	193,727	July 31, 1877
Torpedo Boat	H. Mortensen	202,453	Apr. 16, 1878
Submarine Vessel	T. Nordenfelt	257,604	May 9, 1882
Submarine Boat	J. Jopling	273,851	Mar. 13, 1883
Torpedo Boat	B. B. Hotchkiss	278,708	June 5, 1883
Submarine Vessel	J. H. L. Tuck	297,647	Apr. 29, 1884
Submarine Torpedo Boat	P. B. Walker and H. G. Riggs	310,342	Jan. 6, 1885
Torpedo Boat	C. S. Lee	333,762	Jan. 5, 1886
Submarine Boat or Vessel	A. Campbell and J. Ash	344,718	June 29, 1886
Submarine Torpedo Boat	C. D. Goubet	352,124	Nov. 9, 1886
Submarine Torpedo Vessel	C. D. Shepard	379,991	Mar. 27, 1888
Submarine Vessel	C. De B. Shepard	379,992	Mar. 27, 1888
Submarine Vessel	G. Poore and W. C. Storey	399,693	Mar. 19, 1889
Submarine Boat	J. B. Gerber	406,725	July 9, 1889
Submarine Vessel	F. W. Pool	435,857	Sept. 2, 1890
Submarine Boat	J. F. Auer	470,535	Mar. 8, 1892
Submergible Torpedo Boat	J. P. Holland	472,670	Apr. 12, 1892
Submarine Boat	J. R. Haydon	493,266	Mar. 14, 1893
Submarine Boat	D. T. Freese and J. D. Gawn	521,854	June 26, 1894
Submarine Torpedo Boat	J. P. Holland	522,177	June 26, 1894
Submarine Torpedo Boat	G. C. Baker, dec'd	525,178	Aug. 28, 1894
Submarine Torpedo Boat	G. C. Baker, dec'd M. R. Baker , Administratrix	525,179	Aug. 28, 1894
Submarine Torpedo Boat	G. C. Baker, dec'd M. R. Baker, Administratrix	530,466	Dec. 4, 1894
Submergible Boat	J. P. Holland	537,113	Apr. 9, 1895
Marine Vessel	S. Lacavalerie	538,921	May 7, 1895
Submarine Vessel	J. Scheubeck	575,907	Jan. 26, 1897
Submarine Vessel	S. Lake	581,213	Apr. 20, 1897
Submarine Boat	G. W. Bennum	604,185	May 17, 1898
Submarine Boat	R. Lincoln	615,866	Dec. 13, 1898
Torpedo Attachment for Boats	J. P. S. Sadtler	625,851	May 30, 1899
Submarine Vessel	S. Lake	638,342	Dec. 5, 1899
Submarine Boat	J. P. Holland	681,221	Aug. 27, 1901
Submarine Vessel	J. P. Holland	681,222	Aug. 27, 1901
Submarine Boat	J. P. Holland	683,400	Sept. 24, 1901
Visual Indicator for Submergible Boats	C. A. Morris	685,164	Oct. 22, 1901
Torpedo Boat	T. J. Moriarty	691,160	Jan. 14, 1902
Automatic Diving Mechanism for Submarine Boats	J. P. Holland	693,272	Feb. 11, 1902
Means for Automatically Ballasting Submarine Boats	J. P. Holland	694,153	Feb. 25, 1902
Submarine Boat or Vessel	J. P. Holland	694,154	Feb. 25, 1902
Submarine Boat	J. P. Holland	694,643	Mar. 4, 1902
Submarine Boat	S. Lake	695,215	Mar. 11, 1902
Submarine Boat	J. P. Holland	696,972	Apr. 8, 1902
Submarine Boat	J. P. Holland	702,728	June 17, 1902
Submarine Boat	J. P. Holland	702,729	June 17, 1902
Submarine Boat	J. P. Holland	706,561	Aug. 12, 1902
Submarine Boat	J. P. Holland	708,553	Sept. 9, 1902
Pneumatic Torpedo Firing Apparatus	S. Lake	709,335	Sept. 16, 1902
Storage of Supplies for Submarine Vessels	S. Lake	714,921	Dec. 2, 1902
Anchor Hoisting Device for Submarine Boats	S. Lake	716,059	Dec. 16, 1902
Submarine Boat	S. Lake	717,101	Dec. 30, 1902
Submarine Boat	C. B. Gillette	718,450	Jan. 13, 1903
Submarine Boat	S. Lake	726,227	Apr. 21, 1903
Submarine Boat	S. Lake	726,705	Apr. 28, 1903
Combined Ventilating and Observing Tube for Submarine Boats	S. Lake	726,947	May 5, 1903
Submarine Boat Structure	H. N. Ridgway	731,500	June 23, 1903
Automatic Diving Mechanism for Submarine Boats	F. W. Brady	738,879	Sept. 15, 1903
Submarine Boat	L. Y. Spear	739,734	Sept. 22, 1903
Submarine Boat	D. F. Toomey	746,606	Dec. 8, 1903
Tank for liquid fuel	F. T. Cable and L. Y. Spear	751,609	Feb. 9, 1904
Ballast Compartment for Submarine Boats	S. Lake	754,222	Mar. 8, 1904
Submarine Boat	S. Lake	756,030	Mar. 29, 1904
Buoyancy Regulating Apparatus for Submarine Boats	L. Y. Spear	772,970	Oct. 25, 1904
Compensating Device for Submarine Boats	L. Y. Spear	778,339	Dec. 27, 1904
Compensating Device for Submarine Boats	F. T. Cable	778,350	Dec. 27, 1904
Means for Submerging Submarine Boats	R. L. D'Equevilley	788,525	May 2, 1905

Subject	Patentee	Patent No.	Date Issued
Submarine Boat	R. D'Equevilley	798,501	Aug. 29, 1905
Submarine Torpedo Boat	J. J. Harpain	801,101	Sept. 19, 1905
Ballast Device for Submarine Vessels	S. Lake	803,174	Oct. 31, 1905
Ballast Apparatus for Submarine Vessels	S. Lake	803,175	Oct. 31, 1905
Air Supply Apparatus for Submarine Vessels	S. Lake	803,176	Oct. 31, 1905
Engine Exhaust for Submarine Vessels	S. Lake	803,177	Oct. 31, 1905
Submarine Vessel	S. Lake	803,178	Oct. 31, 1905
Buoyancy Regulating Apparatus for Submarine Boats	L. Y. Spear	805,496	Nov. 28, 1905
Submarine Boat	H. O. Eiane	803,885	Nov. 7, 1905
Construction of Submarine Boats	T. H. Wheless	811,886	Feb. 6, 1906
Means for Steering Submarine and Submergible Boats	L. Y. Spear	812,306	Feb. 13, 1906
Submarine Vessel and Mechanism connected therewith	G. Simpson	812,956	Feb. 20, 1906
Submarine Boat	J. P. Holland	815,350	Mar. 20, 1906
Submarine Boat	M. Naletoff	817,130	Apr. 3, 1906
Automatic Safety Depth Regulating Valve for Submarine or Submergible Boats	L. Y. Spear and T. S. Bailey	820,372	May 8, 1906
Submarine Boat	E. Miehoff	821,595	May 22, 1906
Duct Keel for Submarine Boats	L. Y. Spear	821,895	May 29, 1906
Submarine Boat	T. H. Wheless	822,565	June 5, 1906
Submarine Vessel	S. Wiebe	832,646	Oct. 9, 1906
Immersion Apparatus for Submarine Boats	E. A. Nilsen	834,161	Oct. 23, 1906
Vessel Construction	O. S. Pulliam	836,892	Nov. 27, 1906
Propulsion of Submarine Vessels	S. Lake	846,417	Mar. 5, 1907
Submarine or Submergible Boat	T. S. Bailey and L. Y. Spear	848,872	Apr. 2, 1907
Submarine Boat	J. J. Harpain	850,831	Apr. 16, 1907
Submarine Boat	L. Y. Spear	854,004	May 21, 1907
Submarine Boat	J. M. Cage	854,146	May 21, 1907
Submarine Boat	J. M. Cage	860,126	July 16, 1907
Submarine Vessel	A. Hector	863,532	Aug. 13, 1907
Submergible Vessel	E. L. Peacock	872,842	Dec. 3, 1907
Torpedo Boat	S. Lake	876,564	Jan. 14, 1908
Twin Screw Submarine Boat	L. Y. Spear	878,752	Feb. 11, 1908
Submarine Boat	G. Behrmann	896,613	Aug. 18, 1908
Shelter for Use in Connection with Submarine Vessels	M. A. Laubeut	921,125	May 11, 1909
Submarine Boat	L. Y. Spear	922,056	May 18, 1909
Submarine or Submergible Boat	C. Laurenti	922,298	May 18, 1909
Submarine or Submergible Boat	S. Lake and E. L. Peacock	926,007	June 22, 1909
Submarine Vessel	S. Lake	926,065	June 22, 1909
Entrance Shaft for Submarine Boats	R. D'Equevilley-Montjustin	932,379	Aug. 24, 1909
Craft Adapted to Travel in a Resisting Medium	C. M. Stanley	939,344	Nov. 9, 1909
Submarine Boat	E. D'Equevilley-Montjustin	943,604	Dec. 14, 1909
Submarine Boat	R. D'Equevilley-Montjustin	943,605	Dec. 14, 1909
Propulsion of Submarine Boats	C. Del. Proposto	944,776	Dec. 28, 1909
Boat Salvage Device	G. Salles	945,141	Jan. 4, 1910
Torpedo Boat	H. Maxim	946,944	Jan. 18, 1910
Means for Expelling the Gas Engine Exhaust of Submarine Boats	L. Noe	953,283	Mar. 29, 1910
Method of Maintaining Equality of Weight in Submarine Boats while in operation	P. Winland	953,881	Apr. 5, 1910
Submarine Vessel	A. J. Griffin	958,742	May 24, 1910
Means for Emptying Submergence Tanks in Submergible Boats	L. Y. Spear	964,943	July 19, 1910
Submarine Boat or other Vessel	A. H. Atterbridge	969,128	Aug. 30, 1910
Submarine Boat	S. Lake	970,064	Sept. 13, 1910
Semisubmerged Submarine Gunboat and Torpedo Boat	H. Hertsberg, A. A. Low and M. J. Wohl	971,676	Oct. 4, 1910
Submarine Torpedo Boat	A. M. Fuller	970,210	Sept. 13, 1910
Submarine Boat Equipped with Submerging Planes	L. Y. Spear	973,227	Oct. 18, 1910
Submarine Vessel	S. Lake	947,921	Feb. 1, 1910
Device for Regulating the Submersion of Submarine Boats and the like	M. F. Hay	977,951	Dec. 6, 1910
Submarine or Submergible Boat	C. Laurenti	985,911	Mar. 7, 1911
Submarine Boat	R. D'Equevilley	988,632	Apr. 4, 1911
Submarine Vessel	M. A. Laubeuf	989,371	Apr. 11, 1911
Compensating for Torpedoes Discharged from Submarine Boats	L. Y. Spear	997,713	July 11, 1911
Submarine Boat	S. C. Rockman	998,204	July 18, 1911
Submarine or Submergible Boat	E. L. Peacock	1,003,063	Sept. 12, 1911
Ventilating Apparatus for Submarine Vessels	H. Hertsberg, A. A. Low and M. J. Wohl	1,006,380	Oct. 17, 1911
Conning Tower for Submarine and Diving Vessels	G. J. K. Behrmann and E. Hurlbrink	1,011,012	Dec. 5, 1911
Torpedo Tube Cap	H. Hertzberg and M. J. Wohl	1,006,212	Oct. 17, 1911
Torpedo Boat	H. Maxim	1,028,473	June 4, 1912
Submarine Boat	A. Ehrmann	1,014,95[illegible]	Jan. 16, 1912
Safety Weight for Submarine Vessels	M. A. Laubeuf	1,035,021	Aug. 6, 1912
Hull for Submarine Boats	V. Cavallini	1,044,489	Nov. 19, 1912
Pressure Resisting Receptacle	J. Buttgen	1,045,673	Nov. 26, 1912
Rudders for the Submersion and the Navigation of Submarine Vessels Under Water	C. Laurenti	1,061,088	May 6, 1913
Submarine or Submergible Torpedo Boat	E. L. Peacock	1,067,371	July 15, 1913
Submergible Boat Construction	L. Y. Spear and H. E. Grieshaber	1,072,393	Sept. 2, 1913
Construction and Conning Equipment for Submergible Boats	L. Y. Spear and H. E. Grieshaber	1,072,392	Sept. 2, 1913
Submarine Boat	F. Fenaux	1,089,543	Mar. 10, 1914

Subject	Patentee	Patent No.	Date Issued
Air Supply Apparatus for Submarine Vessels	P. Parnitzky	1,097,356	May 19, 1914
Housing for the Conning Towers, Periscopes and Ventilating Shafts of Submarines	M. F. Hay	1,099,126	June 2, 1914
Periscope	J. Hanson	1,102,046	June 30, 1914
Submarine or Submergible Boat	M. F. Hay and F. Gurhauer	1,107,942	Aug. 18, 1914
Submergible Boat	G. M. Lagergren	1,108,192	Aug. 25, 1914
Diving Chamber for Submarine Operations	C. Petit	1,109,145	Sept. 1, 1914
Periscope for Submarine and Submergible Craft	B. Rosenbaum	1,110,827	Sept. 15, 1914
Torpedo Pilot Boat for Automobile Torpedoes	S. Danenhower	1,111,139	Sept, 22, 1914
Submarine Boat	H. Techel	1,121,210	Dec. 15, 1914
Pressure Regulating Air Circulating for Submarines	T. J. P. Aanstoots	1,115,367	Oct. 27, 1914
Submarine Vessel	C. Laurenti	1,120,392	Dec. 8, 1914
Buoyancy Regulating Apparatus for Submarine Boats	S. Lake	1,123,762	Jan. 5, 1915
Diving Rudder for Submarine Vessels	C. Laurenti	1,125,567	Jan. 19, 1915
Submarine Vessel	G. G. Ullin	1,125,772	Jan. 19, 1915
Submarine	J. M. Cage	1,126,616	Jan. 26, 1915
Submarine Boat	H. S. Epes	1,126,624	Jan. 26, 1915
Ballast Controlling Apparatus	S. Lake	1,127,648	Feb. 9, 1915
Shallow Draft Submarine Boat	F. B. Whitney	1,127,707	Feb. 9, 1915
Pressure Control for Submarine Chambers	M. Klein	1,131,712	Mar. 16, 1915
Means for Conducting Submarine Warfare	C. M. Wheaton, dec'd	1,131,761	Mar. 16, 1915
Submarine Torpedo Boat	J. Barraja-Frauenfelder	1,134,940	Apr. 6, 1915
Submarine Boat	S. Lake	1,135,537	Apr. 13, 1915
Safety Device for Submarine or Submergible Boats	E. L. Peacock	1,143,131	June 15, 1915
Breakwater Shield for Submarine Boats	R. H. M. Robinson	1,146,958	July 20, 1915
Submarine Boat	S. Lake	1,149,373	Aug. 10, 1915
Automatic Air Intake for Submarines, etc.	A. Hoar	1,151,540	Aug. 24, 1915
Submarine or Submersible Boat	E. L. Peacock	1,152,754	Sept. 7, 1915
Submarine Boat	L. Y. Spear	1,153,267	Sept. 14, 1915
Submarine Vessel	J. T. Parker	1,154,126	Sept. 21, 1915
Hull Construction of Submarine Boats	L. Y. Spear	1,154,215	Sept. 21, 1915
Submarine Boat	J. Barraja-Frauenfelder	1,158,883	Nov. 2, 1915
Submarine Vessel	C. Laurenti	1,161,484	Nov. 23, 1915
Submarine Boat	C. Regenbogen and H Vogel	1,164,394	Dec. 14, 1915
Submarine Vessel	N. P. Nelson	1,165,535	Dec. 28, 1915
Device for Controlling the Water Ballast in Submergible Vessels	C. Sacerdoti	1,169,514	Jan. 25, 1916
Torpedo Launching Apparatus for Submarine Vessels	E. Schneider	1,166,940	Jan. 4, 1916
Hull for Submarines	M. F. Hay	1,169,640	Jan. 25, 1916
Submarine Boat	S. Lake	1,169,970	Feb. 1, 1916
Submarine Boat	H. E. Grieshaber	1,170,529	Feb. 8, 1916
Boat	H. W. Jacobs	1,173,431	Feb. 29, 1916
Submarine Torpedo Discharging Device	H. W. Hille	1,174,723	Mar. 7, 1916
Submarine Boat	J. Barraja-Frauenfelder	1,175,219	Mar. 14, 1916
Submarine Boat	S. Lake	1,180,263	Apr. 18, 1916
Submarine Boat	W. R. Mackland	1,180,861	Apr. 25, 1916
Submarine Boat	H. Technel	1,183,695	May 16, 1916
Submarine Boat	K. Voller	1,187,206	June 13, 1916
Submarine Boat	H. E. Grieshaber	1,187,522	June 20, 1916
Pressure Controlled Governing Apparatus	R. Janney	1,187,738	June 20, 1916
Submarine Buoyant Conveyance	A. Schrumpf	1,188,842	June 27, 1916
Submarine Boat	J. Barraja-Frauenfelder	1,190,210	July 4, 1916
Submarine Boat	W. F. Doherty, Jr.	1,192,172	July 25, 1916
Submarine Vessel	C. Laurenti	1,192,537	July 25, 1916
Submarine Vessel	C. A. Nallough	1,202,351	Oct. 24, 1916
Means for Destroying Vessels	F. V. Hagan	1,201,176	Oct. 10, 1916
Torpedo Tube for Submarines or the like	M. F. Hay and G. Ekama	1,204,353	Nov. 7, 1916
Water Tube Boiler for Submarines	G. C. Davison	1,209,678	Dec. 26, 1916
Submarine Steering Apparatus	A. Citroen	1,213,153	Jan. 23, 1917
Torpedo Launching Apparatus for Submarine Boats	S. Lake	1,215,387	Feb. 13, 1917
Apparatus for Moving Diving Rudder of Submarines	M. F. Hay and C. Ekama	1,216,564	Feb. 20, 1917
Safety Device for Submarine Boats	J. P. Ryan	1,219,667	Mar. 20, 1917
Cleaning Periscope Glasses	J. A. Steinmetz	1,222,156	Apr. 10, 1917
Submarine Warfare	J. A. Steinmetz	1,222,498	Apr. 10, 1917
Submarine	F. W. Schoenen	1,224,027	Apr. 24, 1917
Water Tube Boiler for Submarines	G. C. Davison	1,224,105	Apr. 24, 1917

II. LIFE AND VESSEL SAVING DEVICES

Subject	Patentee	Patent No.	Date Issued
Keel for Submarine Boats	W. Hammond	303,843	Aug. 19, 1884
Vessel for Submarine or Surface Navigation	V. B. De Souza	453,560	June 2, 1891
Submarine Locomotive	S. Lake	557,835	Apr. 7, 1896
Submarine Wrecking Boat	W. R. Hinsdale	575,890	Jan. 26, 1897
Combined Surface and Submarine Vessel	S. Lake	650,758	May 29, 1900
Submarine Apparatus	A. Von Hoffmann	657,218	Sept. 4, 1900
Submarine Apparatus	A. Von Hoffmann	664,152	Dec. 18, 1900
Submarine Boat	H. H. Morrell	726,085	Apr. 21, 1903
Means of Escape From Sunken Submarine and Similar Boats	F. T. Cable and L. Y. Spear	799,714	Sept. 19, 1905
Life Saving Boat	J. A. Marley	805,975	Nov. 28, 1905
Salvage Means for Submarine Boats	E. P. Dougherty	807,732	Dec. 19, 1905
Submarine Boat	W. J. O'Haire	814,869	Mar. 13, 1906
Marine Vessel	J. F. Gray	841,961	Jan. 22, 1907
Submarine Boat	R. H. Goldsborough	842,146	Jan. 22, 1907
Means of Escape From Sunken Submarines	E. A. Edney	845,623	Feb. 26, 1907
Submarine Structure	M. E. Pester	845,813	Mar. 5, 1907
Submarine Torpedo Boat	A. Elgar	846,736	Mar. 12, 1907
Means for Effecting Escape of Occupants From Sunken Vessel	I. Fripp	848,615	Mar. 26, 1907
Life Saving Device for Boats	J. Husser	855,890	June 4, 1907
Means for Recovering Submarine Boats	E. Oswald	856,096	June 4, 1907
Life Saving Apparatus for Submarine Boats	O. A. C. Oehmler	857,193	June 18, 1907
Signal Buoy and Lifting Device for Sunken Submarine Boats	E. L. Benson	861,795	July 30, 1907
Submarine Boat	W. J. O'Haire	867,294	Oct. 1, 1907
Means for Effecting Escape of Occupants From Sunken Vessels	D. A. Dempster	876,777	Jan. 14, 1908
Submarine Boat	F. Mott	883,040	Mar. 24, 1908
Boat Salvage Device	G. Salles	922,519	May 25, 1909
Navigating Turret for Submergible Vessels	S. Lake	925,706	June 22, 1909
Life Boat for Submarine Vessels	H. J. Walles	932,921	Aug. 31, 1909
Safety Device for Submarine Boats	W. A. Stevenson	952,379	Mar. 15, 1910
Life Saving Device for Submarine Boats	E. Labowsky	953,473	Mar. 29, 1910
Crew Saving and Submarine Salvaging Device	A. W. Reed	953,642	Mar. 29, 1910
Device for Raising Submarine Vessels	M. A. Laubeuf	955,414	Apr. 19, 1910
Submarine Boat	L. E. Goetz	960,537	June 7, 1910
Life Saving Attachment for Submarines	S. S. Peterson	974,516	Nov. 1, 1910
Life Saving Device	A. L. Bideaux	986,431	Mar. 14, 1911
Means for Indicating and Raising Sunken Boats	J. F. Shea	993,205	May 23, 1911
Submarine Boat	G. B. Yerton	994,552	June 6, 1911
Life Saving Device for Submarine Vessels	D. and J. Chappell	1,002,033	Aug. 29, 1911
Escape Device for Submarine Boats	J. Schnitter	1,007,145	Oct. 31, 1911
Signaling Apparatus for Submarine Boats	J. F. Shea	1,009,800	Nov. 28, 1911
Buoy Attachment for Submarine Boats	G. F. Keating	1,014,398	Jan. 9, 1912
Submarine Life Saving and Observation Tender	S. Pontiere	1,019,356	Mar. 5, 1912
Submarine Rescuing Apparatus	S. Roth	1,026,458	May 14, 1912
Submarine Signaling and Safety Device	C. Brown	1,028,989	June 11, 1912
Device for Raising Sunken Submarine Vessels	H. Aronsen	1,030,701	June 25, 1912
Wreck Raising Appliance	V. Buffulini and R. Rottenbacher	1,030,869	July 2, 1912
Life Saving Apparatus for Submarines	M. Reyngoudt	1,036,150	Aug. 20, 1912
Life Saving Attachment for Submarines	H. C. E. Lindtke	1,064,351	June 10, 1913
Life Saving Device	E. Topper	1,070,639	Aug. 19, 1913
Buoy for Submarine Boats	D. L. Cayo	1,071,393	Aug. 26, 1913
Signaling and Passenger Carrying Device for Vessels	A. Grossich	1,076,496	Oct. 21, 1913
Life Boat for Submarine Vessels	G. Hilgers	1,081,740	Dec. 16, 1913
Submarine Craft	K. Whiting	1,097,700	May 26, 1914
Submarine Boat	A. J. Griffin	1,103,958	July 21, 1914
Signal for Submarine Vessels	F. A. Lovegrove	1,113,799	Oct. 13, 1914
Apparatus for Raising Submarines and Submersibles	L. A. J. LeDuc	1,114,155	Oct. 20, 1914
Attachment for Submarine Boats	S. Danenhower	1,117,555	Nov. 17, 1914
Submarine Life Saving Device	C. W. Flint	1,117,826	Nov. 17, 1914
Safety Device for Submarine Boats	J. E. Conway	1,127,965	Feb. 9, 1915
Submarine Life Saving Appliance	C. G. Ullin	1,128,553	Feb. 16, 1915
Life Buoy for Submarine of Submergible Boats	H. Grieshaber	1,137,131	Apr. 27, 1915
Safety Appliance for Submarine Vessels	J. S. Fraser	1,139,409	May 11, 1915
Life Saving Apparatus	L. H. De Wyk	1,152,305	Aug. 31, 1915
Means of Escape From Submarines	W. J. Kenely	1,152,420	Sept. 7, 1915
Signal Device for Submarine Vesesl	E. B. Walsh	1,153,277	Sept. 14, 1915
Means for Locating Submarine Boats	H. Lotz	1,154,522	Sept. 21, 1915
Safety Apparatus for Submarines	M. J. L. P. Bonard	1,156,970	Oct. 19, 1915
Anchor Cable Cutting Apparatus for Submarine Boats	J. Barraja-Frauenfelder	1,158,160	Oct. 26, 1915
Safety Float for Submarines	H. E. Keller and H. M. Siedschlag	1,159,683	Nov. 9, 1915
Submarine with Detachable Conning Tower for Life Saving Purposes	V. Cavallini	1,159,745	Nov. 9, 1915
Buoy for Submarines	W. H. Amberger	1,160,122	Nov. 16, 1915
Submarine	C. E. and H. E. Beck	1,166,651	Jan. 4, 1916
Submarine	R. Brunet	1 168,707	Jan. 18, 1916
Appliance for Vessels	E. F. Crane	1,169,128	Jan. 25, 1916
Escape for Submarines	E. L. Peacock	1,173,379	Feb. 29, 1916
Escape Apparatus for Submarine Boats	D. C. Marshall	1,173,726	Feb. 29, 1916
Submarine Vessel	C. Von Culin	1,175,848	Mar. 14, 1916
Apparatus for Locating and Raising Sunken Vessels	G. McKenzie	1,176,229	Mar. 21, 1916
Submarine	W. L. Walker	1,177,157	Mar. 28, 1916
Life Saving Device for Use in Submarines	H. F. Wilson	1,177,372	Mar. 28, 1916
Apparatus for Locating Sunken Vessels	J. F. and D. Neal	1,178,094	Apr. 4, 1916
Submarine Signaling and Salvage Apparatus	R. Okusa	1,178,407	Apr. 4, 1916
Signal Device for Submarine Boats	H. E. Nord	1,181,791	May 2, 1916

Subject	Patentee	Patent No.	Date Issued
Submarine Boat Attachment	W. H. Ramm	1,182,208	May 9, 1916
Marine Life Saving Apparatus	J. Konrad	1,183,078	May 16, 1916
Escape Apparatus for Submarines	R. Brunet	1,183,163	May 16, 1916
Wreck Indicating Device	G. W. Heath	1,184,180	May 23, 1916
Detachable Life Boat for Submarine Vessels	A. J. Morrison, Jr.	1,184,981	May 30, 1916
Detachable Conning Tower and Life Buoy	C. Kaempfer	1,188,179	June 20, 1916
Device for Locating Sunken Vessels	C. F. Nyquist	1,188,308	June 20, 1916
Submarine Salvage Apparatus	D. W. Shea	1,188,333	June 20, 1916
Submarine Boat	G. A. Fredericks	1,188,436	June 27, 1916
Means to Raise Sunken Vessels	C. T. Bowers	1,188,888	June 27, 1916
Device for Locating and Raising Sunken Vessels	J. C. Paulson	1,189,864	July 4, 1916
Apparatus for Raising Sunken Vessels	R. W. Bryant and A. E. Moore	1,191,558	July 18, 1916
Automatic Signaling Device for Marine Vessels	E. Nelson	1,194,770	Aug. 15, 1916
Ship Locating Device	C. May	1,196,131	Aug. 29, 1916
Signaling or Indicating Buoy	C. M. Rollo	1,196,588	Aug. 29, 1916
Means for Floating or Raising Fluid Supported Objects	A. Musorofiti	1,197,650	Sept. 12, 1916
Life Saving Apparatus for Submarines	R. A. Willison	1,207,115	Dec. 5, 1916
Submarine Vessel	J. C. Buerke	1,207,851	Dec. 12, 1916
Vessel Locating and Salvaging Apparatus	J. M. Orr	1,208,362	Dec. 12, 1916
Submarine Life Boat	D. V. Reeves	1,210,840	Jan. 2, 1917
Submarine Life Saving and Observation Device	T. E. Burke and J. R. A. Lindholm	1,215,905	Feb. 13, 1917
Marker Buoy	L. A. Carter and L. J. Rector	1,215,908	Feb. 13, 1917
Life Boat for Submarines	W. Brown	1,221,282	Apr. 3, 1917
Vessel Indicating and Raising Apparatus	B. F. Nixon	1,223,606	Apr. 24, 1917

III. TORPEDOES

Subject	Patentee	Patent No.	Date Issued
Apparatus for Discharging Torpedoes Under Water	P. Plant	36,965	Nov. 18, 1862
Marine Torpedo	H. M. Nagel	39,162	July 7, 1863
Towing	J. D. Willoughby	48,124	June 6, 1865
Submarine Torpedo	W. R. King	102,556	May 3, 1870
Propulsion of Marine Torpedoes	J. A. Howell	121,052	Nov. 21, 1971
Submarine Torpedoes and Boats	H. J. Smith	134,493	Dec. 31, 1872
Torpedo Boats	H. F. Knapp	158,501	Jan. 5, 1875
Torpedo Guard	J. H. Fisher	197,262	Nov. 20, 1877
Electro-Magnetic Steering Apparatus for Submarine Boats	J. L. Lay	198,127	Dec. 11, 1877
Torpedo Boat	J. L. Lay	211,301	Jan. 14, 1879
Torpedo Boat	J. L. Lay	211,302	Jan. 14, 1879
Torpedo Boat	J. L. Lay	211,303	Jan. 14, 1879
Valves for Torpedo Boats	J. L. Lay	217,120	July 1, 1879
Marine Torpedo	J. H. McLean	222,718	Dec. 16, 1879
Torpedo Boat	W. H. Mallory	223,855	Jan. 27, 1880
Marine Torpedo	M. Coloney	225,465	Mar. 16, 1880
Torpedo Boat	G. W. McMullen	227,637	May 18, 1880
Submarine Torpedo Boat	M. A. Hardy	243,888	July 5, 1881
Submarine Torpedo Boat	M. Hubbe	243,907	July 5, 1881
Means for Adapting Submarine Guns to Ships	J. Ericsson	245,364	Aug. 9, 1881
Submarine Torpedo Boat	G. H. Reynolds	245,864	Aug. 16, 1881
Torpedo Boat	G. H. Reynolds	246,415	Aug. 30, 1881
Torpedo Guard for Vessels	W. H. Walker	247,717	Sept. 27, 1881
Gas Expansion Chamber for Torpedo Boats	G. E. Haight	250,144	Nov. 29, 1881
Torpedo Boat	G. H. Reynolds	251,288	Dec. 20, 1881
Submarine Torpedo	M. Hubbe and M. A. Hardy	255,386	Mar. 21, 1882
Submarine Torpedo Gun	P. Brotherhood	261,662	July 25, 1882
Submarine Torpedo	H. F. Hicks	263,407	Aug. 29, 1882
Apparatus for Launching Torpedoes	P. Brotherhood	261,805	July 25, 1882
Marine Torpedo	J. A. Howell	311,325	Jan. 27, 1885
Apparatus for Launching Torpedoes	J. A. Howell	311,326	Jan. 27, 1885
Torpedo	T. Nordenfelt	312,579	Feb. 17, 1885
Torpedo Boat Propelled and Steered by Electricity	W. S. Sims	319,633	June 9, 1885
Apparatus for Protecting Vessels Against Torpedo Attacks	A. C. Koerner	338,241	Mar. 16, 1886
Submarine Torpedo Boat	G. E. Haight and W. H. Wood	339,096	Mar. 30, 1886
Marine Torpedo	S. H. Nealy	358,471	Mar. 1, 1887
Electric Torpedo Boat	H. M. Bennett	359,313	Mar. 15, 1887
Safety Mechanism for Torpedo Tubes	E. Kaselowsky	361,066	Apr. 12, 1887
Automatic Brake Apparatus for Torpedoes	E. Kaselowsky	361,525	Apr. 19, 1887
Apparatus for Launching Torpedoes	E. Kaselowsky	361,526	Apr. 19, 1887
Torpedo Boat	A. P. S. Miller	364,364	June 7, 1887
Manufacture of Torpedo Nets and Means for Attaching and Working Them	W. M. Bullivant	379.854	Mar. 20, 1888
Auto-Mobile Torpedo	M. E. Hall	387,353	Aug. 7, 1888
Means for Operating Marine Torpedoes	J. O'Kelly and B. A. Collins	388,299	Aug. 21, 1888
Submarine Torpedo Boat	H. P. Griswold	388,862	Sept. 4, 1888
Net Cutting Attachment for Torpedoes	S. A. Brown	401,773	Apr. 23, 1889
Auto-Mobile Torpedo	A. G. Von Buonaccorsi Di Pistoja	413,113	Oct. 15, 1889
Self-Propelling Torpedo	A. G. Von Buonaccorsi Di Pistoja	413,114	Oct. 15, 1889
Automatic Sinking Valve for Submarine Torpedoes	A. G. Von Buonaccorsi Di Pistoja	413,115	Oct. 15, 1889
Auto-Mobile Torpedo	A. G. Von Buonaccorsi Di Pistoja	413,585	Oct. 22, 1889
Torpedo Launching Gear	H. P. Elwell	414,386	Nov. 5, 1889
Firing Mechanism for Torpedoes	A. G. Von Buonaccorsi Di Pistoja	417,206	Dec. 10, 1889
Torpedo and Gun Boat	R. J. Gatling	424,288	Mar. 25, 1890
Mechanism for Controlling Torpedoes	G. R. Murphy	442,327	Dec. 9, 1890
Marine Torpedo	N. J. Halpine	453,861	June 9, 1891
Universal Torpedo Dropping Gear	C. Dann	455,742	July 14, 1891
Marine Torpedo	A. W. Savage	456,278	July 21, 1891
Marine Torpedo	A. W. Savage	456,524	July 21, 1891
Marine Torpedo	J. A. Howell	458,677	Sept. 1, 1891
Torpedo Boat	J. Ambrose	464,909	Dec. 8, 1891
Torpedo Defense	W. P. Bullivant	466,976	Jan. 12, 1892
Apparatus for Launching Fish Torpedoes	J. B. G. A. Canet	470,286	Mar. 8, 1892
Torpedo Tube Mounting	J. B. G. A. Canet	470,288	Mar. 8, 1892
Torpedo Launching Apparatus	A. Scheibel	472,553	Apr. 12, 1892
Depth Regulating Mechanism for Marine Torpedoes and Other Vessels	F. H. Paine	478,813	July 12, 1892
Torpedo Launching Apparatus	J. A. Howell	484,658	Oct. 18, 1892
Torpedo	S. E. Mower and G. E. Haight	498,183	May 23, 1893
Torpedo Launching Tube	J. B. G. A. Canet	514,810	Feb. 13, 1894
Launching Tube for Torpedoes	E. W. Lloyd and C. W. Hutchinson	517,390	Mar. 27, 1894
Apparatus for Ejecting or Launching Torpedoes	S. Drzewiecki	542,876	July 16, 1895
Apparatus for Launching Torpedoes	E. W. Lloyd and C. W. Hutchinson	548,374	Oct. 22, 1895
Marine Torpedo	L. F. Johnson, W. J. Slacke and H. Lacy	559,711	May 5, 1896
Steering Mechanism for Torpedoes	L. Obry	562,235	June 16, 1896
Steering Apparatus for Torpedoes	E. Kaselowsky	591,768	Oct. 12, 1897
Automatic Steering Device for Torpedoes	E. Kaselowsky	607,440	July 19, 1898

Subject	Patentee	Patent No.	Date Issued
Torpedo Launching Apparatus	J. Whitehead	608,814	Aug. 9, 1898
Device for Starting Torpedoes	L. Obry	621,364	Mar. 21, 1899
Torpedo Launching Apparatus	S. Drzewiecki	621,640	Mar. 21, 1899
Apparatus for Launching or Discharging Torpedoes	H. L. J. C. Turck	626,945	June 13, 1899
Torpedo Launching Apparatus	E. Kaselowsky	631,308	Aug. 22, 1899
Automobile Torpedo	T. E. Barrow	632,089	Aug. 29, 1899
Torpedo	T. W. Just	638,463	Dec. 5, 1899
Automobile Torpedo	H. Maxim	641,787	Jan. 23, 1900
Automatic Steering Device for Torpedoes	C. D. Haskins	661,520	Nov. 13, 1900
Torpedo	E. Kaselowsky	661,535	Nov. 13, 1900
Submersion Regulating Gear for Torpedoes	A. J. Van Stockum	670,041	Mar. 19, 1901
Autotorpedo	H. Shoemaker	680,505	Aug. 13, 1901
Apparatus for Putting Torpedoes on Vessels	C. A. Morris	685,165	Oct. 22, 1901
Propulsion of Torpedoes, etc., by Compressed Air	F. M. Leavitt	693,872	Feb. 25, 1902
Firing Valve for Subsurface Expulsion Tubes	J. P. Holland	696,971	Apr. 8, 1902
Torpedo Launching Apparatus	J. Whitehead	697,906	Apr. 15, 1902
Torpedo Launching Apparatus	S. J. J. Drzewiecki	708,031	Sept. 2, 1902
Torpedo Boat	F. W. Brady	713,198	Nov. 11, 1902
Submerged Broadside Apparatus for Discharging Torpedoes	G. Hoyos	713,985	Nov. 18, 1902
Steering Apparatus for Torpedoes	J. Borresen	716,517	Dec. 23, 1902
Apparatus for Handling Automobile Torpedoes	B. A. Fiske	717,563	Jan. 6, 1903
Torpedo	M. Fischhaber	726,796	Apr. 28, 1903
Compensating Device for Submarine or Submergible Boats	L. Y. Spear	739,735	Sept. 22, 1903
Gyroscopic Apparatus for Steering Torpedoes	F. M. Leavitt	741,683	Oct. 20, 1903
Means for Expelling Torpedoes	F. W. Brady	765,305	July 19, 1904
Safety Device for Automobile Torpedoes	G. E. Edgar	765,769	July 26, 1904
Steering Mechanism for Torpedoes	F. M. Leavitt	785,425	Mar. 21, 1905
Gyroscopic Control Apparatus	F. M. Leavitt	795,045	July 18, 1905
War Ship	J. Slonka	797,235	Aug. 15, 1905
Torpedo Launching Apparatus	A. E. Jones	801,719	Oct. 10, 1905
Boardside Under Water Torpedo Launching Apparatus	A. E. Jones	801,792	Oct. 10, 1905
Torpedo Handling Device for Vessels	G. M. Evans	803,218	Oct. 31, 1905
Automotor Torpedo	H. A. Noalhat and G. Fournier	807,195	Dec. 12, 1905
Torpedo Boat	T. J. Moriarty	807,482	Dec. 19, 1905
Marine Torpedo Guard	J. Neumaier	808,942	Jan. 2, 1906
Starting Valve for Automobile Torpedoes	F. M. Leavitt	814,055	Mar. 6, 1906
Gyroscope Spinning Device	F. M. Leavitt	814,969	Mar. 13, 1906
Torpedo Conveying and Launching Apparatus	T. H. Wheless	815,393	Mar. 20, 1906
Retarding Device for Automobile Torpedoes	F. M. Leavitt	816,019	Mar. 27, 1906
Means for Carrying and Handling Torpedoes on Vessels	T. J. Moriarty	818,390	Apr. 17, 1906
Automobile Torpedo	T. H. Wheless	818,987	Apr. 24, 1906
Valve Attachment for Torpedoes	E. Niehoff	820,888	May 15, 1906
Revolving Torpedo Tube Cap	H. E. Grieshaber	820,925	May 15, 1906
Torpedo Expulsion Valve	J. Barraja-Frauenfelder	822,500	June 5, 1906
Automatic System for Balancing and Controlling Torpedoes	T. Gihon	825,881	July 10, 1906
Steering Apparatus for Automobile Torpodoes	F. M. Leavitt	839,161	Dec. 25, 1906
Automobile Torpedo	G. C. Davison	858,266	June 25, 1907
Means for Carrying and Handling Torpedoes on Vessels	T. J. Moriarty	868,613	Oct. 15, 1907
Torpedo Projecting Apparatus for Submarime and Submersible Vessels	H. Smulders	868,946	Oct. 22, 1907
Tandem Torpedo Tube	L. Y. Spear	871,453	Nov. 19, 1907
Starting Valve for Automobile Torpedoes	F. M. Leavitt	880,030	Feb. 25, 1908
Immersion Regulator	A. E. Jones	881,930	Mar. 17, 1908
Steering Apparatus for Torpedoes	A. J. VanStockum	882,982	Mar. 24, 1908
Means for Actuating Submersion Rudders for Torpedoes	A. E. Jones	883,028	Mar. 24, 1908
Torpedo Boat	E. A. Nilsen	883,664	Mar. 31, 1908
Torpedo Expulsion Tube	L. Y. Spear	888,544	May 26, 1908
Gyroscopic Steering Gear for Torpedoes	F. M. Leavitt	894,838	Aug. 4, 1908
Propelled Torpedo	H. Lacy	895,870	Aug. 11, 1908
Torpedo Boat	E. J. Kelley	896,921	Aug. 25, 1908
Immersion Regulator, Particularly Adapted for Torpedoes	A. E. Jones	899,304	Sept. 22, 1908
Shell or Casing for Standard Torpedoes	C. Davis	901,157	Oct. 13, 1908
Control Mechanism for Steering Apparatus	F. M. Leavitt	901,355	Oct. 20, 1908
Automatic Immersion Regulator for Submarines and Torpedoes	E. Schneider	904,093	Nov. 17, 1908
Torpedo	P. J. Hedlund	906,133	Dec. 8, 1908
Torpedo Launching Tube	A. E. Jones	908,270	Dec. 29, 1908
Torpedo	E. O'Toole	909,321	Jan. 12, 1909
Self-Propelled Torpedo	A. E. Jones	910,823	Jan. 26, 1909
Firing Means for Torpedoes	C. Davis	914,371	Mar. 2, 1909
Apparatus for Launching Torpedoes Under Water	A. E. Jones	916,164	Mar. 23, 1909
Self-Propelled Torpedo	A. E. Jones	917,449	Apr. 6, 1909
Torpedo Launching Device	S. Lake	925,707	June 22, 1909
Steering Mechanism for Torpedoes	F. M. Leavitt	925,710	June 22, 1909
Turbine Installation for Torpedoes	S. Z. De Ferranti	925,889	June 22, 1909
Air Heater for Compressed Air Engines	H. W. Shonnard and W. Dieter	927,434	July 6, 1909
Starting Device for the Compressed Air Motors of Self-Propelled Torpedoes	A. E. Jones	929,954	Aug. 3, 1909
Diving Gear for Submarine Boats	F. M. Leavitt	933,083	Sept. 7, 1909
Gas-Propelled Torpedo	I. N. Lewis	933,086	Sept. 7, 1909
Torpedo Tube	C. Laurenti	934,192	Sept. 14, 1909
Automobile Torpedo	H. Maxim	937,217	Oct. 19, 1909
Torpedo	M. Larsen	940,033	Nov. 16, 1909
Torpedo	J. Tasto	941,111	Nov. 23, 1909
Depth Regulating Mechanism for Moving Vessels	G. C. Davison	946,659	Jan. 18, 1910
Torpedo Launching Apparatus	S. Lake	949,325	Feb. 15, 1910
Torpedo and the like	K. O. Leon	952,451	Mar. 22, 1910
Apparatus for Discharging Excess Exhaust Gases from Motors Working on a Closed Cycle	G. F. Jaubert	953,146	Mar. 29, 1910
Exploder for Automobile Torpedoes	F. M. Leavitt	953,848	Apr. 5, 1910

Subject	Patentee	Patent No.	Date Issued
Torpedo	M. Glass	957,670	May 10, 1910
Attachment for Torpedo Tubes	J. Kimbrell	958,650	May 17, 1910
Torpedo	C. Davis	964,147	July 12, 1910
Torpedo	C. Davis	964,148	July 12, 1910
Gyroscopically Controlled Torpedo Firing Apparatus	C. Davis	972,064	Oct. 4, 1910
Self-Propelling Torpedo	H. W. Shonnard	973,141	Oct. 18, 1910
Automobile Torpedo	G. C. Davison	977,438	Dec. 6, 1910
Automobile Torpedo	W. M. Douglas	978,862	Dec. 20, 1910
Automobile Torpedo	H. G. Gillmor	980,243	Jan. 3, 1911
Gyroscopic Steering Apparatus	J. C. Waldron	983,467	Feb. 7, 1911
Submarine Broadside Torpedo Launching Tube	C. C. A. Fallenius	990,429	Apr. 25, 1911
Water Jet Marker for Torpedoes	G. P. Helfrich	995,138	June 13, 1911
Automobile Torpedo	A. E. Jones	996,412	June 27, 1911
Automobile Torpedo	J. M. O'Kelly	998,383	July 18, 1911
Automobile Torpedo	W. M. Douglas	998,475	July 18, 1911
Percussion Mechanism of Automobile Torpedoes	A. E. Jones	1,005,042	Oct. 3, 1911
Means for the Propulsion of Automobile Torpedoes	A. E. Jones	1,005,647	Oct. 10, 1911
Automobile Torpedo and Method of and Apparatus for its Propulsion	H. Maxim	1,014,014	Jan. 9, 1912
Automatic Controlling Means for Submarine Vessels	H. W. Shonnard	1,022,706	Apr. 9, 1912
Mechanical Air Device for Expelling Water or other Liquids from the Heads of Torpedoes to Aid in the Recovery Thereof After Firing	K. Whiting and J. B. Howell	1,023,907	Apr. 23, 1912
Torpedo Launching Tube	E. Schneider	1,024,424	Apr. 23, 1912
Automatic Steering Device for Torpedoes	H. W. Shonnard	1,030,134	June 18, 1912
Device for Cutting or Destroying Torpedo Nets	W. Golsteyn	1,031,997	July 9, 1912
Diving Gear for Torpedoes	F. M. Leavitt	1,033,810	July 30, 1912
Valve Control Mechanism for Gyroscopic Steering Gear	G. C. Davison	1,033,994	July 30, 1912
Gyroscopic Steering Mechanism for Torpedoes	G. C. Davison	1,033,995	July 30, 1912
Device for Destroying Torpedo Nets	W. Golsteyn	1,034,999	Aug. 6, 1912
Method of Fire Control for Torpedoes	H. W. Shonnard	1,035,647	Aug. 13, 1912
Submarine or Submergible Boat	E. L. Peacock	1,037,519	Sept. 3, 1912
Stopping Device for Automobile Torpedoes	F. M. Leavitt	1,044,543	Nov. 19, 1912
Means for Launching Torpedoes from the Sides of Ships	A. E. Jones	1,046,192	Dec. 3, 1912
Starting and Stopping Mechanism for Automobile Torpedoes	F. M. Leavitt	1,064,349	June 10, 1913
Exploder	F. M. Leavitt	1,068,594	July 29, 1193
Sinking Device for Automobile Torpedoes	F. M. Leavitt	1,076,295	Oct. 21, 1913
Submarine Torpedo	H. W. Shonnard	1,077,311	Nov. 4, 1913
Gyroscope Steering Gear	P. Hennig	1,077,344	Nov. 4, 1913
Steering Mechanism for Automobile Torpedoes	F. M. Leavitt	1,080,116	Dec. 2, 1913
Mechanism for Firing Torpedoes	T. S. Bailey	1,094,963	Apr. 28, 1914
Torpedo Launching Apparatus	T. McC. Gunn	1,097,623	May 26, 1914
Torpedo Launching Apparatus	T. McC. Gunn	1,097,624	May 26, 1914
Torpedo Launching Apparatus	T. McC. Gunn	1,097,625	May 26, 1914
Gyroscopic Steering Mechanism for Torpedoes	F. Zottich	1,098,074	May 26, 1914
Torpedo Steering Mechanism	J. J. Dallier	1,098,230	May 26, 1914
Guide Block for Torpedoes	W. J. Doolan	1,099,971	June 16, 1914
Broadside Firing Deck Torpedo Tube	M. F. Hay and F. Guhrauer	1,100,481	June 16, 1914
Broadside Firing Torpedo Tube	M. F. Hay and F. Guhrauer	1,100,676	June 16, 1914
Torpedo	G. P. Helfrich	1,117,843	Nov. 17, 1914
Indicator for Submarine Vessels	G. P. Smith	1,120,417	Dec. 8, 1914
Means for Automatically Steering Torpedoes or the like	K. O. Leon	1,121,563	Dec. 15, 1914
Torpedo Launching Apparatus	G. C. Davison	1,122,699	Dec. 29, 1914
Apparatus for Launching Torpedoes	G. C. Davison	1,122,700	Dec. 29, 1914
Gyroscopically Controlled Torpedo	E. F. Chandler	1,127,403	Feb. 9, 1915
Device for Saving Torpedoes	E. Durr	1,130,585	Mar. 2, 1915
Torpedo	G. P. Helfrich	1,133,282	Mar. 30, 1915
Torpedo and Other Submarine Apparatus	K. O. Leon	1,137,222	Apr. 27, 1915
Mine Catcher	J. K. Kendrick and J. W. Halterman	1,138,225	May 4, 1915
Mine Catcher	P. Zakit	1,138,525	May 4, 1915
Torpedo Guard	E. R. Trammell	1,139,239	May 11, 1915
Gyroscopic Steering Device	F. M. Leavitt	1,145,025	July 6, 1915
Diving Gear for Torpedoes	W. Dieter	1,145,355	July 6, 1915
Mine Raising Apparatus	J. C. Lobato	1,148,103	July 27, 1915
Automobile Torpedo	W. Dieter	1,148,155	July 27, 1915
Torpedo Launching Tube	W. Dieter	1,149,505	Aug. 10, 1915
Gyroscopic Steering Mechanism	W. Dieter	1,153,678	Sept. 14, 1915
Device to Prevent the Admission of Water into the Interior of the Hollow Shaft of a Torpedo's Propeller	C. Radiguer	1,154,206	Sept. 21, 1915
Dirigible Torpedo	M. P. Otto	1,154,427	Sept. 21, 1915
Gyroscopic Steering Mechanism for Automobile Torpedoes	F. W. Dodd	1,156,350	Oct. 12, 1915
Safety Mechanism for Operating the Muzzle and Breech Doors of Torpedo Firing Tubes	J. Barraja-Frauenfelder	1,158,884	Nov. 2, 1915
Torpedo Expulsion Tube	J. Barraja-Frauentelder	1,161,182	Nov. 23, 1915
Torpedo	G. A. Knox	1,163,158	Dec. 7, 1915
Torpedo Mechanism Starter	G. A. Knox	1,163,159	Dec. 7, 1915
Gyroscopically Controlled Torpedo	H. W. Shonnard	1,163,606	Dec. 7, 1915
Automobile Torpedo	H. W. Shonnard	1,163,607	Dec. 7, 1915
Mounting for Torpedo Tubes or the like	H. H. Parsons	1,164,957	Dec. 21, 1915
Mine Destoryer	I. M. Ritter	1,174,026	Feb. 29, 1916
Automobile Torpedo	B. H. Scott	1,177,280	Mar. 28, 1916
Steering Apparatus for Torpedoes	F. M. Leavitt	1,179,440	Apr. 18, 1916
Steering Mechanism for Torpedoes	F. M. Leavitt	1,179,439	Apr. 18, 1916
Torpedo Tube	C. Laurenti	1,179,848	Apr. 18, 1916
Mine and Submarine Destroyer	W. H. Norfolk	1,181,339	May 2, 1916

Subject	Patentee	Patent No.	Date Issued
Method of Gyroscopic Control	H. Anschuetz-Kaumpfe	1,180,365	Apr. 25, 1916
Buoyancy Varying Device	D. F. Asbury	1,180,366	Apr. 25, 1916
Torpedo Construction	H. W. Shonnard	1,181,548	May 2, 1916
Torpedo Launching Apparatus	D. R. Battles	1,184,409	May 23, 1916
Shield for Battleships	J. Taggart	1,185,145	May 30, 1916
Ship Protector	H. J. Charles	1,185,983	June 6, 1916
Mine Destroying Means	E. T. Robeson	1,187,179	June 13, 1916
Gyroscopic Steering Device	O. K. Cazin	1,189,239	July 4, 1916
Diving Gear for Torpedoes	W. Dieter	1,190,871	July 11, 1916
Means for Preventing Attacks of Torpedoes and the like	K. O. Leon	1,195,042	Aug. 15, 1916
Ship's Torpedo Tube	B. Rosenbaum	1,195,739	Aug. 22, 1916
Apparatus for Launching Automobile Torpedoes	G. C. Davison	1,196,745	Aug. 29, 1916
Gyroscopic Steering Mechanism	F. M. Leavitt	1,197,134	Sept. 5, 1916
Mine Guards for Ships	W. H. Baker	1,200,068	Oct. 3, 1916
Mine or Torpedo Guard for Vessels	W. H. Baker	1,200,069	Oct. 3, 1916
Torpedo Guard	T. M. Daniels	1,202,810	Oct. 31, 1916
Gyroscopic Steering Mechanism	W. Dieter	1,204,852	Nov. 14, 1916
Mine Sweeper	M. W. Green	1,206,432	Nov. 28, 1916
Torpedo Construction	H. W. Shonnard	1,207,333	Dec. 5, 1916
Torpedo Tube	C. Laurenti	1,209,729	Dec. 26, 1916
Torpedo	A. Extrand	1,212,468	Jan. 16, 1917
Torpedo Catcher and Mine Destroyer	H. O'Grady	1,217,812	Feb. 27, 1917
Torpedo Guard for Ships	A. Carlson and F. A. Swanson	1,218,371	Mar. 6, 1917
Torpedo and Submarine Guard	J. A. Steinmetz	1,219,879	Mar. 20, 1917
Mine Catcher and Ship Protector	M. Feller	1,219,929	Mar. 20, 1917
Automatically Controlled Floating Mine	L. A. Bockstahler	1,221,964	Apr. 10, 1917
Torpedo Firing Control and Signal Apparatus for Torpedo Boats	E. G. Gallagher	1,222,198	Apr. 10, 1917
Aeromarine Torpedo	J. A. Steinmetz	1,223,212	Apr. 17, 1917
Torpedo Shield for Vessels	J. O. Travelstead	1,223,536	Apr. 24, 1917
Ship Protecting Shield	W. A. Shephard	1,223,627	Apr. 24, 1917
Submarine Vessel	A. J. Van Stockum	1,223,747	Apr. 24, 1917

GENERAL ELECTRIC REVIEW

A MONTHLY MAGAZINE FOR ENGINEERS

Manager, M. P. RICE
Editor, JOHN R. HEWETT
Associate Editor, B. M. EOFF
Assistant Editor, E. C. SANDERS

Subscription Rates: United States and Mexico, $2.00 per year; Canada, $2.25 per year; Foreign, $2.50 per year; payable in advance. Remit by post-office or express money orders, bank checks or drafts, made payable to the *General Electric Review*, Schenectady, N. Y.

Entered as second-class matter, March 26, 1912, at the post office at Schenectady, N. Y., under the Act of March, 1879.

VOL. XX., NO. 9

SEPTEMBER, 1917

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Gas-Producer Plant and Turbine Generating Station of the Fushun Colliery, South Manchuria Railway
(See page 705)

GENERAL ELECTRIC REVIEW

THE HEADLIGHT PROBLEM

The headlight question has been one of considerable interest for some time; recently it has come to the front owing to special legislation. The rapid growth of the trouble has obviously been due to the increase in the density of traffic, the development of powerful light sources, and the consequent higher running speeds.

What impressions are gained from a broad survey of the existing situation?

In the main, we are struck by the frequency with which complete ignorance of the technical facts is to be found among those concerned, both in and out of the automobile trade. Two considerations justify this assertion; namely, the conspicuous maladjustment or lack of adjustment among the headlights to be seen any evening on any suburban road, and the enormous sales of certain devices possessing no merit beyond saleability.

It is true that in some matters of detail, headlight questions are not adapted for ready apprehension by the layman, even the engineer layman. At the same time, the generalities are extremely easy to grasp and verifiable by experiments which call for no special facilities.

In the first place it would hardly seem necessary to state that no device can increase the light emission from a headlight, yet advertisements have appeared in which the claim is made. Secondly, there is the common illusion that glare is an adventitious feature of the illuminators used, which might be removed entirely without drawback, just as one can filter water.

Unfortunately, this is entirely untrue; in fact, we can safely say that under the practical limitations which occur glare is an inseparable attribute of a really useful degree of illumination. Thus the illumination falling on another traveler's face, if it is intense enough to facilitate recognition, will certainly lead to glare. With this premise it is evident that the problem is purely one of distribution with regard to two opposed requirements, viz., maximum comfort and safety for the man behind the light, and maximum comfort and safety for the man facing the light. At the one extreme we have the user completely satisfied, but everyone who meets him is likely to encounter glare; at the other, extreme glare is eliminated under all possible road conditions, but the user of the light is wretchedly served. It is easily possible to contrive a means such that glare will occur in relatively rare road circumstances, and yet the user will have reasonably good driving light.

Appreciation of the fact that all solutions must be of the nature of a compromise disposes of the plea that it is unsatisfactory to see only the wheels of vehicles and the legs of animals.

The article in this issue by Dr. H. P. Gage explains and illustrates these matters with unusual clearness. Later we hope to see a popular explanation of the means available for obtaining such results as are here discussed.

In conclusion, we would anticipate a possible objection that compromise is not absolutely essential; that, in fact, by proper use of dimmers, tilting devices, or double equipment controlled by the driver, complete satisfaction will result for all parties concerned.

A community is conceivable in which the implied virtue might be found; unfortunately (or should we say fortunately?) we have yet to encounter such a community.

METHODS FOR MORE EFFICIENTLY UTILIZING OUR FUEL RESOURCES

PART II

UTILIZATION OF WASTE AND UNDEVELOPED FUELS IN PULVERIZED FORM

By V. Z. Caracristi

Vice President, Locomotive Pulverized Fuel Company

The cheapness of high-grade fuels in this country has, in the past, resulted in almost exclusive dependence upon them. In parts of the country at a distance from the mines, however, the transportation charges have far exceeded the original cost of the fuel. Now that the facilities for the production of high-grade fuels have been overtaxed, with consequent increase in the price of these fuels, other sources of supply should be developed especially in parts of the country where the utilization of local resources of low-grade fuels would reduce the transportation charges. The lack of development work on methods of satisfactorily utilizing these fuels is largely responsible for their neglect, as well as for the neglect of low-grade fuels that might be produced as by-products from existing coal mines. The use of fuel in pulverized form offers a basis for further development work in this connection. The author reviews the advantages of pulverized fuel for generating steam, and outlines the basis for comparing the cost of this method with the methods more commonly used. Also, the problems incident to its application to boiler furnaces, and to metallurgical and industrial work.—Editor.

The present period of commercial and industrial activity in the United States and Canada, in combination with the use of liquid fuels for automobiles and marine purposes, has accentuated the inadequacy of our commercially developed fuel supply and has directed specific attention to the fact that the known sources of fuel are being rapidly depleted.

In addition to the developed sources of high-grade bituminous and anthracite coals, there is available a large amount of low-grade fuel. An accurate figure as to the amount of this fuel is difficult to obtain, but based on the area in which fuel is found, the supply, unquestionably, largely exceeds the supply of fuel now being commercially utilized.

This fuel is divided into two divisions, i.e., lignites and peats, and coke breese and graphitic coal, such as is found in the New England States and in the Canadian Northwest; and in addition to this undeveloped source of fuel, modern methods of mining, together with the necessity for taking out the thinner veins, have resulted in an increase of mine waste which is not utilized but which is rich in fuel value.

The reasons underlying and accountable for the lack of development and utilization of this low-grade fuel can be summarized as follows:

1st. The cheapness with which the high grade fuels could, in the past, be mined and transported to the market.

2nd. Lack of development work which is required in order to utilize the full thermal efficiencies of such fuel.

Use of Low-grade Fuel for Steam Generating Purposes

Whereas a great deal of work has been accomplished in power generating stations in the direction of increasing the thermal efficiencies of the higher grade fuels, at the same time much more remains to be done in this direction, particularly in the direction of utilizing the full value of the fuel at high rates of combustion. When the fact is taken into consideration that high rates of combustion are, in large power plants particularly, of extreme economic importance, the capital investment being reduced in direct proportion to the rates of burning, nearly all of the accepted types of boilers are way beyond the capacity of the furnace in their ability to utilize the heat generated in the furnace, and particularly when the boiler equipment is supplemented by economizers or other means of utilizing the heat lost through high waste gas temperatures. Although owing to the small specific heat of the gases, in combination with the loss of efficiencies brought about at low temperatures in the transmission of such heat to the water in the boiler tubes, the high stack temperature is not as great an econcmic loss as is popularly supposed.

The development work done in combustion through the use of stokers, in combination with under-grate blowers and retorts, has about exhausted the possibilities in this direction, and a radical departure from the existing practice is necessary in order to utilize to the fullest possible extent the thermal energy of fuel.

The use of fuel in pulverized form offers a basis for further development work in this connection.

The fact that fuels having relatively high volatile contents, when dried and pulverized, are so readily combustible, has caused a great many experimental developments in this direction to be failures, particularly when efforts were made to maintain a rate of combustion in excess of that normally obtained through the use of stoker equipment having under-grate blast. It has, however, been demonstrated in service that it is possible to burn to CO_2 better than 98 per cent of the combustible matter with an excess of air supply of less than 10 per cent, without any deductions for combustible in the ash, this being irrespective of the volatile or ash content of the fuel or the analysis of such ash. This result is being obtained at a rate of combustion equivalent to 175 pounds of coal per square foot of grate area per hour, and without the necessity of increasing the combustion space volume by high boiler setting; the CO_2 contents of the escaping gases under these extreme overload conditions being very close to the theoretic, and the CO content of the escaping gases being nil.

The use of pulverized fuel in stationary boiler plants when the installation is of sufficient size to absorb a reasonable amount of increased capital account expenditures, is justified for the following reasons:

1. Ability to force the boilers, without loss of combustion efficiency, to a rating which will develop a horse power for each four or less square feet of heating surface.
2. Greater heating value per cubic foot of furnace volume, eliminating the necessity for raising the boilers in order to secure overload capacity.

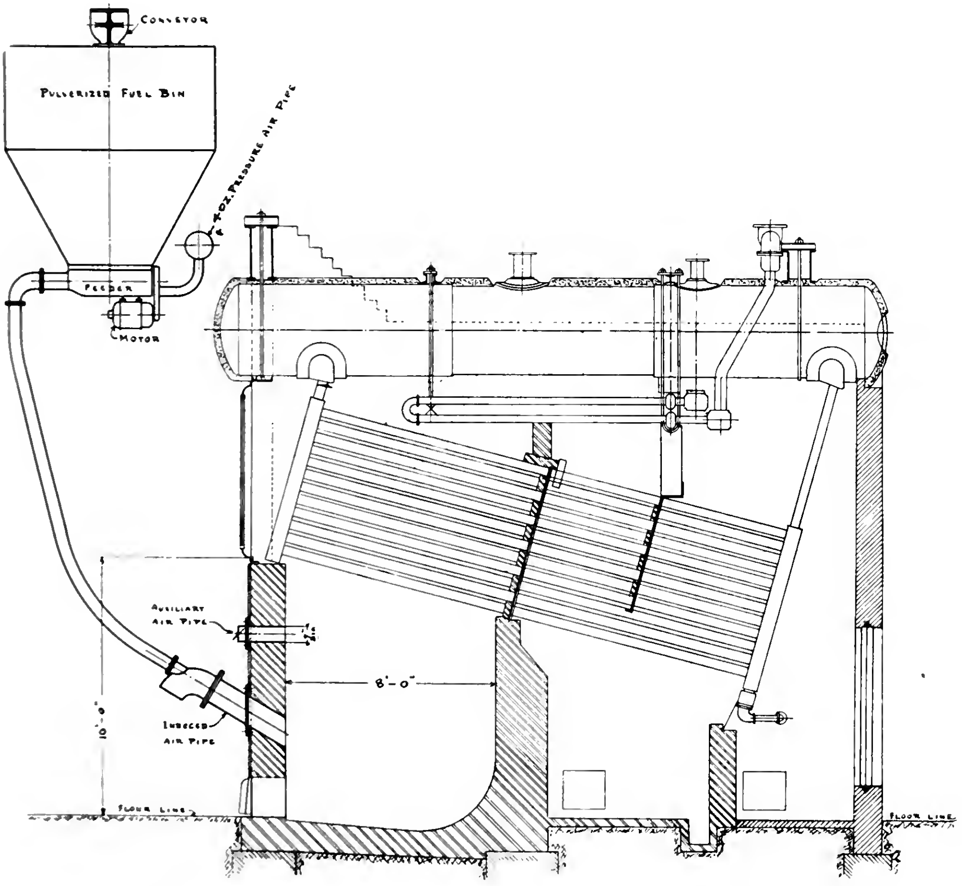

Fig. 1. Application of pulverized fuel to Babcock & Wilcox type of boiler

3. Reduction of the initial capital investment in the boiler plant on account of the reduction in the amount of heating surface in the boilers necessary to carry a given load under operating conditions.
4. Ability to maintain full steam pressure with low-grade fuels under extreme overload conditions.
5. Ability to utilize from 96 to 99 per cent of the heating value of the combustible, irrespective of the ash content or analysis.
6. Elimination of grates and mechanical equipment for stoking and the maintenance incident thereto.
7. Elimination of draft blowers for the purpose of securing overload capacity.
8. Elimination of operating difficulties brought about by the clinkering of coal on grates and the resultant loss in boiler capacity during periods of cleaning fires.
9. Ability to quickly take on heavy overload and to cut out the fuel feed when the necessity for such overload has ceased. The cutting out of the fuel feed in a pulverized fuel installation instantly stops combustion and the use of fuel, whereas in a grate-fired installation the amount of coal remaining on the grates is of necessity lost.
10. Elimination of the necessity for keeping banked fires in order to take care of irregular peak loads. With the use of pulverized fuel steam from cold water can be raised to working pressure as quickly as from a banked fire.
11. Elimination of smoke from the stack and the consequent freedom from liability under legislative requirements as to the smoke nuisance.
12. Reduction in the size of the buildings necessary to hold the boiler equipment, together with a reduction in the cost of the steam and water piping in the boiler room.

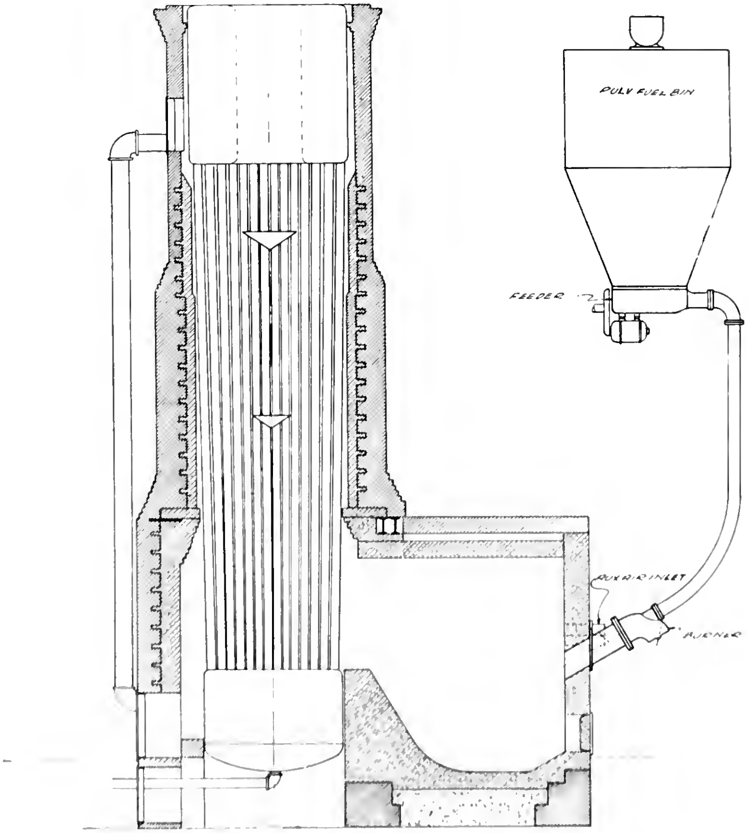

Fig. 2. Application of pulverized fuel Cahall boiler

13. Material reduction in the height of the stack, this reduction in height being brought about by the fact that all of the air admitted to the firebox passes direct into the combustion zone, without the necessity of passing through a fuel bed, permitting the boiler to be operated under an overload with less vacuum.
14. Reduction in the cost of operation, brought about by the fact that the feeding of pulverized coal to the firebox requires practically no attention.
15. Reduction in the cost of handling ashes, brought about by the greatly reduced volume.

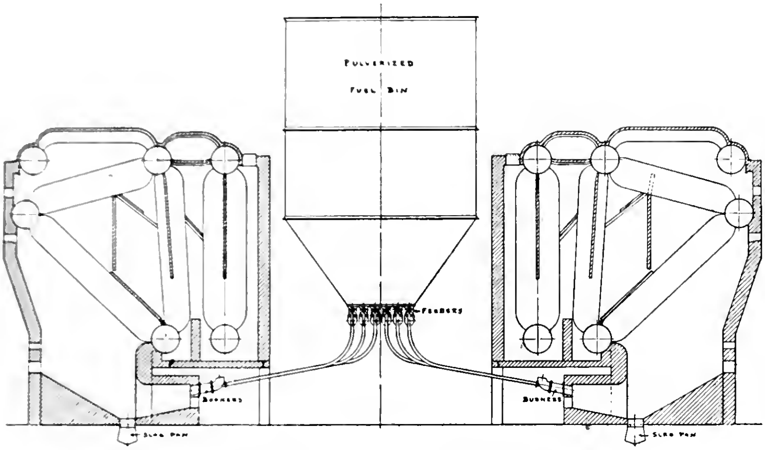

Fig. 3. Application of pulverized fuel Badenhausen boiler

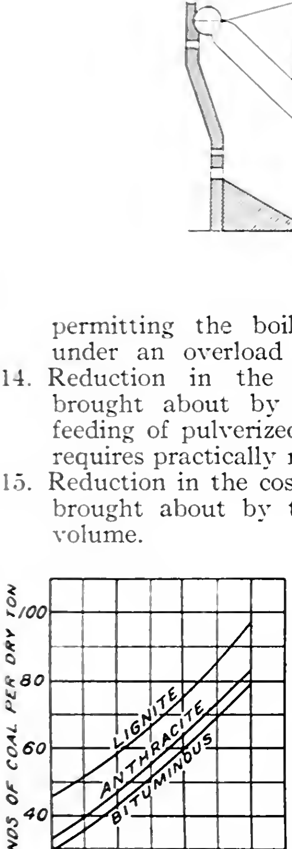

Fig. 4. Fuel required for drying

As an offset to the above advantages may be set up the cost of preparing the fuel for burning in pulverized form.

The expense of properly preparing the fuel may be divided into four divisions:

1st. The expense of crushing the coal, freeing the coal from stray iron, and *elevating the same to bins,* preparatory to pulverizing.

In so far as this equipment is concerned it is the same as would be required in hand or stoker fired installations.

2nd. The cost of drying the coal. With equipment which is commercial the coal can be freed from moisture at a power and fuel expense as shown by the diagrammatic charts, Figs. 5 and 6, from which it will be noted that the power and fuel required are greater with lignite than with anthracite or bituminous coal, bituminous coal being more easily dried than either of the other fuels.

3rd. The power required to pulverize. Although accurate figures are not available, the power required to pulverize coal to a fineness necessary for combustion in suspension, with commercial equipment as manufactured at the present time, is from 8 to 9 kilowatt hours per ton for bituminous coal and lignite, and from 15 to 17 kilowatt hours per ton of coal for anthracite or graphitic coals and coke breese.

4th. The maintenance of equipment necessary to prepare fuel. The maintenance on the equipment for the preparation of fuel will be approximately, using present commercial equipment, from 2 to 3 cents per ton for bituminous and lignite coals, and from 4 to 5 cents per ton for anthracite and coke breese.

The cost of preparing and pulverizing, however, should not be considered as an operating charge. This cost is directly chargeable against the cost of fuel, and in determining the savings which can be effected by means of burning pulverized fuel in suspension, this cost should be added to the cost of the fuel on a B.t.u. basis arrived at. When making a comparison of the cost of fuel on a B.t.u. basis in terms of evaporating results, when burned on grates and in pulverized form, it is conservative to figure that the combustion results will be from 20 to 30 percent better with pulverized fuel. This increase in combustion results will be sufficient to more than offset the cost of pulverizing, leaving the difference in saving in cost per B.t.u. due to the less price for the lower grade or otherwise unusable fuel, as a net saving.

The process of burning pulverized fuel differs from the process of burning gases arising from coal burned on grates or the burning of fuel oil, in the fact that the temperature of the ash in suspension, when burning pulverized fuel, becomes great enough to make the process of combustion self-sustaining, and reducing to a minimum the necessity for heat radiating or regenerating refractory surfaces when the velocity of the flame through the combustion space is not too great.

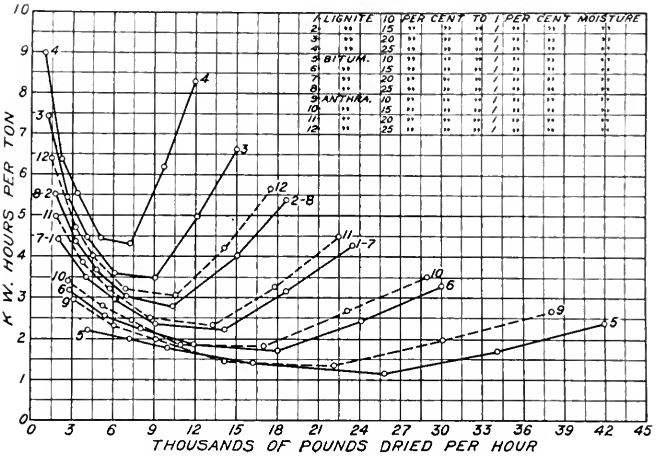

Fig. 5. Power required for rotating the dryer

There is a considerable field for the development of equipment necessary for the drying and pulverizing of fuel, but under the present commercial conditions the cost of preparing fuel is not prohibitive, even when considering the use of low-grade fuels having a high ash and low B.t.u. content.

When burning oil or pulverized fuel in suspension and forcing the boilers to a reasonable overload capacity the maintenance of the brick work is generally increased. The deterioration of the brick work, however, under systems of burning pulverized fuel which have been used in the past was brought about largely by the impingement and blowpipe and scouring action of the flame directly against the refractory walls, this being due to the furnace brick work design and arrangement and to the use of a low pressure air supply for combustion. However, when the necessary air for combustion is introduced into the firebox the direction of the flame is toward the openings and the firebrick has to stand the radiation effect of the heat only, and is relieved of the scouring action above mentioned.

In the selection of equipment for the burning of pulverized fuel under boilers it is essential that feeders be furnished which will have a wide range of capacity under absolute control and be of such a design that they will deliver from 3000 to 5000 pounds of pulverized fuel per hour; and that the pulverized fuel handled by the feeder will be thoroughly intermingled with the air used as a conveying medium. Any irregularity or lumpy contents of the feed will result in irregular combustion and the formation of coke in the firebox. It is also essential that the velocity of the fuel entering the firebox be less than the velocity of the combustion air surrounding this fuel inlet.

Experience has demonstrated that it is practicable to burn, within a very limited space, 5000 pounds of coal per hour fed by one burner, the fuel being converted into gases within the distance of less than 10 feet, provided the incoming mixture is uniformly distributed throughout the cross section area of the delivery pipe, so that a refractory wall located a distance greater than 10 feet from the fuel inlet will be free from any impinging or cutting action of the flame.

An item of prime importance is to operate the firebox under a vacuum. This vacuum can be as low as 15/100 of an inch of water. It is also of importance that auxiliary air for combustion be induced into the firebox in or near the zone of maximum temperature.

Burning pulverized fuel at high rates of combustion and in large volume tends to form a layer of CO_2, preventing the access of oxygen to the unconsumed core of the flame, and unless this core is broken up by cross currents it will pass into the cold area surrounding the boiler tubes and combustion will not be completed.

The matter of combustion of pulverized fuel within a limited space of firebox is controlled by an element of time, and the slower the passage of gases through the firebox the more efficient the combustion results.

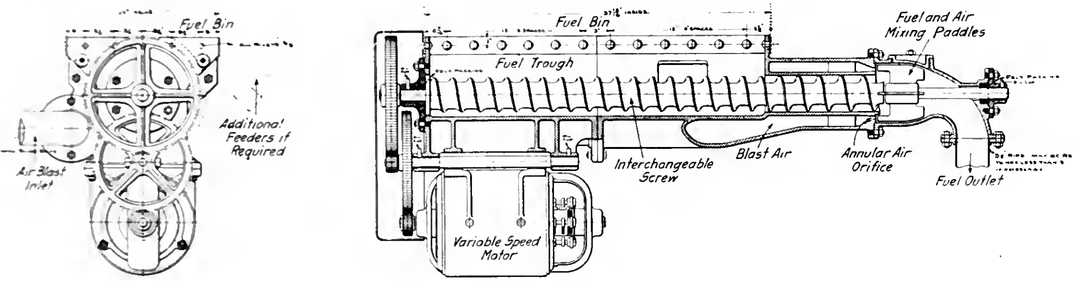

Fig. 6. Pulverized fuel feeder

The items which affect the combustion of pulverized fuel are:

1. Volatile contents, affecting the temperature of the flash point.
2. The degree of fineness to which the fuel is pulverized.
3. The amount of moisture in the fuel.

Low volatile contents can be offset by increasing the fineness of the fuel.

The amount of moisture in the fuel is of only minor importance in so far as combustion is concerned. The reduction of moisture affects the thermal results only slightly, and the combustion practically not at all; from which fact it can be noted that the higher the volatile content of the fuel the less is the expense necessary for pulverizing.

The formation of honeycomb and clinker on the heat-absorbing surfaces is brought about largely by the iron content in the ash, and can be prevented by a through oxidation of such iron in the combustion zone.

The formation of slag in general will be in direct ratio with the amount of incandescent surface with which the ash in suspension has an opportunity of coming into contact. The ash in suspension which does not come into contact with incandescent surfaces will readily pass out of the stack in extremely minute particles in the form of a very light haze, a small proportion remaining in any eddies which the boiler setting may cause in the passage of the gases to the stack, and the use of horizontal baffles should be avoided.

The Use of Pulverized Fuel in Metallurgical and Industrial Work

The combustion conditions are different in this class of work, owing to the fact that it is necessary to operate the furnace under a pressure so that the opening of the doors, necessary for the removal of the material being heated, will not cause an inrush of cold air, with consequent cooling effect on the product. This necessitates the use of a low pressure air supply of sufficient volume to support combustion, and in order to utilize the full area of the furnace it is necessary, in order to get the best economic results, to complete the combustion within the shortest possible time and to have the gases travel through the furnace space at a very low rate of speed. No serious difficulty has been met in the substitution of the use of pulverized fuel for fuel oil in furnaces of large volume where the feeders utilized were such as to deliver the fuel at a uniform rate, without a lumpy condition at the delivery point. Serious difficulties have had to be overcome in order to apply its use to furnaces of small volume.

It is necessary in furnaces of small volume to reduce the velocity of the incoming fuel to the minimum. This velocity should be less than the velocity of the low pressure air used for combustion, which should have less than ¼ in. of water pressure and which should be thoroughly intermingled with the fuel before combustion is commenced. If this intermingling is attempted where the temperature is sufficient to draw off the volatile constituents from the coal and form coke, serious difficulties in the combustion and ultimate entire stoppage of the furnace operation will take place.

Furnaces having a working chamber of 9 in. by 33 in., and a roof averaging 12 in. in height, served by a combustion space 18 in. square by 22 in. in height are being used, and the output of such furnaces is equivalent to the best oil practice.

It has been found possible to operate pulverized fuel furnaces so as to give an oxidizing or reducing atmosphere and to secure very close temperature regulation as low as 400 degrees Centigrade, such furnaces being used in chemical work.

The relative cost of fuel under these conditions, with an allowance of 35 cents per ton for pulverizing and a cost of $3.00 per ton for the coal, is comparable with fuel oil at 1½ cents per gallon.

For metallurgical and industrial purposes it is desirable to have a volatile content in the coal in excess of 22 per cent, and to pulverize this coal to a fineness so that 75 per cent of the total will pass through a 200-mesh screen, and that the product will be relatively free from particles of coal of a coarseness to exceed an 80-mesh screen.

It is also desirable that the coal be dried so that the moisture content of the 22 per cent volatile coal be less than 1 per cent. The moisture content of coals from 36 to 38 per cent volatile may be as high as 2½ to 3 per cent.

In the design of pulverized fuel furnaces it is essential that the flow of the gases through the furnace be impeded as little as possible, as each impediment to the travel of the gases will result in an accumulation of slag, which is formed by the impingement of the ash in suspension with an incandescent surface, and the introduction of any surfaces in a direction such as to cause this impingement is to be avoided.

Provision should be made in the furnace for conveying the products of combustion and ash held in suspension out of the building. This can be taken care of by a proper design of hood located over the working doors, these hoods at the same time forming a shield for the protection of the operators of the furnace.

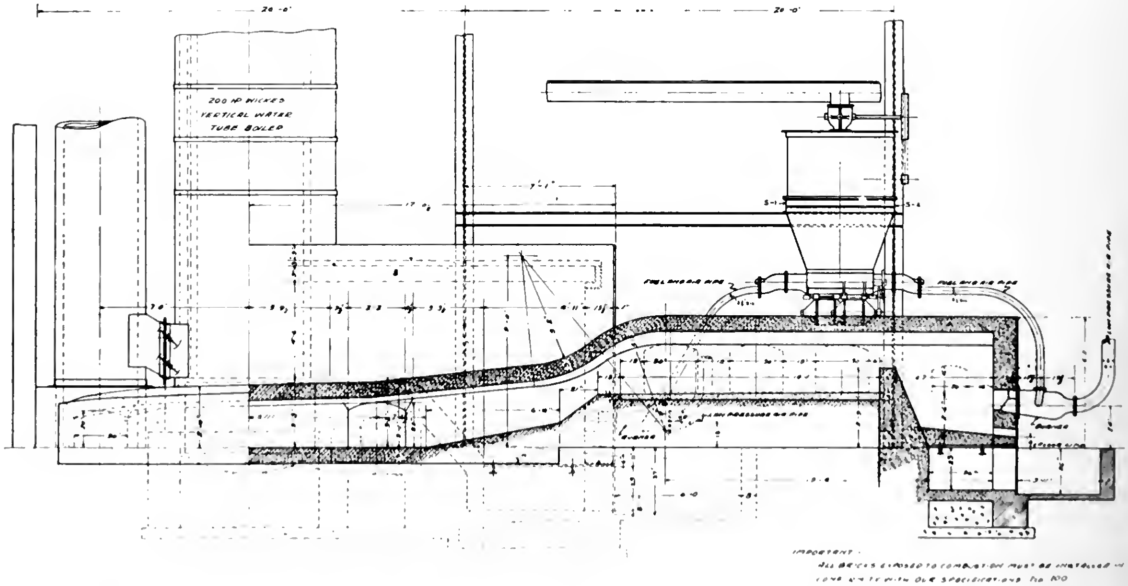

Fig. 7. Application of pulverized fuel to a forging furnace with waste heat boiler. Boiler being equipped with auxiliary furnace for operation during periods when furnace is not in service

METHODS FOR MORE EFFICIENTLY UTILIZING OUR FUEL RESOURCES

Part III

THE FUSHUN COLLIERY AND POWER PLANTS OF THE SOUTH MANCHURIA RAILWAY

By S. Nakaya
Chief Engineer, Fushun Colliery
and
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Foreign Department, General Electric Company

The authors describe a very interesting power plant where the coal is burned in by-product gas producers in order to recover the large nitrogen content in the form of sulphate of ammonia—a valuable fertilizer. A unique feature is the method of obtaining a supplementary supply of low pressure steam from turbines, for cooling the producer fires and generating ammonia vapor. This plant supplies electric power for lighting the colliery and for mining purposes. Power is also supplied to a 1200-volt direct-current railway connecting the colliery with the main line, and an electrochemical plant. The methods of mining the coal are described as well as the electrical equipment.—Editor.

The South Manchuria Railway is a standard gauge steam road located in Manchuria, Fig. 1; and it extends from the seaports of Dalney and Port Arthur to Chang-chun where it connects with the Chinese Eastern Railway, which in turn connects with the trans-Siberian Railway. A branch extends to the port of Antung, connecting with the Korean Railway. A further branch extends to the Fushun Colliery, passing through the city of Mukden where is located a modern lighting plant equipped with a Curtis turbine.

The coal mines in the Fushun district were first worked by the Koreans 600 years ago, the coal being used by them in baking earthenware. On the occupation by the Chinese, mining was entirely suspended. During the Russo-Japanese war the mines were worked on a small scale by the Russians, but not until 1907, when the property was transferred to the South Manchuria Railway, was mining undertaken on a large scale.

Fig. 1. Map showing location of South Manchuria Railway

The coal field covers about 19 square miles and coal is mined from the Chien-chin-tzai, Yang-pai-pu, and Lao-hu-tai pits, from the Oyama and Togo shafts, and open-cut mining is carried on at Ku-chen-tzu. A new slope has also been recently opened at Wau-tah-oh.

The main coal bearing district consists of shale with a thick coal seam. The shale overlying the coal is very thick and partly bituminous, being about 2000 ft. measured by out-crops. The seam varies in thickness from 78 to 280 ft.; and the coal obtained is bituminous caking of a very uniform quality and is especially suited for gas making and steam raising. The analysis of an average sample follows:

Moisture	7.00 per cent
Volatile matter	40.00 per cent
Fixed carbon	48.00 per cent
Ash	4.00 per cent
Sulphur	0.80 per cent
Specific gravity	1.28 per cent
Heating value per lb. of coal	12,400 B.t.u.

The Power Plants

There are at present two power stations which supply three-phase 60-cycle 2200-volt current to all the pits, electric railway, electric lighting both on the surface and underground, and the electro-chemical industry.

Plant No. 1 is a steam-power plant, coal being burned in the boilers for raising steam. This station has a capacity of 4500 kw. in high-pressure condensing turbines and is equipped with Babcock and Wilcox boilers, mechanical stokers, and superheaters. The station auxiliaries are either motor- or turbine-driven.

Plant No. 2 with a present capacity of 3000 kw. in mixed-pressure turbines is connected in parallel with station No. 1 and runs continuously at full load, while the latter takes care of the peaks. The boiler equipment consists of eight Babcock and Wilcox boilers designed to burn Mond producer gas. Arrangements are also made so that four units may be coal fired, while one is also designed for tar firing.

Fushun coal has a very high percentage of nitrogen, the nitrogen content averaging 1.8 to 2 per cent. This quality of coal offered an inducement for the installation of a gas plant equipped to recover ammonia. Accordingly, in 1914 the company installed a plant consisting of ten Mond single-shell type gas producers with a capacity of 240 tons of coal per day, and as a by-product obtain 95 lbs. of ammonium sulphate per ton of coal gasified. The operation of the producers is as follows:

The air required for gas generation is first blown into an air saturator by engine-driven blowers. Here the air is heated and saturated by hot water conducted from the coolers. On leaving the saturator, the moistened air is mixed with low-pressure steam from the turbines and then collected in the air main from which it finally enters the producers through the superheaters where it is further heated by hot gases.

Gas from the superheaters is conducted to the gas collecting main, then passed through mechanical washers where it is cleaned of dust. It subsequently passes into the ammonia absorbers in which it comes into contact with a spray of acid which recovers the ammonia in the form of ammonium sulphate. Thus freed of dust and ammonia, the gas is collected through two coolers into a gas holder, and there held ready to be served as fuel to the boilers by centrifugal exhausters.

This application of gas-producer plant, gas-fired steam boilers, and mixed-pressure turbines for supplying the necessary low-pressure steam to the producers, is probably the first of its kind ever tried; and three years experience has proved the operation to be very economical.

The heavy demand for ammonium sulphate and the rapid progress in developing the mines have necessitated the extension of the plant. There are now being supplied two banks of eleven producer sets and three 3000-kw., 0.8 p-f., three-phase, 60-cycle, 2200-volt Curtis turbines running at 3600 r.p.m. Two of these units will operate condensing and one non-condensing, the exhaust steam being used by the producers. The two stations operating together will have an ultimate capacity of 16,500 kw. It is expected that a peak load of 9000 kw. (65 per cent load-factor) will be required for mining, railway, and lighting, while the surplus power will be sold to an electro-chemical company manufacturing ammonium sulphate by the cyanamide process. The entire station load-factor is therefore expected to be 100 per cent.

The frontispiece of this issue of the REVIEW shows the generating and boiler buildings, the gas-producer plant, and the water-cooling basin of Plant No. 2.

The Mines

The mines are operated principally by the sand flushing or hydraulic storage system. Steam shovels are employed for sand excavating and the flushing material is transported by a 1200-volt direct-current trolley railway.

The open-cut coal mining systen at the Ku-chen-tzu mine is unique. This location comprises about 50 acres of nearly flat farm land underlying which coal is found at a depth of from 30 to 250 ft.; it is estimated that this district contains not less than 6,000,000 tons. At the present time soils and shales have been cleared from a space of 8 acres, and the coal is worked by cutting steps downward in the form of a large basin. There are now nine steps each 12 ft. high and the coal is removed by hand shoveling. As work progresses steam shovels will be introduced and the steps reduced to three with a height of 60 ft. each. Work proceeds continuously and the working surfaces are lighted at night by hundreds of incandescent lights. These will be superseded shortly by searchlight projectors located on the circumference of the basin.

The mine is equipped with seven motor-driven turbine pumps and two motor-driven haulage machines. Excavation of the top-soil and shale is done by means of steam shovels and the waste material used for sand flushing in the existing shafts and pits. The appearance of the open-cut mine is shown in Figs. 1, 2, 3 and 4. One-half ton tubs are used in removing the coal. After the addition of two 300-h.p. haulage machines and two motor-driven pumps, the output of this mine is expected to reach 2000 tons per day.

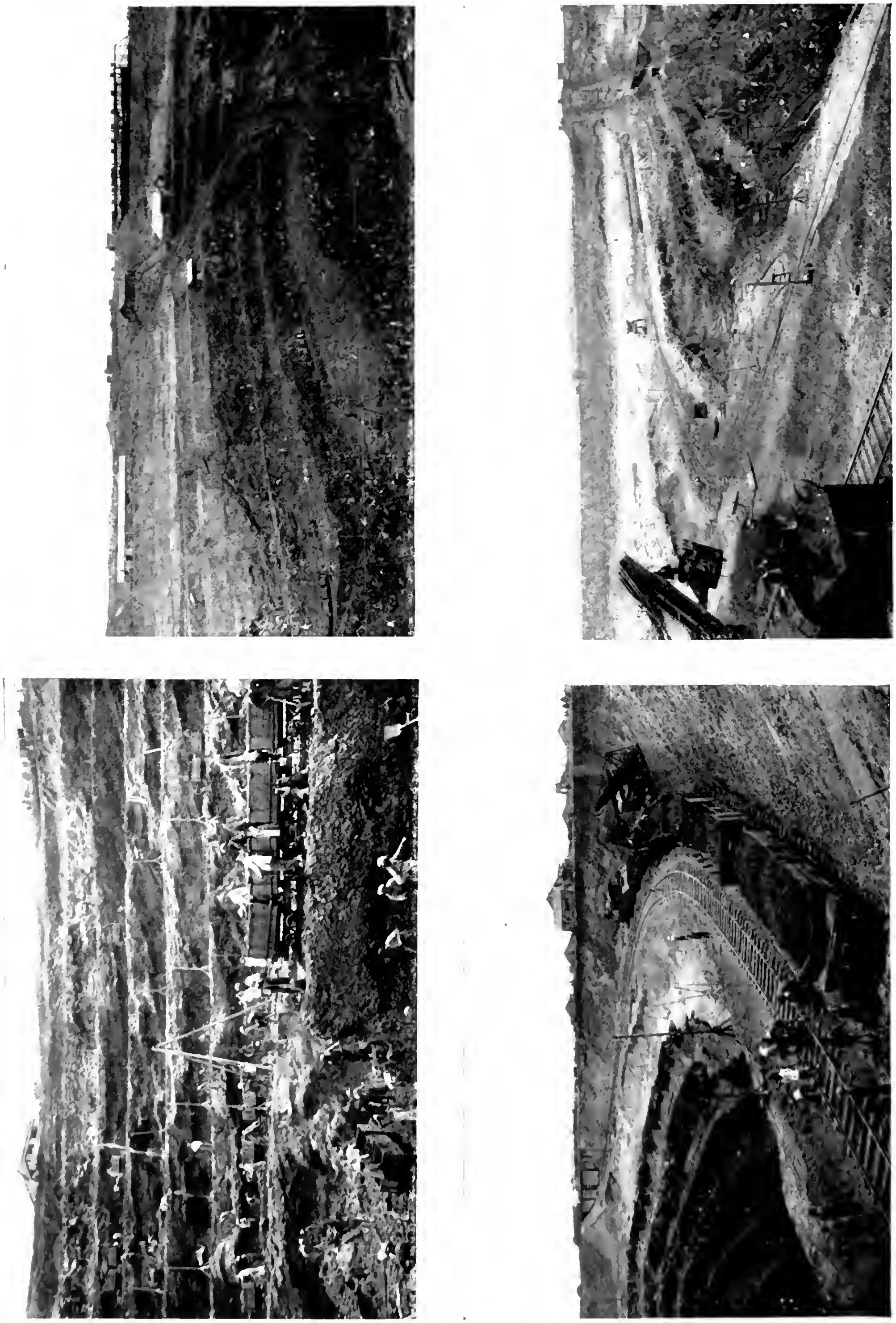
The arrangement at the Oyama and Togo pits is similar, each being provided with two brick-lined shafts about 1234 ft. deep. The inside diameter for the down-cast is 21 ft. and for the up-cast is 18 ft. Single-deck cages, having a capacity of four tubs and two tubs respectively, are operated at present by means of Corliss winding engines. The tubs have a capacity of 20.3 cu. ft. and are operated on 24-in. gauge tracks. Along the inclines to the shafts the tubs are moved by single-haulage gear manufactured in the colliery's own workshops and driven by three-phase motors having special enclosing covers for operating in the explosive atmosphere. Each pit is equipped with eight haulage machines of 5- to 150-h.p. capacity. On equipments larger than 50 h.p. the regenerative system is adopted, the motors operating as synchronous generators and returning power to the line when lowering the empty tubs to the lower workings. This is claimed to be the first extensive use of this system in mine haulage.

Fig. 2. Locomotive Shed, 45-ton Locomotive and 28-ton Motor Passenger Car

The screening plant is electrically operated and has a capacity of 510 tons of coal per hour. Coal from the screens drop on conveyors, and the slate and dirt is removed by coolies. At the end of the conveyors the screened and dressed coal is loaded into railroad cars by deflecting loading jibs.

Fig. 3. Oyama Shaft and Screening Plant

Each mine is provided with engine-driven ventilators, and a pumping station located



Views of the Ku-chen-tzu Mine. The Steps are 12 ft. high near the bottom of the shaft is equipped with high-lift turbine pumps driven by high-speed three-phase induction motors. Mine operations are to be extended by the addition of two 900-h.p., two 550-h.p., and five 460-h.p. induction motors. The two larger sizes run at 1200 r.p.m. while the small units run at 1800 r.p.m. The motors are to be direct connected to turbine pumps.

The Colliery Railway

The colliery railway with a total length of 43 miles is the first 1200-volt direct-current system in the Far East and has been in successful operation since 1914. The overhead construction is of the 5-point catenary suspension type with a pole spacing of 150 ft., angle-iron lattice poles being used. The trolley wire is of No. 0000 B.&S. grooved copper. The automatic block signal system is employed.

The rolling stock consists of a total of eight electric locomotives, three of which are 45-ton units, each equipped with four 100-h.p. motors and capable of handling 400 tons on a level tangent track.

For passenger service, a number of 36-ton cars are included, each equipped with Type M control and air brakes.

The traffic has become so great that an extension is contemplated, consisting of four 25-ton and four 50-ton locomotives and additional passenger cars. Fig. 2 shows the locomotive shed, a 45-ton locomotive and a passenger car. Fig. 3 is a view of the Oyama shaft and screening plant, with a 45-ton locomotive and a passenger car.

Power for the railway is obtained from three 400-kw. synchronous motor-generator sets converting three-phase 60-cycle current at 2200 volts to 1200 volts direct current. These sets are located in power station No. 2 and an extension of one 750-kw. set is to be installed.

Electric light is provided by 17,000 lamps, consuming nearly 450 kw. Three thousand of these are located in the various pits and the others are used for office, workshop, hospital and town lighting.

The plant is provided with a machine shop, blacksmith shop, foundry, and carpenter shop, in which a great deal of the apparatus used is manufactured and repaired.

A rescue station and laboratory provides means for all necessary rescue work and chemical analyses. The heat for the engineers', clerks', and foremen's quarters, offices, school, library, etc., is furnished by a central heating station.

The plant is also provided with a brick factory having a capacity of 20,000 bricks per day. A gas works supplies gas to all houses for cooking purposes; and a sulphuric acid plant produces 48 tons of chamber acid per day. The acid plant's output is to be doubled within the next year. The acid is employed in the manufacture of ammonium sulphate by the Mond recovery plant, as well as in the electro-chemical industry mentioned.

Coal from this district is shipped throughout the Far East, the total sales of the company being 2,270,000 lbs. in 1913, and the output has been increasing steadily since that date.

MAKING AN ELECTRIC LOCOMOTIVE ENGINEER OUT OF A STEAM LOCOMOTIVE ENGINEER

By W. F. Coors

Railway and Traction Engineering Department, General Electric Company

The human side of a big project is frequently quite as interesting as the technical aspect, and appeals have been received from time to time for information as to what the railroad man thinks of electrification. The author's narrative of his varied experience in the instruction of steam road engineers gives abundant testimony that the steam engineers are uniformly pleased with the electric locomotives now operating on the C. M. & St. P. Rwy.—Editor.

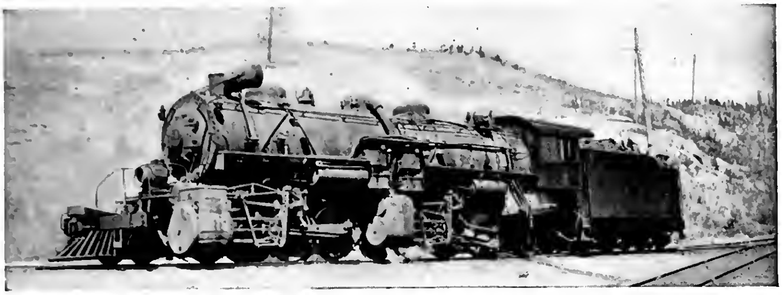
One of the important features of railway electrification is that of dealing with the men who are to run the electric locomotives, or "motors" as practical usage has it. This feature is often not considered until actual operation is to be started, which condition is largely necessary because little effective electrical instruction can be undertaken with practical steam engineers until the machines are actually available for demonstration. Moreover, it is rare that any two railway electrifications will use machines which are in any way identical in practical details; and instruction books, wiring diagrams, and photographs which may have been made for a previous installation will not apply to the new equipment. It is rather difficult to write an efficient instruction book on a new type of machine working under untried conditions, and such a work while it could be generalized at the start would be much more applicable in its details if deferred until its author had acquired considerable practical experience with the actual operating conditions to be met.

Scenic Profile of Electrified Portion of C. M. & St. P. Rwy.

Generally, the line work will first receive the close attention of the railway men and later the substations to a lesser degree. While these are being constructed the locomotive will be being built at the factory, so timed that the first few will just about be appearing in the field when power is ready to be put on the line. In the meantime the freight engine crews, through work-train line-construction service, will have become well acquainted with such details as come under their observation. They may also investigate the substations at occasional intervals when the opportunity presents itself; and by talking with the construction and line men they may gain the idea that electricity is some mysterious agent which will take them a lifetime to understand, and whose handling will require a deep technical knowledge of wire splicing, insulation, magnetic actions, and high-sounding terms. Up to this stage, the passenger crews will possibly be slower in acquiring such more or less confusing "knowledge." Their observations are more likely to be limited to the increasing difficulty of getting over the road with so many work trains out on the line and to the attendant increase in the number of train orders to be observed. There is also the possibility that a new block-signal system may have to be installed and that the pole line for the trolley will obscure the vision from many order boards and signal posts, thus adding to their difficulties.

During this stage of the work, there will probably be many roundhouse and switch-shanty discussions pro and con about the prospective change, and various theories put forth as to what it means to the men themselves. Such discussions are quite likely to be founded largely on hearsay gained from some "boomer shack" or brakeman who has worked on many roads; and the men successful in electric operation will later look back on these ideas with amusement and wonder how they ever came to be entertained at all.

Among the rumors which always get out on a new electrification is the one that the manufacturing company will have to furnish electrical engineers to run the motors and that the steam-locomotive men will all likely lose their jobs. This substitution would be manifestly impossible for many reasons, especially on an undertaking of considerable size requiring some 200 men and it would have no precedent anywhere in the past. An electrical engineer would have some little study to become familiar with a new electric locomotive and would require an extraordinary amount of experience in train rules and operation and air brake handling. These latter features, which are more important than any others, have for years been a part of the steam engineer's experience; consequently he will be more efficient with a few days' training on an electric locomotive than any purely electrical man would be in months.



Mallet type of steam locomotive replaced by electric locomotives on the electrified zone of the C., M. & St. P. Rwy.

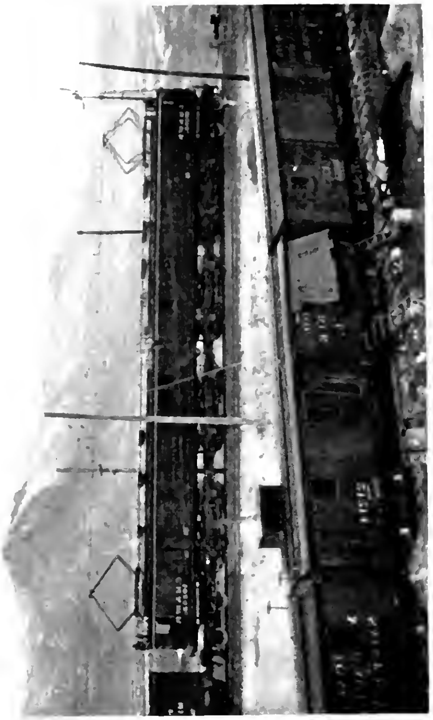
Another subject for discussion among the railroad men is the fact that the new motive power will haul so much greater tonnage per unit that the men well down on the engineers' seniority list will have to go back to firing, the decrease in the number of locomotives running requiring fewer engineers. This objection, while having some grounds, does not work out in practice to the full extent that the arithmetical figures on possible tonnage per train would indicate. Even on a large electrification, there will always be "caboose-hops" where a locomotive will have to run light from one terminal to another as occasioned by the direction of the main freight traffic, work trains, and light local traffic, usually steam. Moreover, on roads where the basis of pay is made on the tonnage rating of the motive power used, the men "firing" the heavy motors will possibly average more per month wages than when running the lighter steam engines; and the more satisfactory working conditions on the electric make up for the slight difference in wages for the heavy work involved in handling steam locomotives of the Mallet type.

Freight train without helper on two per cent grade at Donald (Continental Divide)

Changing motive power on passenger train on entering electrified section

Freight train ascending 1.6 per cent grade east of Butte

Freight train ascending Belt Mts. east of Summit



Regenerative braking down west slope of Rocky Mts.

The old steam railway men who run a motor will not consent gracefully to being called "motormen"—this sounds too much like street-car work; and the old steam firemen will not generally be termed "helpers" or "assistant engineers" even though perhaps they would not object to these terms. As an old "electrified" passenger engineer says, "The fire-boy fires the train-heating boilers and is not much help or assistance anyway. You electrical men are going too far with these 'helper' and 'assistant' names when applied to ordinary tallow-pot smoke-makers."


"Electrified" steam locomotive engineer


Electrical instructor

However, as soon as the electric locomotives are in operation all objection by the *engine* crews to heavy trains ceases, there being no difference in their work whether they have forty or one hundred cars in a train; but this objection is taken up by the *train* crews with increased vigor. The "car-captain's" or freight conductor's car records, termed "hard" or "soft" lists, get as large as a dictionary, and the work of setting out cars at stations and the mile walks from the rear to the head-end of the train total quite a little at the end of a day's work. To lessen such difficulties, various expedients are often lightly suggested, such as sky-rockets and smoke bombs to signal from the caboose or "crummie" to the engineer; a telephone system along the train with a portable attachment which can be plugged in on any car; a smooth run-way on top of the cars so that roller skates can be used by the train-men; and a smooth foot-path along the sides of the track so that at any stop the men could ride bicycles when making car inspections and in carrying train-orders up to the engineer.

Under steam operation methods where the locomotives may be changed every division of 110 miles, it is also customary to change the caboose as well. For this reason every freight conductor will have his own "private car," homely it is true but his very own, and will have it fitted up with the necessary culinary utensils and sleeping equipment according to his bachelor ideas. In fact, some of them get so that even when at home terminals they would rather be aboard the old "crummie" than at home tending to the garden or helping out in domestic roles.

But when the motors take hold of a train, they stay with it for at least two divisions and the respective crews make a "main-line change" at the intermediate division point. The train is not broken up and the caboose goes straight through; all the paraphernalia of the one crew being thrown off and that of its successor being put aboard. The running time over the old divisions may be shortened from twelve to eight hours, and so, everything considered, even the train crews may look favorably on the motors. Among the best boosters for electric operation may be found railroad men's wives, who somehow find their husbands' home time about doubled.

Many of the train operating men are skeptical about their chances of escape in case of a wreck when the trolley wire may get down on the ground or cars and electrocute the whole personel thereon, leaving the train to run wild. This condition looks easily impossible to the electrical engineer, but it is not easy to explain away from the minds of men who have never had any experience with electricity. From this standpoint alone, the old operatives are preferable to men who have had a little experience with low-voltage circuits, just enough to be fool-hardy with higher voltage. The steam men know nothing about "juice," they admit it and are ready to go to extreme precautions before undertaking the handling of any electric apparatus whether energized or not.

It is significant that in a recent large electrification only a few serious accidents have occurred and that none of these have happened to the men operating the trains; the very men, in fact, who had never handled electric energy before and who perhaps have the major part of this work to do in actual operation. Pantographs have been wrecked and tangled in the overhead work, steam locomotives have caught and torn down the wire, snow slides have taken out long stretches of pole-line, and, in rare instances, the wire has broken and dragged on the roofs of the steel passenger cars, yet with all these troubles nothing more than a slight scare of the witnesses has occurred.

In one instance at the beginning of electric operation, when the passenger trains were still equipped with steam locomotives, a broken wire on a severe curve hung down and struck the train, throwing out fire at every contact. The engineer, following a life-time practice for all kinds of accidents, immediately stopped the train. The dining car came to rest under the broken place and amid the sputtering and flashing it is said that one of the colored waiters knelt down between the tables and prayed, "Oh, Lawd, make this coon a better niggah." However, no great damage was done and the engineer learned a new feature in electric operation for future practice, i.e., if a stop cannot be made before reaching wire trouble, to keep on running through until entirely clear of it.

In fact, it was a little difficult for the engineers to realize just how important the trolley wire and pantographs were, until they had an accident or two involving these equipments. In the early stage of their learning, they were intent on the operation of the locomotive only, and if they were headed by a careless switchman into a track which had no trolley wire, it was ten chances to one that they would take the signal and back right into it only to discover that they had a dead motor and couldn't get back to the wire again or the pantograph had been caught and smashed against the overhead span wires. However, with a little experience of this kind, it soon became second nature for the men to watch the trolley wire almost as much as the track. This, on electrified roads, will evidently require a slight change in the rendition of that old "Casey Jones" song wherein the "hog-eye" engineer is supposed "to keep his hand on the throttle and his eye on the track," to include the trolley work as well.

At present on this electrification, wire and pantograph trouble is almost eliminated excepting that which comes from shifting or settling track or change in the outer rail elevation on curves. The men have been instructed never to go on top of the locomotives or to open any covers over electrical apparatus in the locomotive with either of the pantograph current collectors up against the wire. Each locomotive is equipped with a long pole hook and dry rope which can be used to pull a pantograph out of a wire entanglement, and in rarely bad cases the power is cut off at the substations by request from a portable set attached to the despatcher's telephone circuit and the line grounded at the motor. Since there are two pantographs on each machine, it is comparatively easy to disconnect one which is damaged and to use the other one in operation. The trouble from this cause rarely occasions a delay of more than thirty minutes.

Another viewpoint, from the human comfort side, was that before the electric locomotives were put in operation and for some time afterward the men operating them thought they were extremely cold affairs in winter time. This was perfectly natural for men who had been accustomed to work with their knees up against a hot boiler head and with leaking steam all around. This complaint was easily overcome by placing a small electric heater in front of the engineer's operating position, and with the much drier working conditions many old chronic cases of rheumatism and winter sickness among the men have disappeared with consequent fewer lay-offs and winter vacation trips to warmer climates.

With this type of motor the engineer is located at the "front of things" and many of the men at first wondered what would be left of them in case of a head-on collision. For quite a while, one of them in pusher service persisted in using the rear-end operating cab for fear that the cars up ahead might smash through the head end of his motor. Several accidents, which with steam engines the men admit their chances would have been slim, have demonstrated that the electric locomotive cab construction and arrangement takes very good care of them in such emergencies. The unobstructed front view not only gives the men a chance for earlier warning and more time to apply air brakes at the prospect of a coming collision and so minimize its effect, but also they can take steps "to unload" themselves and get out of danger. There have been cases where these machines have run into landslides and rolled down embankments not injuring the men at all. The pantograph in such cases immediately leaves the wire and the machine is electrically dead. There are no steam pipes to burst, red-hot fire boxes with gas and smoke to overwhelm the men caught in the cab, nor tender with flying coal to crash up into the cab. With a steam engine, as one old timer said, "It's not the first smash I'm afraid of so much as the hell let loose afterward, especially if I get caught in the cab and can't get out."

The operating men on this electrification regard the whole arrangement as a success. The shorter working hours, the cleanliness of the surroundings at work, little on the locomotive requiring close attention, less danger involved, no anxiety as to whether they have enough coal or water to reach the next supply, increase in pay and confidence in the equipment through a thorough knowledge of its operating details, etc., has won many friends to the electric locomotives from the men who use them and who, it is admissible, could make or break the success of any type of motive power.

From this viewpoint, that the ultimate success of electric operation finally depended on the men themselves, the railway officials were especially lenient with them for all electrical detentions and every effort was made to give the best opportunity for becoming familiar with the motors at the start. The men were in turn very receptive of all instructions given them and were able to remember and willing to observe such instructions with very little repetition.

The first division was put under electric operation as soon as several motors arrived from the factory. Men were sent out by the manufacturer as instructors to ride with each and every new engineer when his turn came to go out on a motor until he should be sufficiently qualified to operate alone. These factory men were variously termed "experts," "instructors," "inspectors," and in some cases "slickers" by the facetious. They were called out by the regular call-boy who summoned the train crews to duty, and many an hour's "terminal-delay," which gives double-pay to the crew called if the train does not pull out of the terminal within an hour after it is supposed to, was occasioned by the call-boy who often forgot that a motor crew consisted of three men instead of the usual engineer and fireman. Lists of men who were "qualified" by the instructors were posted in all conspicuous places, and there was some friendly banter coming to the men who were a trifle slower than the average in "getting hep" to the new machines. It cannot be said that the younger men were exclusively able to qualify quicker than the older ones but such was generally true. However, from an instructor's point of view, when one of the older men did express his confidence in himself and showed sufficient progression, there was no need to worry about him later, while the boys who had lately been "set-up" from firing were likely enough to call for help over the dispatcher's telephone when out in the middle of their run. It always gave the older men a great deal of satisfaction to be able to help them out of some such minor difficulty if they met on the road.

Since the airbrakes were practically identical to those used in steam practice, this feature tended toward greater confidence in the engineer who almost invariably said to the instructor on the first run, "Well, you may have to start her up but I know how to stop if necessary."

One young engineer after successfully hauling a long train up to the summit of the worst grade on the road, said to the instructor, "Here, *you* take her down the grade. I've only been running as engineer for a short time and have never been down here before even on a steam engine." Here was something of a quandary. The instructor had never been down the grade but a few times himself and then had not handled a train and was in nowise anxious to figure in a runaway. But considering the great confidence given the factory men at the start by the Railway, it was imperative that something should be done to warrant it for the future. The train was safely brought down the hill, regenerative braking making it easy. Here, in the engineer's charge, the train was "made-up" to ninety cars with a dead mallet locomotive on the rear end. This was an ideal train for even an expert to handle and the engineer proved his right to be "set-up" by pulling into the terminal without a mishap. The next week he was qualified for running a motor.

On the succeeding three divisions, instruction work was much easier. The men would talk over the new machines among themselves and their various experiences with each particular feature, so that much instruction work could be briefly passed over. The Railway Company placed a caboose at the instructor's disposal at terminals for an instruction car, and the men after being out on the road were very willing to drop in for a few minutes to talk and become acquainted with the motor blue-print wiring diagrams and learn just what operation details were necessarily required. Later, instruction books were prepared and distributed to each engineer for home study, and to their credit it may be said that the books proved to be a valuable aid to the instructors who it seemed at first had tackled an endless job. By these means, the period of actual road instruction per man was cut down from one to two weeks to a maximum of five days and in many cases to only two days. In each case, however, as work on a new division was about to be started, the men who had already qualified in electric operation would honestly offer the assurance that the men on the next section would "take a year's time to learn anything. We all had to go over there and show them how to use the oil-burners"—or mallets, or some other new motivepower innovation that the Railway Company had installed in times past. This friendly rivalry between the divisions always inspired the newer men to extra effort. In fact, on the last division to be put under electric operation, it was not uncommon for the instructor who was called to go out on a run with a new man to find him already coupled up to the train, the air tested and merely waiting for orders to go.

Passenger engine crews were given more work in learning than the freight men since on through-runs there was little opportunity to show up the "fine" points to be learned. These men usually had a half-day off every other day and came to the round-house where an instructor would purposely remove fuses on a spare locomotive, put match stems in the relays, and cause a multitude of troubles for the engineers to locate and remedy. Due credit must be given to the Railway Company's regular travelling engineers who took hold of this line of electrical instruction and becoming proficient themselves, were able to offer valuable assistance in getting their brotherhood into the game at an early date.

Here, as in all lines where teachers deal with some new phase of instruction, they often learned more than those they were supposed to teach. The different methods used by the men in handling long trains and short cuts in switching, hand and lantern "short-hand" signalling, and many other practical details, all of which are slightly different in railway practice than as taught in the rule books, were of educational value.

The technical terms used by the electrical engineer for apparatus and electrical quantities are readily taken up by steam man where they are not confusing or where one term for the same thing is strictly adhered to. It is easy to explain the difference between kilowatts and kilowatt-hours to the beginner, but the various indefinite distinctions *drawn* by technical men between potential, tension, and voltage—for example, when referring to electric pressure—are not readily received by operating men who are told that such pressure is measured in *volts*, and who, therefore, are prone to conclude that the proper term should be "voltage" and that exclusively. While water and air pipe analogies are useful in explaining direct-current actions, they fail on practical hearers when alternating current is dealt with. Steam, water, and air valves when *open* permit the flow of current while electric switches and contactors permit the flow of current when *closed;* so the old steam man must be excused sometimes if he wonders what a set of instructions or wiring diagrams mean if these terms are used indiscriminately or if they sometimes allude to contactors as *switches* or relays as *regulators* depending on the purpose for which they are utilized. He can only judge from the external appearances when beginning, and if such a piece of apparatus on the electric locomotive is called one thing in one location and a similar affair is called something entirely different when in another location, it can only mean an extended length of time before the steam locomotive engineer can become qualified for electric locomotive operation.

A CASE OF SEVERE THIRD DEGREE BURNS TREATED WITH AMBRINE

By Charles G. McMullen, M. D.

Schenectady, N. Y.

The new and radical treatment described in this article has to date been practiced principally upon the horribly severe burns received in modern warfare. The reports that have been made of its wonderful healing properties induce us to recommend that the medical profession consider its possibilities in treating electrical burns. In the article Dr. McMullen describes the technique of the treatment and reports the progress of healing in a particular case. The appendix very interestingly summarizes the literature on the paraffin treatment of burns.—Editor.

The letters by Miss Edith May, published in the *Outlook*, August 2, 1916, excited a somewhat skeptical interest in the use of ambrine as practiced by Dr. Berthe de Sandford at Issy-les-Moulineaux in France. The caustic editorial of Dr. Simmons in the Journal of the A. M. A., August 12th, still further confirmed my skepticism. In February, 1917, at the Meeting of the Third Conference of Physicians, Department of Labor and Industry at Harrisburg, Pa., after hearing Dr. Sherman's paper on the Carrell Dakin technique, in the discussion of which paper Dr. Sherman made some very commendatory remarks about the ambrine treatment, my real interest in the subject was aroused. The atomizer and apparatus necessary to carry out the technique were purchased at Philadelphia, and a supply of ambrine was secured through the efforts of Mr. A. L. Rohrer of the General Electric Company.

I had under treatment, at this time, a patient who had been very extensively burned about the face and hands by a hydrogen gas explosion, and more deeply burned about both thighs and legs from the ignition of his clothing. He had been under treatment since February 5, 1917. The burned tissues of the legs were sloughing and he was having considerable constitutional disturbances as the result of absorption. Large boric packs were used until the sloughs had separated, which took place on the 21st, sixteen days after the burn was received.

At this time the use of ambrine was begun. The patient was somewhat skeptical about "experiments," and hesitated about having us use the new treatment. After the first application of ambrine, he was fully converted, and the comfort experienced while wearing the dressing and the absence of suffering while the dressing was being changed was exceedingly gratifying to both patient and myself.

I expected of course that several operations of skin grafting would be necessary in order to cover such extensive surfaces. The very remarkable advance of epithelium and the small autografts developing from time to time, which also developed with the same rapidity, obviated the necessity of grafting. The daily dressings were continued until May 30th, when the patient was discharged from the hospital. The extent of the burns, the progress of the case, and the manner of healing are shown by the accompanying illustrations. Ambrine or similar paraffin dressings are infintely superior, as regards the comfort of the patient, to any method of treating burns known to the writer.

Its remarkable efficacy as regards rapidity of growth of newly formed epithelium is, I believe, due to the fact that this dressing does not in any way interfere with the delicate layer of advancing epithelium.

The granulations never become exuberant; therefore it is never necessary to use escharotics to destroy them.

The period of convalescence is shortened one-third to one-half, and the scar tissue is unusually soft and pliable and, as yet, this case has shown no tendency to contractures.

Regarding the technique, the first coat of ambrine is best applied with an atomizer, even a soft camel's hair brush is somewhat painful. An atomizer with a hand bulb is not satisfactory, however. An electric compressed air apparatus obviates this difficulty.

The ordinary absorbent cotton teased out in thin bits and applied was found to be much better than sheet cotton. The dressing must be changed each day.

A résumé of the literature prepared by Helen R. Hosmer, of the Research Laboratory of the General Electric Company, is appended.

APPENDIX

Literature on the Paraffin Treatment of Burns

Reference[1] gives a brief general account by the correspondent of the Medical Record of Paris on the efficacy of ambrine treatment of the terrible burns caused by liquid fire from shells. A hospital of 150 beds for the treatment of such burns has been established at Issy-les-Moulineaux, just outside of Paris, under the charge of Dr. Berthe de Sandford, the originator of the ambrine treatment in France. The substance was originally devised as a treatment for rheumatism, but application in an emergency to extensive burns gave such good results that Dr. Sandford was led to advocate its use even in the face of much indifference from his colleagues.

Hull[2] has investigated the ambrine treatment for burns and believes that it produces singular rapidity of healing in slight burns and improved results in bad burns.

"Observations carried out in a military hospital gave one the impression that the treatment was valuable. Burns healed with rapidity; constitutional symptoms rapidly abated; pain was reduced to a minimum; scarring appeared to be obviated, or at any rate was not apparent. The need for grafting large burns appeared to be avoided. . . . . . The patients were singularly free from sepsis. . . . . . Observers who had large experience of burns treated by picric acid, ointments, and other methods in ordinary use, were unanimously of the opinion that the paraffin method was superior to the older methods. The experience of those who had witnessed the results of burns after liquid fire attacks was that the ambrine treatment would save many lives and accelerate the recovery of all burns."

He attributes its efficacy to mechanical factors; protection from air, prevention of damage to newly formed granulations, keeping the tissues immobile by the splint-like effect of the wax, and the heat of application encouraging the flow of blood and lymph to the new capillaries.

By laboratory experiments he found that heating a suitable paraffin to 130 deg. C. with superheated steam lowered its melting point two degrees and made it mobile and workable. The results obtained by the use of such paraffin were indistinguishable from those obtained with ambrine. But, addition of antiseptics and stimulating substances was always found to give great help in cleaning up the wound, etc.

He prepared a formula, known as No. 7 Paraffin, which gives excellent results, better than ambine, healing severe burns without cicatrices or extensive scarring.

This consists of:

Resorcin	1 per cent
Eucalyptus oil	2 per cent
Olive oil	5 per cent
Paraffin molle (soft)	25 per cent
Paraffin durum (hard)	67 per cent

The resorcin may be reduced to 0.25 per cent, or 0.25 per cent of betanaphthol may be used instead.

Hull uses the paraffin for the first dressing, sometimes replacing after two days, for two days with hot boric fomentations. The burn is first washed with sterile water, and dried, preferably with an electric blower. Without interfering in any way with blisters, it is then covered with wax at 50 deg. C. applied with a brush, sterilized in wax, or in very painful cases with a metal spray. A very thin layer of cotton wool comes next and is covered with a second layer of paraffin, more wool and a bandage. The dressing is changed daily, until the pus formation is small, and then every two days. Dead skin layers are removed at the second dressing. Sloughs usually separate after a few dressings.

"The results obtained by the use of No. 7 Paraffin have surpassed the results obtained by ambrine or any other tried preparation. Severe burns of the third degree, accompanied by sloughing, and in a very septic condition, have cleaned and taken on healthy repair under this treatment. Severe burns of both palmar and dorsal surfaces of the hands, extending to the tendon sheaths, have healed in three weeks without contracting cicatrices."

. . . . . .

"The treatment is practically painless and patients rarely complain of pain after the first application. It has never been found in the least necessary to give an anaesthetic for the first or subsequent dressings. The rapidity of healing, the absence of sepsis or pain, the healthy new skin resulting without contractile cicatrices or deformity, have been really remarkable. Burns come clean more rapidly than under ambine treatment. Sloughs of deep tissues, in some cases down to bone, readily separate, and the burns become clean."

Matas[3] explains the lack of interest shown by the medical profession in the use of ambrine by the fact that its originator has allowed it to be exploited as a proprietory product and has kept its composition secret at a time of so great a crisis. His personal experience has confirmed the favorable reports of others. The history of the discovery of ambrine given in reference (1) is repeated and Hull's article describing the beneficial action of the ambrine treatment is quoted almost in full.

Matas has prepared Hull's formula No. 7 Paraffin containing betanaphthol, of which the cost is less than 18 cents a pound against $5.00 a pound for ambrine.

Experience with the paraffin treatment in some ten cases has been very favorable. It is easily applied at 100 deg. F. by means of a cotton mop for the first layer and a brush for the subsequent layers, of which there should be several in the more movable regions. Drying by gentle mopping and exposure to the air is sufficient. The mixture is soothing and pain ceases immediately in every type of burn and the relief continues while the wax is in place. The favorable observations of others are repeated.

Dowd[4] gives clinical details of several bad burns treated to show comparative results for paraffin and other dressings. He used a mixture of

Paraffin	2 parts
Vaseline	2 parts

Stearic acid 1 part, which melted at 112 deg. F. (44 deg. C.).

Other cases where ambrine was used were mentioned in discussion. The dressings were very painful and there was little or no evidence of superiority in the treatment.

Haworth (Western Pennsylvania Hospital)[5] recommends for the treatment of severe burns or other wounds that fail to epitheliate, the application of a wax made up as follows:

Paraffin (Gulf Ref. Co., Pittsburgh)	7.0 gm
Liquid petrolatum, U.S.P.	3.0 cc
White beeswax	10.0 gm
Rosin	7.0
Resorcin	0.2
Sudan III	0.05
Alcohol (95 per cent)	10.0 cc

Other ingredients desirable for special cases may be added. Directions for mixing are given.

Reference[6] gives the formula of Parresine, a mixture said to have the same properties as ambrine, as follows:

Paraffin (M.P. 48-49 deg. C.)	94-96 per cent
Gum elemi	0.20-0.25
Japan Wax	0.40-0.50
Asphalt	0.20-0.25
Eucalyptol	2.00

Alkannin and gentian violet to color.

This is prepared by the Abbott Laboratories, Chicago. (No patent. Trade mark applied for.)

Leech[7] gives the brief history of ambrine and describes the appearance of the three similar preparations, Hyperthermine, Parresine and Mulene.

Ambrine has about the following composition:

Paraffin	97.0
Fatty oil (sesame?)	1.5
Asphalt-like body	0.5
Coloring matter and undetermined	1.0

Mulene appears to contain paraffin, beeswax, a fat-soluble red dye, and considerable rosin.

Leech gives directions for making a mixture of:

Paraffin (M.P. by U.S.P. method 47.2 deg. C.)	97.5 g.
Asphalt	from 3-5 drops
Olive oil	1.5 cc.

This closely resembles paraffin, melts at 454 deg. C., is very pliable and strong at 38 deg. C., adheres exceedingly well to the skin, and detaches easily. The cost of materials is about 10 cents a pound.

Leech has examined and determined the properties of 25 different brands of paraffin and of the proprietory products similar to ambrine. The values are given. He concludes that nearly all have properties that would make them useful. Several appear superior to ambrine and it probably could be substituted for it. Such are:

"Paraffin 118-120 F.," Standard Oil Co. of Indiana.
"Paraffin 120-122 F.," Standard Oil Co. of Indiana.
"Paraffin No. 9." Waverly Oil Works, Pittsburgh.
"Hard paraffin," Robert Stevenson & Co., Chicago.
"Paraffin 118-121 F," The Atlantic Refining Co., Phila.

Sollmann[8] has studied the physical properties of a series of paraffin mixtures designed for use in the place of ambrine and the other

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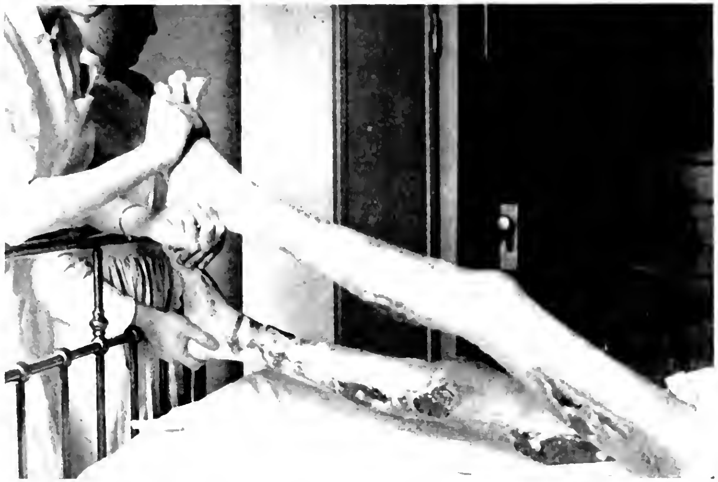

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Photographs showing progress of burns treated with ambrine after one, two, three, and four months similar proprietory products now appearing. He has formulated the important properties as: melting point between 48 and 53 deg. C., hardness, ductility, and pliability, and he has devised simple measures for the last three which he explains quite fully. He gives a table of the properties of 28 substances, none containing more than two constituents, of the following classes:

I. Paraffin
II. Paraffin-wax
III. Paraffin-asphaltum
IV. Paraffin-oil
V. Paraffin-petrolatum.

Burns covered with thin film of ambrine

Showing method of applying ambrine

The commercial paraffins, melting between 48 and 53 deg. C., are quite similar to ambrine, possibly a little more fragile. The addition of small quantities of wax modifies the properties very little. The proprietory products, ambrine, Mulene, and Parresine are of this class and approach very closely in properties to the simple paraffins. The last named is softer and more fragile than ambrine. The paraffin-asphaltum mixtures are distinctly more pliable, adhesive, and capable of forming thinner layers but do not form perfect mixtures. Paraffin-oil combinations are considerably softer and weaker than the paraffins. The paraffin-petrolatum mixtures are very soft, greasy, and crumble easily.

Tests of their behavior on application to the skin showed that the three proprietory mixtures mentioned and some nine of the other mixtures did not differ essentially from the simple paraffins.

Sollman[9] continues his experimental studies of the paraffin treatment of burns and other open wounds by considering the effect and value of the various constitutents upon the physical properties and reporting clinical results.

Simple paraffin will accomplish all that any of the mixtures can do. Admixture of other waxes produces no improvement except that asphalt does increase adherence a little. Rosin and most of the waxes tried raise the melting point. The effect of the addition of some fourteen different oils, etc., is given, but none produces significant improvement.

Certain paraffins are very superior to others. The choice should be those which are liquid at or below 50 deg. C. and the thin film should be pliable at 28 deg. C. and ductile at 31 deg. C. Such are easily produced. Addition of antiseptics is of no effect as only an infinitesimal quantity reaches the surface.

Sollmann finds that the application of the first coat is apt to be painful, and avoids the difficulty by preceding it with a coat of liquid petrolatum, applied with an oil atomizer. To this may be added any medication desired. The author is working out a series of solutions for this purpose. A film of cotton and the paraffin coating are next applied in the usual way.

Sollmann states that almost all surgeons who have used the paraffin treatment are more or less enthusiastic as to its advantages over the older methods of treatment. As it is particularly desirable at this time to get a correct estimate of its value as soon as possible, he proposes a number of methods of comparing its efficacy with that of other methods. He also suggests a number of substances, local anesthetics, antiseptics, epithelial agents, etc., that should be tested out in conjunction with the use of the initial coating of petrolatum.

Beiter[10] (of the United Alloy Steel Corporation) has used the paraffin mixtures with various oils, antiseptics, etc., on over 4000 dressings of burns and lacerated wounds. In the absence of any observed advantage these mixtures were discarded in favor of the commercial paraffin, "Parrowax." The method of application proposed by Sollmann was found preferable to direct application by brush, especially by the patient.

Beiter seems to find the chief advantage of the paraffin to arise from the fact that the granulating surface does not grow into or adhere to it as it does into gauze, and consequently is not destroyed at redressing. This very much increases the rate of epithelization and the comfort of the patient. The method produces quicker healing of superficial burns than any other familiar to the author. It does not, however, shorten the time of healing nor decrease the scar tissue formed in deep burns. The comfort at dressing is much greater than with any other treatment. The firmness, rigidity and smoothness of the covering is also conducive to comfort at other times. Also, when properly applied, it is cleaner than any other dressing because the discharges are confined, do not soil the linen, and produce no unpleasant odor.

The paraffin dressing is inexpensive, a pound of wax and a pint of liquid petrolatum together costing about 65 cents and being sufficient for many burns. It replaces the rather expensive gauze. It is, however, time consuming.

Hudson,[11] after mentioning the fact that the early skepticism of physicians concerning the ambrine treatment of burns was due to the fact that the substance recently made its appearance in France as a patent medicine applicable to rheumatism and other ailments, describes a spraying apparatus which he had to devise and make for his own use. The mixture has to be kept between 50 and 70 deg. C. during application, and this necessitates the use of an electric heater for the air used in order to avoid solidification in the nozzle. An illustration and dimensions are given.

The apparatus, which is not patented, works perfectly and with a 10-lb. air pressure and a hole in the nozzle the size of a No. 47 drill an area of one square foot can be covered in about two seconds, a great advantage in extensive burns. A smaller hole may be better for ordinary use. The container should hold about two pounds of melted ambrine.

It is necessary to have a good volume of air as from a compressed air tank or an electrically operated automobile pump such as the "Lectroflator." The latter must have a safety valve to keep the pressure down. Hand bulbs and small pumping machines are not satisfactory.

The few cases in which the treatment has been tried indicate considerable good in the method, though it may be advisable to give a preliminary cleansing of the wound as by wet dressings of Dakin's solution for a day or two.

Application is not painful if the ambrine be kept below 70 deg. C. and redressing is easy, rapid, and painless.

REFERENCES

[1] Medical Record, *91*, 160-1, Jan. 27, 1917.

[2] Hull, (Roy. Army Med. Corps) British Medical Journal, Jan. 13, 1917. Canadian Practioner and Review, *42*, 169-73, April, 1917. Abs. Jl. Amer. Med. Assoc. *68*, 373, 1917.

[3] Matas, New Orleans Medical Journal, *69*, 677-88, 1917.

[4] Dowd, Annals of Surgery, *65*, 781-5, 1917.

[5] Haworth, Journal Amer. Med. Assoc. *68*, 1404, May 12, 1917.

[6] Journal Amer. Med. Assoc. *68*, 1406, May 12, 1917.

[7] Leech, Journal Amer. Med. Assoc. *68*, 1497-1500, 1917.

[8] Sollmann, Journal Amer. Med. Assoc. *68* 1037-41, 1917.

[9] Sollmann, Journal Amer. Med. Assoc. *68*, 1799-1801, June 16, 1917.

[10] Beiter, Journal Amer. Med. Assoc. *68*, 1801-2, June 16, 1917.

[11] Hudson, Med. Dir. N. Y. Medical Journal, *105*, 301-2, 1917. H. I. du Pont de Nemours Co., Medical Record, Jan. 27, 1917, p. 160. Southern Medical Journal, Dec. 1916.

ROAD ILLUMINATION BY MEANS OF AUTOMOBILE HEADLAMPS*

By H. P. Gage

Corning Glass Works

This article deals with the distribution of light and the intensity of light from the automobile headlamp. Illumination of the road without glare to approaching drivers is the problem that is considered. A number of photographs show the distribution from various headlighting equipments. The author suggests that the regulations governing the glare from headlamps should not only specify the limitations of glare, but also what devices can, and what devices cannot be made to eliminate glare when properly adjusted and installed.
—Editor.

This is one of a series of contributions to the subject of automobile headlights. Papers on this topic have been given at the lecture course of the Illuminating Engineering Society in Philadelphia, before sections of the Illuminating Engineering Society in New York, Pittsburgh and Boston, and also before the Society of Automobile Engineers in New York City.

The ground has been covered from nearly every possible standpoint, including the difficulties and dangers which are caused by the dazzling glare encountered when passing automobiles with bright headlamps, the legislation designed to overcome this evil, the design of the headlamps and descriptions of devices intended to change the natural light distribution produced by the headlamps, the beam candlepower necessary to illuminate the roadway with sufficient intensity for driving, and the necessity for accuracy in construction and the need of care in focusing the headlamps.

Mr. A. L. McMurtrey, at the March 15 meeting of the Society of Automobile Engineers in New York City, besides showing the principles involved in headlamp construction, discussed the two methods now in use to eliminate glare, namely, diffusion and deflection. Mr. McMurtrey asked the society to investigate these two methods and to make a definite decision as to which principle should be adopted. The method of diffusion has the advantage that no special adjustment of the bulb and reflector is needed, and the disadvantages, that no warning beam is thrown ahead when approaching blind crossings, and elimination of glare is accompanied by insufficient intensity for driving. The method of deflection has the advantage of illuminating as brilliantly as desired those portions of the road which must be seen without blinding approaching drivers, and the disadvantages of requiring accurate focusing and adjustment and that road irregularities or topping a hill will allow momentary glare.

All through these talks has run a serious undercurrent of discussion as to the type of light distribution most to be desired. Generally this problem of light distribution has been left in the form of the question: "If glare is eliminated, what light distribution is best suited for driving purposes?"

Fig. 1. Type B macadamized state road taken from headlamp position

In the formal papers so far presented emphasis has not been laid upon the exact extent of the roadway itself which should be illuminated or the question as to exactly how much light thrown in the approaching driver's eyes should be considered as

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* A paper presented before the Philadelphia Section of the Illuminating Engineering Society, April 20, 1917.

dangerously glaring, and while some suggestions along these lines have been made, it seems to me that a material addition to the subject under investigation can be made by the presentation of some data in the form of photographs which illustrate the method which has been adopted in the laboratories of the Corning Glass Works to study some of the engineering details which must be known in order to construct satisfactory automobile headlamps.

Fig. 2. Type B macadamized state road taken from driver's position

It is a comparatively simple matter in the laboratory to measure the intensity of light projected by a parabolic reflector, either alone or combined with some light-distributing device, and to measure in degrees or in radian measure the extent of this beam. But what do these figures mean when the light projector is fastened to the front of a car and the machine is driven through the dark at a fairly high rate of speed along a smooth macadam road where many other cars are passing? The answer to this question involves so many elements that we must take each element and analyze it separately. The first consideration would seem to be the type of road which it is necessary to illuminate.

Types of Road

It is important to distinguish three different types of roads.

The Type A road is the ordinary country road, on which the motorist meets no obstructions to speak of, and certainly has very little difficulty from glare from any other automobile. The road is rough; the driver has to look out for ruts, ditches and occasional bridges which may be missing. He only needs a comparatively small amount of light because he cannot travel very fast, yet he can have all the light he wants because there is nobody to interfere with. From the automobilists' standpoint this is a simple proposition because but few automobilies travel on such roads.

The Type B road is the macadamized road, what we call the State road in New York State, because practically all the state roads are macadamized, and *vice versa*. There are a large number of automobiles, on pleasant summer evenings a constant stream, going in both directions, and there is a great deal of difficulty caused by glare. Sometimes there is a wagon on that road that does not carry any kind of light, or if it does, the light is carefully concealed from both the front and the rear.

Fig. 3. Same. Taken at night, using device illustrated in Fig. 9

It is only a matter of legislation that any light at all is carried. There are occasional pedestrains who carry no light, although if I were the pedestrian walking on such a road I think I would carry a lantern as "Safety First" precaution.

Then there is the Type C road, the city or independently lighted road. There again the headlamp situation is simple; headlamps are used only as position markers.

Fig. 1 shows the Type B road taken from the headlamp position. The camera equipped with an objective of 11 in. (28 cm.) equivalent focus, to secure uniformity with the photographs of the screen images described later, is set at a height of 42 in. (107 cm.) above the road level. A tape or surveyor's chain is used to measure a distance of 50 ft. (15.3 m.) from the camera, and a rule held up to measure a height of 42 in. (107 cm.) above the road.

A similar photograph, but taken from the driver's position, is shown in Fig. 2. In this case the distance is measured from the headlamps.

The night photographs in Figs. 3 and 4 are also taken from the driver's position.

Road Illumination *vs.* Glare

The statement has been made that in order to get sufficient road illumination for comfortable and safe driving, a beam of light of such high intensity is required that if this beam of light is directed into the eyes of an approaching driver the glare is so intense that it is highly dangerous in passing. If then it were not possible to so direct the rays of light that only the road were illuminated, as for example, if a very powerful arc lamp were mounted on the front of the car, a serious state of affairs would exist, and anyone using the highway at night would make himself highly objectionable and dangerous to all of the other users of the highway. If such a state of affairs did exist, it would be necessary to limit the power of headlamps to such a point that the glare produced would not be so great, but that all the users of the road could get by each other, and at the same time they would be able to have enough road illumination to proceed at a slow rate of speed. The question would then be simply one of road illumination versus glare.

Fig. 4. Night View. The men stand 50 and 100 feet from the car

If, however, we accept the solution of directing the light toward those portions of the roadway which it is necessary to see, and by keeping strong light intensities away from the pathway which would be followed by the eyes of the drivers of approaching vehicles, the problem becomes more simple. The problem then consists of determining just what light pattern is the best to project, and of furnishing suitable devices with engineering instructions for their use so that the ordinary driver of automobiles can utilize this light distribution on his car.

Light Patterns Produced by Projectors

The light pattern projected by a fairly well shaped parabolic reflector is shown in Figs. 5, 6, and 7. In Fig. 5 the filament of the bulb is at the exact focus of the parabola, and in Fig. 6 the bulb filament is 1/10 in. (2.5 mm.) inside this focus, and in Fig. 7 it is 1/10 in. (2.5 mm.) in front of the focus. In these photographs the axis of the light beam is represented as the crossing of the two heavy lines. The screen is at a distance of 25 ft. (7.6 m.) from the headlamps, and the lighter lines are each 1½ ft. (0.45 m.) from the center lines. In terms of radian measure these finer lines are 6 per cent (6 ft. at a distance of 100 ft. or 6 m. at a distance of 100 m.) from the center line, or, in terms of degrees, they are 3.4 deg. from the axis. (If metric measures were used the same results would be secured with a screen 10 m. from the lamp and the fine lines each 60 cm. from the axis lines.) What these figures mean with reference to road illumination is not easily understood.

To introduce the road a double print was made, the negative of the projected screen image and one of the road negatives were both printed on the same paper, care being taken to print the crossing of the axial lines directly on the bend in the rule; *i.e.*, 42 in. (107 cm.) above the road level and directly down the road. Those portions of the road which would not receive light directly from the headlamp are black, while those which would be illuminated by the headlamp show the picture of the road. Thus Figs. 5a, 6a, 7a, show the portions of the road illuminated by parabolic projectors whose axes are horizontal. The light pattern projected by different devices is shown in Fig. 8-14, and the portions of the roadway illuminated are shown in the night photograph in Figs. 3 and 4; also in the double contact prints, Figs. 8a-14a.

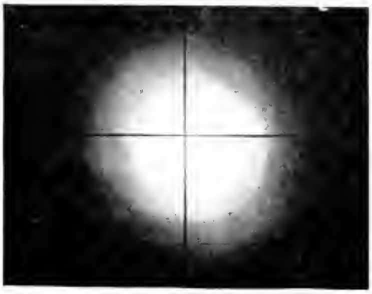
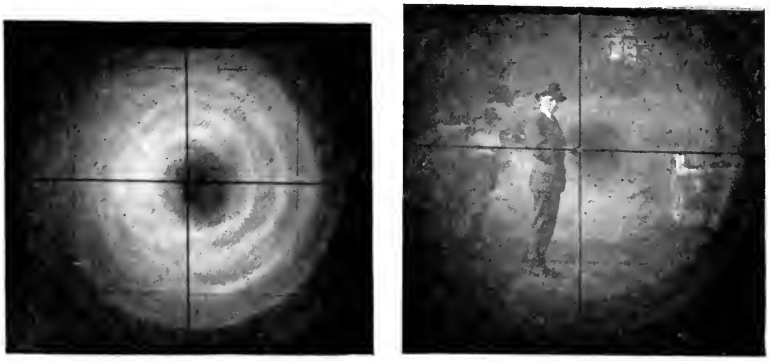
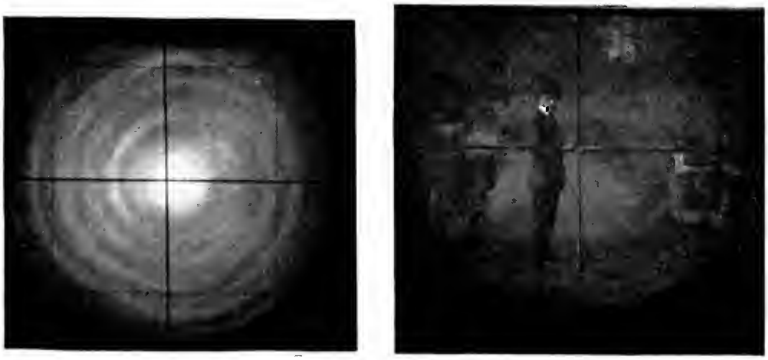


Fig. 5. Screen image of beam projected by parabolic reflector. The bulb is at the focus of the parabola

Fig. 5a. Same as Fig. 5, double contact print of Fig. 5 and Fig. 1, showing extent of roadway illuminated by this light distribution



Figs. 6 and 6a. Screen image, bulb back of focus



Figs. 7 and 7a. Screen image, bulb in front of focus

Without mentioning the names of the particular devices which are here illustrated, I think it perfectly legitimate to criticize the effects from the standpoint of the driver of the car and from the standpoint of those who are trying to proceed in the opposite direction.

In Fig. 5 it is evident that directly down the road a terrific glare would be encountered, but at a distance of approximately 75 ft. (23 m.) the approaching driver's eye is outside of the direct beam, and little interference would occur from that distance to the point of passing. From the driver's standpoint objects at a distance down the road would be clearly seen, but the near objects, such as fences, ditches, etc., are not well illuminated, and in case a car is encountered, which itself produces blinding glare, difficulty will be experienced in passing, as it will be nearly impossible to distinguish ditches and other road characteristics 75 ft. (23 m.) or less from the front of the car.

In Figs. 6 and 7, which illustrate more or less spreading light beams, the intensity down the road is less. It is difficult for an approaching driver to get outside of the projected beam, and therefore the glare will continue to a point quite close to the car. From the driver's standpoint the distant illumination is less intense, but on the other hand greater spread is obtained and ditches, etc., are rendered more visible. If the headlamps are bent downward, as in Fig. 11 the effect of glare is eliminated. This light distribution is, however, unsatisfactory from the driver's standpoint, as the brightest part of the light strikes the road at a distance of between 50 and 60 ft. (15 to 18 m.) in front of the car, and there is insufficient spread to the light beam.

In Figs. 8 and 9 we have illustrations of the light beam bent downward and at the same time spread out across the road. This eliminates the troublesome glare, due to light above the horizontal, and at the same time lights up the ditches at the side of the road. This light distribution can be somewhat improved upon a device which distributes part of the light (Fig. 9) in a fan-shaped beam, and part is directed in an intense beam directly down the center of the road and just below the horizontal.

In Fig. 10 we have what may prove to be a still further improvement in the light distribution, in that some of the light is allowed to rise above the horizontal and illuminate the right hand side of the road, rendering sign-posts, vehicles, etc., more visible, and yet no light is directed toward the upper left-hand quadrant. It is in this upper left-hand quadrant that the faces of the drivers of approaching vehicles are located.

In Fig. 13 we have an illustration of light which is projected so far below the horizontal as to illuminate a small path directly in front of the car, but no appreciable amount of light falls beyond a distance of 60 ft. (18.3 m.) from in front of the car, and the spread is insufficient to see either ditch.

In Fig. 12 is shown a light pattern consisting of two distinct beams of light. The lower beam is intense and is in fact undesirable, as it produces a bright spot of light directly in front of the car in a place where it is not needed, and yet it reduces the sensitiveness of the eye to the more distant parts of the road which are less brilliantly illuminated.

In Fig. 14 we have the type of light distribution obtainable from the diffusing type

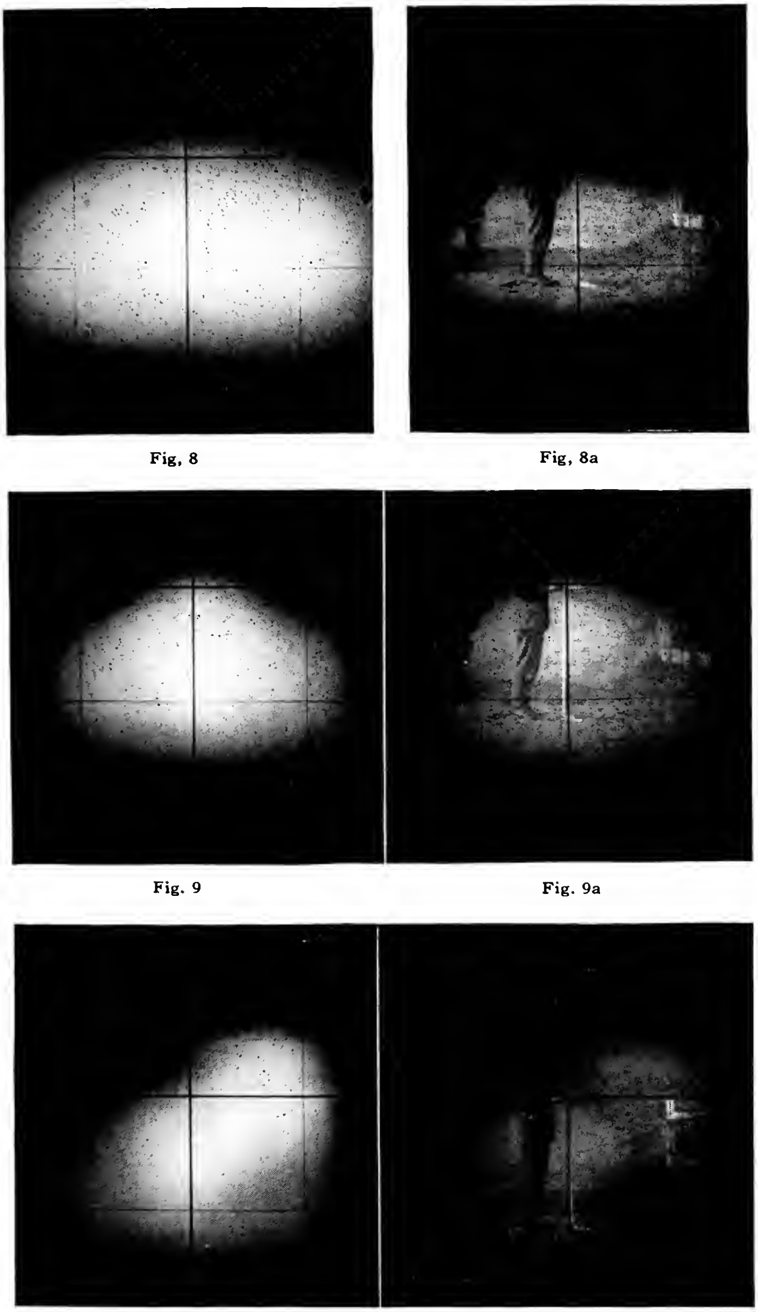


Fig. 8
Fig. 8a
Fig. 9
Fig. 9a
Fig. 10
Fig. 10a

Figs. 8–10. Screen image with deflecting front glasses of cover glass. It is an old saying that "you cannot eat your cake and have it too." All who deal with light know that if you have a given amount to start with, you can illuminate a small surface brilliantly or a large surface dimly. It is true that by placing a diffuser in front of a parabolic projector, the glare is reduced, but only to an extent corresponding with the reduction in beam intensity. The same condition holds that holds in the case of Figs. 6 and 7, in which the bulb is not at the focus of the parabola, only to a much greater extent. The driver of an approaching vehicle is in the beam of the headlamp from the most distant point until he is even with the headlamp. If the intensity of the light is sufficient for the driver of the automobile to see the road, then the driver of the approaching vehicle will experience a blinding glare until the automobile is actually passing. From the standpoint of the driver of the automobile equipped with such a diffusing device, the foreground is so brilliantly illuminated as to reduce the sensitiveness of the eye to the more distant parts of the road, and unless bulbs of excessively high power are used, wagons and other large obstacles will suddenly loom up at short distances in front of the car with confusing suddenness.

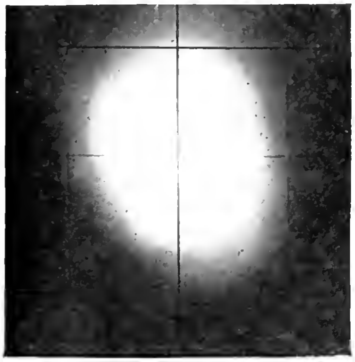
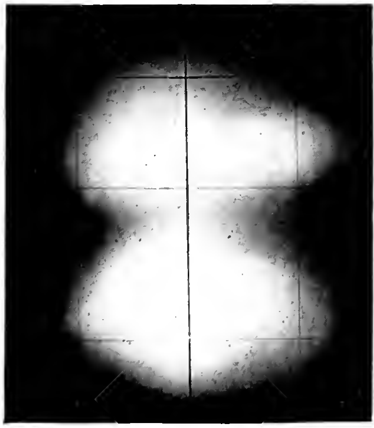


Fig. 11

Fig 11a



Fig, 12

Fig, 12a

Fig. 13

Fig, 13a

Figs. 11–13. Screen images with deflecting front glasses

In Figs. 8a to 14a, by combining the photographs of the screen images with a photograph taken to the same scale of a road, we may predict what parts of the road will be illuminated by a particular light distribution. Whether this road illumination is actually obtained can be determined only by night test. Photographs made at night of a road illuminated by the light distribution shown in Fig. 10, are given in Figs. 3 and 4. These photographs together with the corresponding daytime photograph, Fig. 12, were taken with a 6-in. (15 cm.) objective and are not uniform with the others.

What is Glare?

Having taken up the problem of road illumination mainly from the standpoint of the driver, how are we to determine what constitutes glare? A method of studying this is illustrated in Figs. 15–19.

Fig. 14. Screen image with diffusing front glass

Fig. 15. Apparatus for testing glare of headlamps

If we look directly into a glaring headlamp, objects near this headlamp cannot be distinguished. Fig. 15 illustrates the apparatus which was used in such a study, namely, a set of illuminated letters in the center of which is placed a headlamp. In order to make a consistent series four photographs, Figs. 16, 17, 18 and 19, were taken with the same exposure, 12 sec., for the letters, but in Fig. 17 there was in addition a 2-sec. exposure looking directly into the full beam projected by an unmodified parabolic reflector, and in Figs. 18 and 19 a 2-sec. exposure when a deflecting device was used in front of the reflector. The confusion of the letters near the headlamp form a crude measure of the amount of glare present. In these illustrations, while the mechanism which produces the confusion is different from that of the eye, the appearance fairly well represents that experienced by the observer.

Fig. 14a

Fig. 16

Fig. 17. Looking into parabolic reflector

Fig. 18

Fig. 19

Figs. 18–19. Looking into headlamps equipped with deflecting glasses

From experiments such as these I would say, roughly, that if the beam candlepower in the direction of the driver's eye does not exceed 1,000 candlepower, and if a reasonable road illumination is produced by his own headlamps the glare will not be of such high intensity as to be seriously disturbing. When, however, the maximum beam candlepower obtainable from a parabolic projector, that is, a beam of 20,000 to 60,000 candlepower, is projected into one's eyes it is impossible to see anything beyond the headlamps.

In conclusion I wish to say that the Type B, or macadamized roads, on which glare is prone to be the greatest obstacle to safety and comfort in driving are provided and maintained by the state, and their use is, therefore, legitimately subject to state control for the purpose of securing the greatest usefulness and safety for all travelers on the highway. In the particular field of the illumination of these roads by portable lamps the legislation now being enacted has some regard for the scientific requirements of illuminating engineering, thanks to the agitation of the automobile clubs, and the engineering data supplied by the Illuminating Engineering Society, the Society of Automobile Engineers, and to a certain extent by the manufacturers of anti-glare devices.

The question of official approval of particular devices has often been agitated, and it has been pointed out that without such approval the owner of a car is at sea and does not know whether his car complies with the law or whether he is subject to arrest by the first traffic policemen he meets.

If a certain light distribution is passed upon as legal without regard to what device is employed to produce such light distribution, the responsibility of securing the required light distribution rests with the car owner. As the majority of car owners and even garage men have not familiarized themselves with the laws of optics, a vast amount of education will be necessary before the law can be intelligently complied with. The indefinite term "blinding glare" is employed in many ordinances. If, however, all car owners honestly attempted to eliminate "blinding glare" in directions which this glare should not exist I doubt if many cars would present any difficulties in passing.

While there are serious drawbacks to giving official permits to special devices and allowing freedom from police interference to users of such devices, would it not be entirely feasible to give permits stating that when certain devices are properly installed and the headlamps properly adjusted that the ordinance can be complied with, thereby eliminating the many devices which are so crudely designed, that by no adjustment whatever can they be considered as glare eliminators?

REORGANIZATION OF INDUSTRIAL PROCESSES AFTER THE WAR*

By Rockwood Conover
General Electric Company

Mr. Conover sees ahead of us, following the termination of the war, a period of intense industrial activity that promises to completely reorganize our present manufacturing methods. The more important phases of this readjustment will include organization for more specific purposes, building construction providing for unlimited expansion, greater concentration and segregation of manufacture, reduction in the function of human labor, and government aid. Mr. Conover discusses separately the probable course of each of these factors in the readjustment of the world's industries.—Editor.

Among the important world-wide changes that are bound to take place during the period of reconstruction after the war is over and peace finally re-established, a readjustment of industrial methods and practices, wider in its scope than anything that has yet been conceived, is likely to occur. This readjustment, which will include nearly all phases of industrial undertaking from organization and plant construction down to the simplest mechanical process, will doubtless be as unique and revolutionary in some of its aspects as has been the great advancement in many things pertaining to engineering and manufacturing that has taken place during the two or three decades just passed.

Among the more important phases of this readjustment that are worthy of our attention, several features stand out clearly as being of immediate and pressing value to both producer and consumer, and as meriting chief consideration among the developmental processes affecting the manufacturing side of industrial life that the new conditions will bring about. Briefly these are: Organization for more definite and specific purposes; building construction providing for unlimited expansion; greater concentration and segre-

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* By Courtesy of American Machinest.

gation of manufacture; elimination of the function of human labor and increase of mechanical performance; government aid in the process of readjustment to the country's needs.

At the present time the human mind cannot clearly conceive the magnitude of the work of reconstruction, the new activity of human endeavor and the amazing stride at which the rehabiliment of the world must go forward. These things will come upon us with a suddenness and magnitude that will require the maximum of ingenuity and power to meet.

Organization for More Definite and Specific Purposes

It has been the custom to some extent in past years to build up factories and industries for the production of certain kinds of classes of apparatus as a finished product, without clearly defined plans of procedure in reference to the many and varied integral parts of which the completed unit is composed. The production of automobiles, farm machinery, machine tools, and many other kinds of product is illustrative of this. The plan in the mind of the owner or manager heretofore has chiefly been to provide buildings sufficiently large in which to manufacture his product without careful preliminary analysis as to what portions or details might be purchased in the open market or from other factories at a less cost than he could produce them. Even at the present time the manufacturer quite generally seeks to make all parts of apparatus, both large and small, within his own factory. He does this with the conviction that the labor and material cost in his own shop will be less than the outside purchase price for the various elements required and that an economy in production will be effected. Not infrequently he overlooks the item of overhead expense, which he should add to his own labor and material in arriving at this conclusion, and that what he chiefly saves is the producer's profit, other things being equal.

The manufacturer can sometimes produce the separate elements of a piece of apparatus for less than he can buy them in the open market. This is an often demonstrated platitude of business. But it is not always so, and in many instances is proved otherwise. Equipment and facilities for the production of small parts in quantities often enable the company engaged in this class of manufacture to offer its product at lower prices than the individual manufacturer, not so equipped, can produce them. Overhead expense involved in the exclusive production of this class of product is normally much lower than in the production complete of apparatus of uniformly greater bulk and weight, resulting in a distinct gain to the producer of the former class and, ultimately, to the buyer as well.

Analysis of Conditions Necessary

It is evident that during the new period of reconstruction it will become increasingly desirable for the individual manufacturer or corporation contemplating the founding of an industry to analyze carefully these most important phases of organization, and to proceed with fully defined plans as to the specific purposes for which buildings can be erected and equipment purchased to secure the greatest economic advantage in production. The new problem before the industrial world is likely to be that of the establishment of factories devoted to the assembly and sale of finished product, and the establishment of other factories and foundries whose function is to feed these great assembly plants with the supply of castings and various details incident to the production of the finished unit.

And here the question may naturally be asked: Why should the manufacturer of the greater product undertake the production of the smaller details on a limited number of automatics, lathes, or other machine tools (located in segregated sections or departments of his shop and often operated interruptedly and expensively), any more than he would engage in the production of the thousand and one small items of shop supplies that he normally uses and which he is accustomed to purchase in the open market? The concentration of production of small product in one or a limited number of factories offers the distinct advantage of large orders, continuous operation and other features not possible under the old plan. Under the new period of reconstruction it will be necessary to give consideration to a greater degree of diversification in industrial processes than we have been accustomed to contemplate in the past, in order to secure the largest economic advantage that the world-wide commercial readjustment will make both desirable and imperative.

It is evident that in building new industrial plants we must provide for a far greater expansion than ever before in the history of industrial undertaking. Not only must the layout of the buildings provide for a large expansion of assembly floors and greatly increased space for machine tools and preliminary productive processes, but the areas between buildings must also be larger than ever before. Where 50, 75 or 100 ft. was considered ample space between shops, doubtless 200 ft. and even more will be required. Sudden expansions of businesss will require the erection of one- or two-story additions and lean-tos to provide additional assembly space, or space for more machine tools with which to get out greater products sold on limited delivery dates of shipment. Larger areas for storage sheds and platforms between shops will be required, and there must also be provision between the buildings for expansion of tracks and sidings, overhead cranes, scales, and facilities for rapid unloading of every description.

In the larger type of industries now existing and in those that will be organized in increasing numbers during the new period, it will doubtless be necessary to set aside a considerable definite area for the receiving and storage of castings and metal stocks and such materials as may be kept in open and covered spaces. These receiving and storage yards will need to provide for big expansions through ample equipment of sheds, platforms, narrow- and broad-gauge trackage, gantry cranes, railroad scales, conveyors, etc. More materials will be received and handled than ever before, and the railroads will demand and need our co-operation and assistance. Every provision must be made to relieve congestion and save demurrage and minimize the tying up of cars.

The removal of chips, turnings, metal sheet trimmings, and scrap and refuse of every nature will have to be provided for with improved methods. With the great increase in productive output it will become desirable to handle these materials more expeditiously and economically, either by means of conveyors operating below shop floors in close proximity to the lines of machine tools or by other means not interfering with or detrimental to the operation of the regular shop equipment, or detracting from space required for the movement and handling of castings and other materials in process of manufacture.

Concentration and Segregation of Processes

The new industrial conditions will force corporations and managers more and more to give attention to concentration and segregation of all manufacturing operations, and to concentration of supervision in order to establish such co-operative routine of directive effort as will result in the greatest economy in manufacturing methods in the shop, and influence all functions of the factory's organization in efficient and profitable channels. The small manufacturer will need to more carefully analyze his practices, to segregate more definite assembly processes from preliminary processes, in order to secure a speeding up of all operations and prepare for a more intensive production of product. In the small shop where specialization has only partly superseded the old methods much can be done along this line. Instead of the all-round machinist making apparatus complete, as in the past, the owners or managers of the smaller sized factories will find it desirable and necessary to concentrate assembly work as far as possible, and segregate from this the machine operations and manufacture of small details, in order that through this grouping of similar processes all tools may be kept in constant operation and the greatest speed and efficiency in productive activities secured. Only in this way can the small shop hope to exist with the bigger factories in the driving competition that is bound to come.

During the next two decades the grouping of industrial enterprise and the building of big assembly plants will receive greater attention than has ever been given the subject heretofore. The world-wide demand for products, for rapid fulfillment of big contracts, and the increasing competition of purchasing power, will all contribute to direct the trend of the world's industrial development and progress. The making and supplying of small parts is, comparatively speaking, one of the simpler phases of production. It is chiefly a question of capacity for quantity, for precision, and for reduced cost of output. It is the big business, the assembly of completed apparatus of medium, large, and still larger proportions that makes imperative the adoption of new methods of production on a scale more gigantic than anything we have yet conceived. Assembling and shipping, it is possible to conceive, may become the chief function of the big industry of the future, the thousand and one smaller details being fed into these big assembly plants automatically through other channels—the foundries and factories erected for their manufacture, either apart from or in combination with the big home unit.

Segregation Will Be Essential

The segregation of production of small parts from assembly processes is diametrically opposed to decentralization of manufacture, which involves the grouping of all equipment required for the production of a given class of product as far as possible within the limits of the factory in which the product is made. There are advantages in favor of both methods of procedure, but it is doubtless true that under the new conditions which the manufacturer will have to face, a more diversified application of both manual and machine performance will be essential to keep pace with the demands of consumption. Specialization will be carried far beyond its present bounds, and will be limited only by the specific conditions of manufacture involved and the kind of product for which the industry is organized.

The evident results of this growing change will be greater refinement and precision in all manufacturing operations. Constant repetition of effort, whether directive, manual or mechanical, must invariably result in greater uniformity of action and in a more perfect accomplishment of the thing desired. The decades to come will be marked with a tendency toward a condition of more intensive progressiveness and a greater insistence in demands on the part of the buyer and consumer, all of which will make for the reorganization and establishment of industrial enterprise on the basis of the highest refinement and economy of effort and procedure.

Coincident with the new era in industrialism will come the elimination in an increasing degree of the factor of manual labor in productive processes. More and more the purely manual task will be superseded by machine-tool performance. Greater demands will be made upon the tool builders. The skill of scientific men will more and more be required to design tools for new and untried mechanical processes. The new and worldwide development in all commercial undertaking will bring about a condition of productive activity greatly emphasized in its intensiveness.

This does not mean that the all-round tradesman machinist will no more be needed. It means that the evolution of shop practice toward specialization and machine performance is rendering his skill less a factor of necessity in manufacturing operations and placing this class of highly educated labor in the minority. There is always room, however, for the skilled tradesman higher up, doing the tasks of laying out, lining up and assembling, which the handy man or purely mechanical performance cannot always do. With the increasing intensity of production and constantly growing demand for product there must obviously arise a condition in which there will be work for all classes and kinds of men. The substitution of mechanical performance for manual tasks will in no wise be able to keep pace with the new and growing needs of the industrial world. Should the processes of transformation under the new era develop an excess of manual labor of certain grades, which with the rapid organization and building of new industries is not likely to occur, there is always open to the individual the field of agriculture, which, now more than at any other period of recent history, is in need of re-establishment on a profitable and enduring basis.

Government Aid in the Readjustment of Industry

Government aid may be rendered the manufacturer through bureaus or commissions already appointed for the study of industrial conditions by giving counsel and direction in the establishment of new manufacturing projects, and by furnishing him with such data as may be of assistance in the grouping of assembly plants in localities where the natural resources of power and facilities for transportation by rail or water to and from the world's markets and sources of supply are economical and advantageous. Near these greater assembly plants, or in conjunction with them, it will doubtless be desirable to group the segregated shops and factories for the manufacture of small parts in order that the greatest economy in cost and transportation may be secured. In the founding of industrial enterprise under the new conditions the manufacturer will require more than his own knowledge and experience to guide him in the more important considerations of the project. He will need the expert knowledge and information which may be obtained through the co-operation and service of a friendly Government commission.

A NEW ELECTRIC MINE HOIST AT BUTTE, MONTANA

By R. S. Sage

Power and Mining Engineering Department, General Electric Company

A description of equipment in connection with a recent Ilgner-Ward Leonard hoist installation at the Elm Orlu Mining Company, Butte, Montana. This installation is one of the two largest of this type in operation in this country. Complete data on two sets of tests are included; the first conducted to analyze a typical day's run and the second to determine efficiency while hoisting under known conditions. This paper was read at a special meeting of the A.I.E.E., New York, June 28, 1917.

General

During the past year and a half, a period to be remembered for its tremendous industrial activity, extraordinary progress was made in the field of mine electrification; and in particular in the electrification of mine hoists of more than average capacity and importance, and for whose operation the highest type of electrical system was demanded. This progress extended to both the coal mining and the metal mining fields.

Illustrative of the extent of this progress, it may be said that the number of Ward Leonard and Ilgner-Ward Leonard hoist equipments which will have been put into operation in this country during the two years of 1916 and 1917 will equal the total number operating prior to 1916, and the aggregate horse power capacity will be 50 per cent greater.

A recent Ilgner-Ward Leonard hoist installation of considerable interest is that at the mine of the Elm Orlu Mining Company at Butte, Montana. This equipment has been in regular productive operation since the first week of last February having been put into commission to replace an old steam hoist at that time. This type of hoist but recently made its appearance in the Butte district, and the present installations are but forerunners of many electrifications which will undoubtedly be made in the near future.

This equipment is of interest, first, because of its capacity, it being one of the two largest of this type in operation in this country, and, second, because of its unusual smoothness of operation, simplicity and ease of control, it being so noted throughout the Butte camp.

A series of tests under operating conditions were carried out, the results of which, together with a description of the equipment are given herein.

The hoisting equipment is installed in a very substantial brick building of one room, the motor-generator set with flywheel, the slip regulator and the switchboard occupying all of one end. A view of the hoist motor and the control equipment is shown in Fig. 1. The building is exceptionally well lighted, both by day and by night, and there is a particular absence of crowding and congestion. Two 20-ton* hand-operated traveling cranes provide adequate capacity for the handling of the heaviest parts.

Duty

As is well known, for the driving of large high-speed shaft hoists, considerations of accuracy of control and safety of operation necessitate the use of equipments operating on the Ward Leonard system. This system combined with a flywheel for load equalization, commonly known as the Ilgner-Ward Leonard system, is necessary wherever the conditions of power supply require it. In this instance, as for the majority of equipments of this character, flywheel equalization was imperative, as the reservation charge is based on the maximum instantaneous demand. For this reason, flywheel capacity was supplied sufficient to completely equalize the maximum duty cycle met in balanced hoisting from the deepest level.

The shaft has been sunk to a depth of 1800 ft. (548.6 m.), and ore is being hoisted regularly from the 1100-, 1200-, 1300-, 1400-, 1500- and 1800-ft. (335.2 m. to 548.6 m.) levels. Ultimately, the ore will be taken from a seam 3500 ft. (1066.8 m.), below the surface.

The general characteristics of the hoist on the basis of which the equipment was designed are as follows:

Inclination of shaft with horizontal	90 deg.
Present maximum lift	1800 ft.
Ultimate maximum lift	3500 ft.
Weight of skip and man cage	11,000 lb. (4989 kg.)
Weight of ore per trip	10,000 lb. (4535 kg.)
Weight of one rope (3500 ft.)	12,500 lb. (5669 kg.)
Maximum speed of skip during hoisting	2,500 ft. per min.
Diameter of cable	1.5 in. (38.1 mm.)
Weight of cable, per foot	3.55 lb. (1.58 kg.)
Drums—cylindrical—double-clutched.	
Diameter of drums	10 ft. (3 m.)
WR^2 of drums	3,600,000 lb. ft.^{2}
Maximum hourly tonnage (2000 lb.) 3500 ft. level	155
Assumed mechanical efficiency	85 per cent

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* One short ton = 0.9 metric ton.

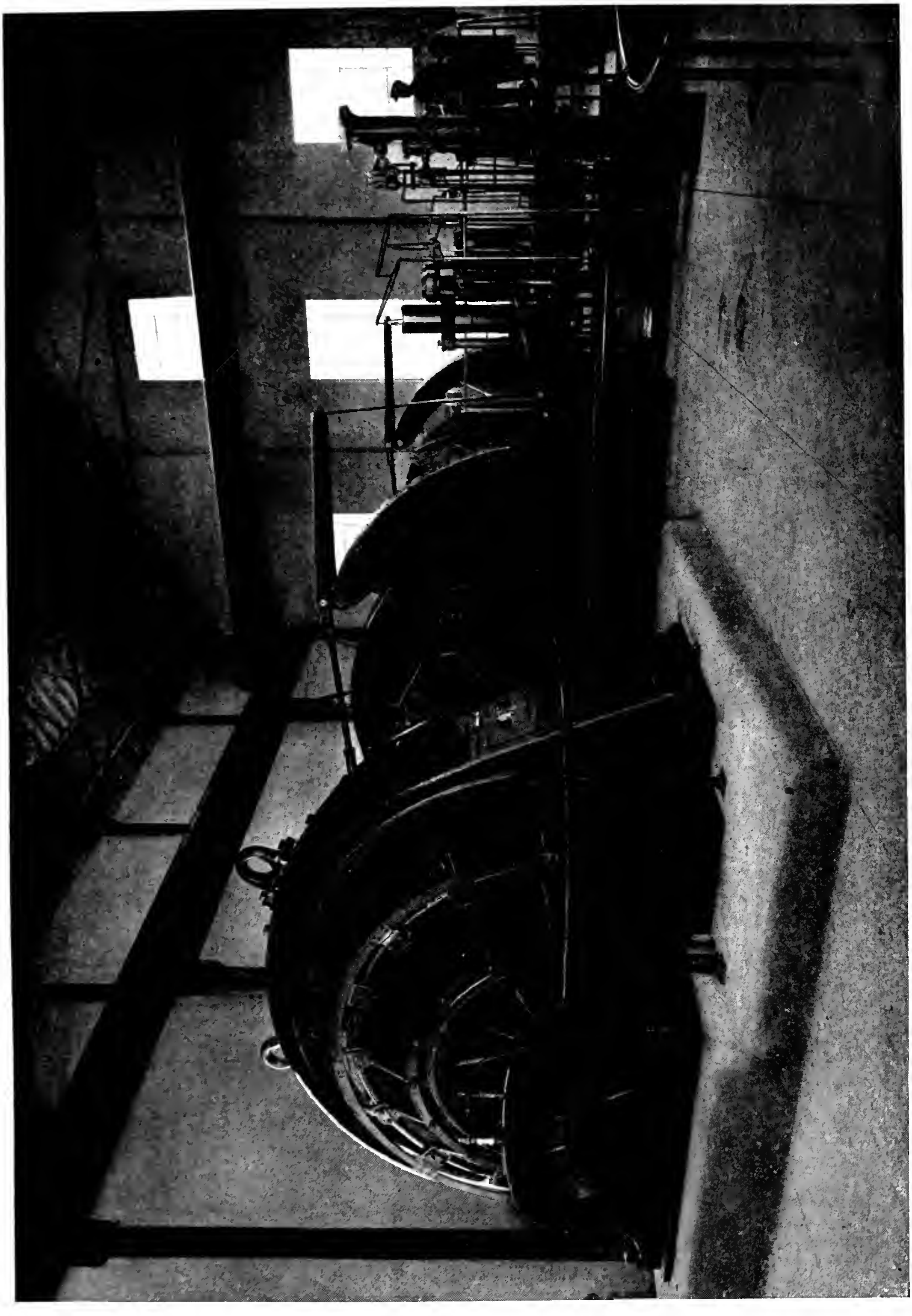


Fig. 1. View of Hoist Motor and Control Equipment

The calculated cycles of duty for the various levels, upon which the capacity of the electrical equipment was based, are shown in Fig. 2. It is practically impossible to exactly predict the actual operating schedule in this class of service, but to insure continuity of service, the most important consideration in installations of this kind, the first requisite is that the driving machinery have a safe margin of capacity. A heating guarantee of 40 deg. C. rise for all parts of the electrical equipment was therefore made, for continuous operation, when hoisting the specified hourly tonnage from any level. The efficiency curves for the various machines are given in Fig. 3.

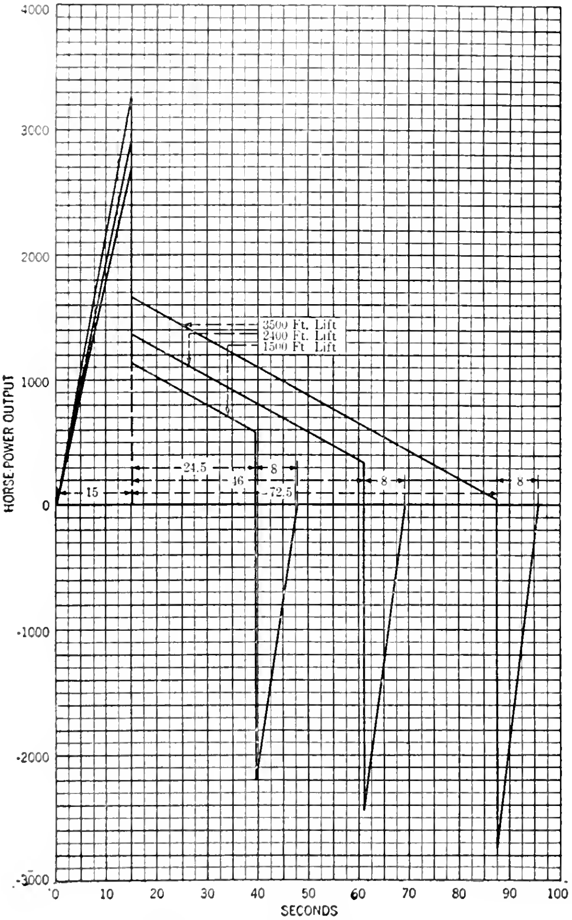


Fig. 2. Calculatd Hoist Duty Cycles

The estimated limits of demand from the power supply for the various levels were as follows:

1500-ft. level..........................650 kw.
2400-ft. level..........................760 kw.
3500-ft. level..........................865 kw.

The estimated overall efficiencies corresponding to the maximum hourly tonnages are as follows:

1500-ft. level—overall efficiency......46.2 per cent
2400-ft. level—overall efficiency......48.3 per cent
3500-ft. level—overall efficiency......47.7 per cent

The hoist is also used for practically all of the hoisting of an unproductive character, such as handling waste, men, timbers and supplies, and the hoisting of ore is done simultaneously with this sort of work.

The overall efficiency at which the ore is hoisted, that is, the ratio of the net work done in lifting a day's output of ore, to the kilowatt hours of electric energy used per day, is therefore much less than the figures given above. The mine is still in the development stage so that the unproductive work is a large proportion of the total required of the hoist.

At the present time the slip regulator is adjusted so as to limit the demand to 400 kw., as this is sufficient for the present depths, and the present manner of hoisting.

Description

The hoist consists of two steel-plate drums 10 ft. in diameter, grooved to hold 1900 ft. (579.1 m.) of 1.5 in. (38.1 mm.) steel cable per layer. The drums are mounted between three bearings, on a single shaft which has an extreme length of 40 ft. (12.1 m.). Each drum is provided with an axial-plate-type clutch and a parallel-motion post brake.

	100%	75%	50%	25%	Per Cent of Maximum Hourly Tonnage
1500 ft..............	267	200	133	67	Hourly tonnage
	2.46	2.58	2.83	3.57	Kw-hr. per ton
2400 ft..............	202	152	101	50.5	Hourly tonnage
	3.74	3.89	4.23	5.07	Kw-hr. per ton
3500 ft..............	155	116	77.5	38.7	Hourly tonnage
	5.54	5.75	6.17	7.45	Kw-hr. per ton

The diameter of the brake tread is 14 ft. (4.3 m.). The post brakes are made of structural shapes and steel plate to form a box girder. The brakes are released and the clutches operated by means of oil thrust cylinders with floating-level control, served by an oil accumulator in connection with a motor-driven triplex oil pump. A two-horse power motor supplies all the power required for the brake and clutch engines. The weights by which the brakes are set are in the form of cylinders moving vertically in guides formed by part of the brake engine. In addition to the regulation dial-type depth indicators, the drum flanges are entended to provide a surface for spotting marks.

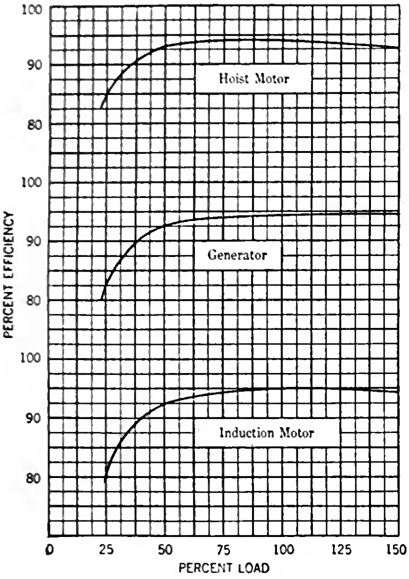


Fig. 3. Efficiency Curves

The bearings are all of the two-part type provided with gravity feed lubrication, in addition to oil rings. Sight-feed oil gauges are provided for all the bearings.

To the drum shaft is coupled an 1800-h.p., 80-r.p.m., 525-volt d-c. motor, front and side elevations of which are shown in Fig. 4. The motor is supplied with two bearings, and sole plates; the armature shaft is 14 in. (36 cm.) in diameter in bearing by 11 ft. 5 in. (3.4 m.) long, and has a forged half-coupling for connection to a corresponding half-coupling on the drum shaft. The armature is 9.5 ft. (2.8 m.) in diameter, while the outside diameter of the magnet frame is 14 ft. 5 in. (4.3 m.). The motor has 16 main field poles, the coils being wound for 125-volt excitation, and has commutating poles to insure good commutation at the heavy overloads encountered in the service. The bearings in addition to being ring oiled, receive lubrication from the gravity feed oiling system. The extreme length of the hoist, with motor, is 51 ft. 9 in. (15.7 m.).

The motor receives its power through a set, consisting of a generator driven by an induction motor, and a direct-coupled flywheel and exciter, shown in outline in Fig. 5.

The generator has a continuous capacity of 1300 kw., at 525 volts, and in order to successfully commutate the heavy currents at the low voltages, it is equipped with commutating poles, and, in addition, a compensating winding is placed in the pole faces of each of the 12 main poles. As in the case of the hoist motor, the main-field excitation is at 125 volts.

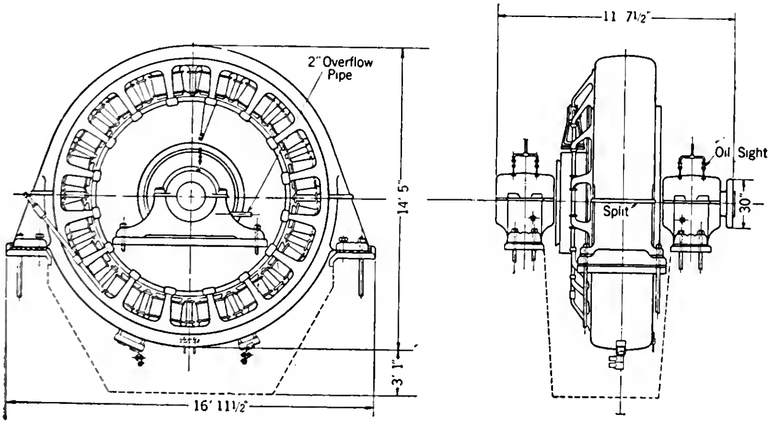


Fig. 4. Outline of Hoist Motor

The induction motor is rated 1150 h.p., three-phase, 60 cycles, 2200 volts, and has a synchronous speed of 514 r.p.m. It is of the wound-rotor type, with collectors for connection to the automatic slip regulator.

The flywheel is built up of rolled steel plates, 11 ft. 10 in. (3.6 m.) in diameter, so that the peripheral speed at synchronism is 19,100 feet (5.8 km.) per minute. The width of face is 20.5 in. (52 cm.) making the total weight 92,000 lbs. (41,730 kg.), exclusive of shaft. The plates are securely riveted together by steel rivets. The wheel is mounted between two bearings, and coupled to the generator by a Francke-type flexible coupling. A special grade of hard babbitt is used in the supporting bearings. Lubrication is afforded both by means of a low-pressure oil pump geared to the shaft supplemented by ring oiling. The geared pump begins to supply the bearings with oil practically as soon as the wheel turns over. The oil reservoir is sunk below the floor line at the end of the flywheel bearing, and contains coils for the circulation of cooling water.

In order to reduce the demand on the power system, when starting the set, a small motor-driven, high-pressure oil pump is provided to supply oil pressure under the bearings, this pump being put into operation only when required for this purpose. With this starting pump in operation, the set and wheel started from rest with 80 per cent of full-load current from the power system.

A close-fitting steel plate cover is provided for the wheel above the floor line, the pit in the foundation virtually forming the lower portion of the enclosing casing.

The exciter armature is mounted on an extension of the induction motor shaft, the field frame being bolted to an extension of the base. The exciter has a continuous rating of 21 kw., at 125 volts.

A cast iron base is provided under the induction motor and generator and sole plates under the flywheel bearings. The foundation under the various units is of re-inforced concrete extending down to the bed rock, insuring stability of alignment.

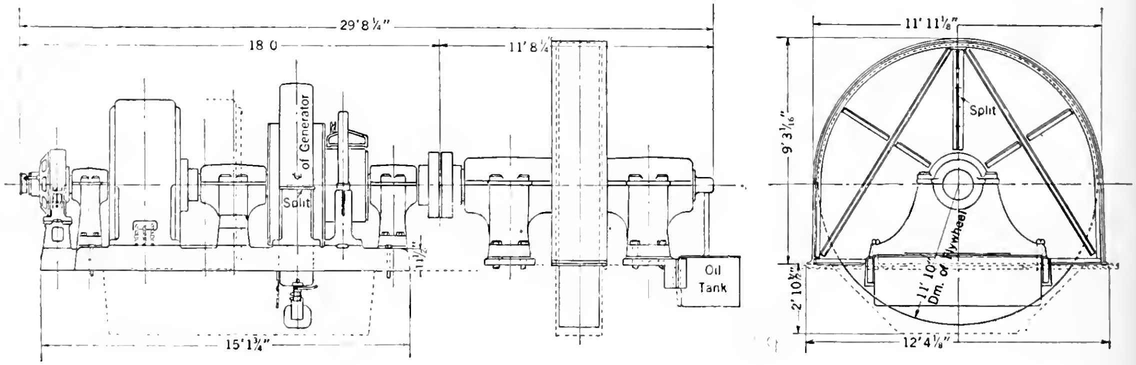


Fig. 5. Outline of Motor-Generator Set

Control

The hoist-motor speed and direction of rotation are controlled by varying the strength and reversing the polarity of the generator field. The field rheostat is provided with a large number of points giving a corresponding large number of speeds in both directions. Between the motor and generator there is inserted an overload circuit breaker and a single-pole line switch.

In the design and installation of the entire equipment, careful consideration was given to the matter of safety of operation, with the result that the effects due to carelessness on the part of the operators are obviated and protection to the men and apparatus is provided in almost every emergency.

The arrangement of the control levers is extremely simple, there being but one power lever, a forward movement corresponding to one direction of rotation and a backward movement, the reverse. This lever with the two brake levers, one on either side, completes the lever group. The clutches are operated by a throw, either in or out, of a crank through an arc of 180 deg.

A center-zero d-c. ammeter and voltmeter are mounted in the line of vision with the depth indicators.

A Welch safety device compels slowing down at the proper rate and provides protection against overwinding and overspeeding.

As an additional protection, limit switches actuated by the skips themselves are installed in the guides. These switches, as well as the Welch device, cause the d-c. circuit breaker to open, in addition to setting the hoist brakes. In general, any emergency which will cause the d-c. circuit breaker to open will cause the brakes to be applied. The d-c. circuit breaker will open under any of the following emergencies:

(a) Extreme d-c. overload
(b) Overwind top or bottom
(c) Loss of exciter voltage
(d) Loss of motor-field excitation
(e) Overspeed of hoist
(f) Overspeed of motor-generator set.

The opening of the main line a-c. oil circuit breaker will not open the d-c. circuit breaker, nor set the hoist brakes, but the operator is free to continue hoisting as long as the stored energy in the flywheel will permit. The opening of the line switch is indicated in the usual manner by the ringing of a bell. When the d-c. circuit breaker has been opened under any of the above mentioned emergencies, and an application of the brakes made, the brakes cannot be released until the controller lever has first been returned to the central position.

After an overwind has occurred, it is necessary for the hoist operator to throw a small switch before power can again be applied to the motor and motion is possible only in the lowering direction.

The total energy in the flywheel at 94 per cent synchronous speed is 117,000 h.p.-sec. of which approximately 50 per cent is available for operating the hoist in the event the set was disconnected from the power supply, the limitation being the speed at which the d-c. exciter is no longer able to hold up its voltage. If required, a complete trip with a fully loaded skip could be made from a depth of 1500 ft. (457.2 m.) on the energy of the flywheel, and a load of men could be hoisted from the deepest level.

Hoisting "out of balance" can be carried on without causing excessive speed reduction of the set nor necessitating a higher limit of demand from the power supply.

The liquid slip regulator used with this equipment is worthy of special mention, as being a decided departure in important details from the heretofore generally accepted design. In the latter, it was necessary to make a water-tight joint between the tile or porcelain vessels and the cooling tank, and also between the tile and the electrodes, clamping rings or draw volts being used for this purpose. In many instances, this construction in connection with temperature changes resulted in broken tiles, causing much annoyance.

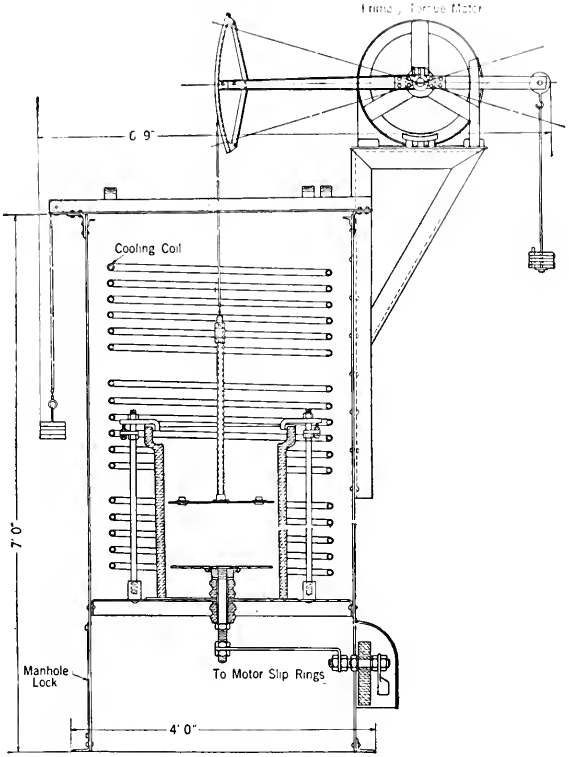


Fig. 6. Automatic Slip Regulator—Cross Section

In the present design, a sectional end view of which is shown in Fig. 6, the tiles are simply placed upon a rubber mat on the steel bottom of the tank, the only water-tight joint being that between the lower electrodes and the bottom of the tank. Only enough pressure is applied on the tile by the holding down bolts to hold it in place, the purpose of the tiles being merely to serve as barriers to prevent leakage between phases. Common sewer tiles are used for the purpose. The value of the input limit is adjusted in the usual manner by varying the number of the counterbalancing weights.

Tests

The first set of tests was for the purpose of analyzing a typical day's run under ordinary conditions, as regards its relation to the electrical equipment.

In the second test, measurements were made of the electrical quantities for a few trips, to determine, if possible, the efficiency while hoisting under known conditions.

In conducting the tests, the following measuring instruments were used:

Curve-drawing a-c. wattmeter—30-in. feed per hour.

Graphic recording a-c. ammeter.
Graphic recording d-c. ammeter.
Graphic recording d-c. voltmeter.
Indicating a-c. wattmeter.
Indicating a-c. voltmeter.
Indicating a-c. ammeter.
Indicating liquid column tachometer.
Integrating polyphase watthour meter.
Karlic tachograph.

First Test. A log was kept of all the movements of the hoist from 7:00 a.m. to 7:00 p.m., recording the time, the nature of all trips, quantity of ore, etc. The only instruments in use were the a-c. recording wattmeter—30 inches feed per hour, Karlic tachograph and integrating watthour meter.

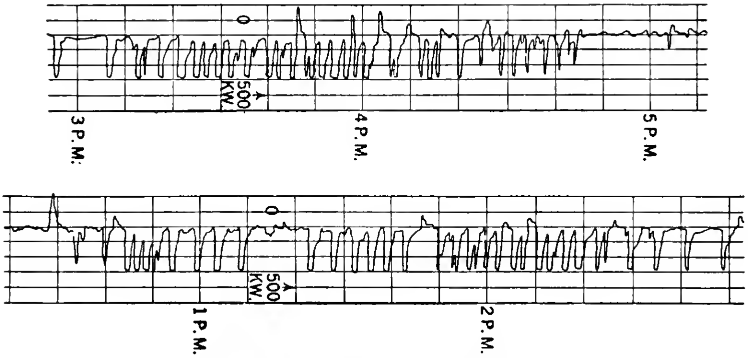


Fig. 7. Load Diagram of A-C. Input

As mentioned in the preceding paragraphs, there are no special designated periods of the day during which the hoist is used exclusively for the hoisting of ore, but this is carried on simultaneously with the unproductive work, as the conveying of timber, men and supplies. Moreover, the hoisting is of such an intermittent nature, that a straight line input to the motor-generator set is not even approximated, even at the low limit of 400 kw. Storage ore bins are under construction, but were not in operation at the time of the tests. To illustrate the character of the load, a portion of a typical day's load chart is shown in Fig. 7. This curve is reproduced from one of the daily records from the 3-in. per hour curve-drawing wattmeter included with the switchboard equipment.

The results of this test are given below.

Duration of test...............	12 hours
Actual time hoist in motion.....	3.5 hours
Total number of trips made.....	280
Number of skips of ore hoisted..	63
Percentage ore trips of total....	22.5 per cent
Total weight of ore hoisted.....	252.5 tons
Average weight of ore per skip..	4.01 tons
Average lift of ore............	1428 ft. (435.2 m.)
Net work done on ore-total.....	272 kw-hr.
Net work done on ore per trip..	4.32 kw-hr.
Net work done on ore per ton...	1.08 kw-hr.
Kw-hr. energy used during day..	1500 kw-hr.
Total kw-hr. energy used, including non-productive work per ton ore hoisted..............	5.94 kw-hr.
Kw-hr. used while hoist at rest..	680 kw-hr.
Kw-hr. used while hoisting ore..	582 kw-hr.
Kw-hr. returned to power system	14.6 kw-hr.
Overall efficiency while hoisting ore.......................	46.7 per cent

The trips with ore were divided among the levels as follows:

Level	No. Trips	Actual Lift
1000 ft. (304.8 m.)	6	1068.5 ft. (325.6 m.)
1100 ft.	3	1170.0 ft.
1200 ft.	3	1271.2 ft.
1300 ft.	20	1372.5 ft.
1400 ft.	7	1473.5 ft.
1500 ft.	22	1574.5 ft.
1800 ft. (548.6 m.)	2	1915.2 (583.7 m.)

The weight of ore hoisted was obtained by observing the number of cars dumped into each skip and using an average weight per car obtained from a large number of cars.

The calculated net work done in lifting the ore is subject to some error, inasmuch as during about 25 per cent of the trips timber or men were lowered in counterbalance with the ore. On the other hand, men were hoisted with the ore during about 20 per cent of the trips.

During about 50 per cent of the trips with ore, at least one stop was made between the loading level and the dump, there being a maximum number of six such stops. The total kilowatt hours used was obtained from readings taken on the watthour meter at the beginning and end of the test.

The energy used during the ore trips was obtained from the record made by the 30-in. per hour curve-drawing wattmeter with the aid of a rolling planimeter. The energy returned to the system was obtained in the same manner.

The time during which the hoist stood at rest was taken from the tachograph record.

Second Test. In order to secure as rapid hoisting as possible, there was accumulated at the 1500-ft. level, 30 cars of ore making possible 5 consecutive trips, as fast as the skips could be loaded.

Continuous records were made on the graphic meters of the d-c. voltage and current and of the a-c. current. A time marker marked every second on all of the records, simultaneously. The speed of the motor-generator set was read at frequent intervals and telegraphed to one of the graphic records at the instant of reading, a record of the consecutive readings being kept which was later transferred to the graphic record. The speed of the hoist motor was taken from the tachograph record and the 30-in. per hour recording wattmeter supplied a record of the power delivered to the motor-generator set.

Fig. 8 is a consolidation of all of the records and readings taken for the five consecutive trips.

By combining the two d-c. graphic records, the d-c. power curves were obtained.

The following conditions pertain to this test:

Hoisting done in balance:	
Duration of test	565 seconds
Lift	1574.5 ft. (479.9 m.)
Number of skips hoisted	5
Weight of ore hoisted	20.3 tons
Average weight per skip	4.06 tons
Net work done—total	24.1 hr.
Average time per trip	113 sec.
Actual running time total	310 sec.
Actual running time average per trip	62 sec.
Time at rest-total	255 sec.
Time at rest average per trip	51 sec.
Average time for acceleration	22 sec.
Average time for running at full speed	15.5 sec.
Average time for retardation	24.5 sec.
Average rope speed	1525 ft. per min.
Max. rope speed	2580 ft. per min.
Average speed of M-G. set	486 r.p.m.
Hoist motor input (exclusive shunt field)	32.64 kw-hr.
Hoist motor output	28.2 kw-hr.
Mechanical efficiency of hoist	83 per cent
Energy input to M-G. set total	50.5 kw-hr.
Kw-hr. per ton	2.49
Overall efficiency	47.7

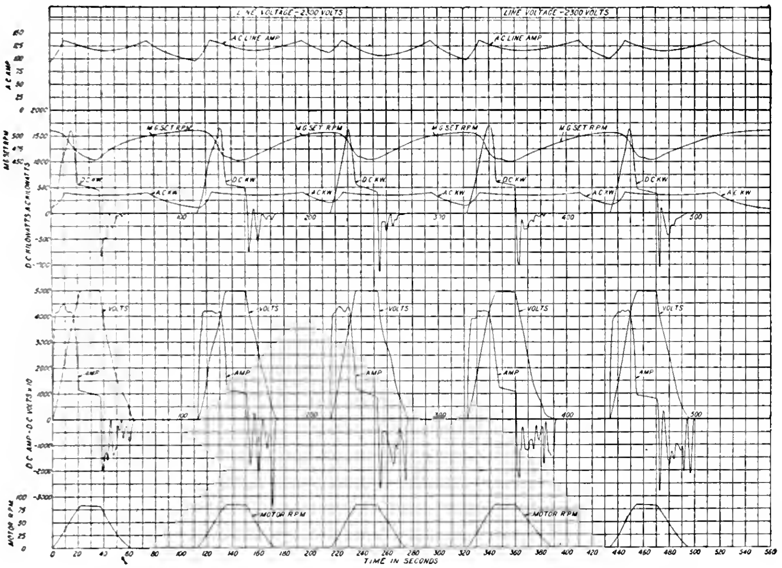


Fig. 8. Consolidated Curves from Tests

The energy dissipated in the various parts of the equipment was found to be as given in the table below.

	Kw-hr.	Per cent of net work
Losses in mechanical parts of hoist, sheaves, guides, etc.	4.1	17.0
Hoist motor losses	6.25	25.9
Generator losses	5.53	22.9
Induction motor losses	3.99	16.6
Flywheel losses	4.08	17.0
Slip regulator losses	2.12	8.8
Exciter losses	0.39	1.6
Total losses	26.46	109.8 per cent
Net work done on ore	24.1	

Total energy consumed 50.56 kw-hr

Overall efficiency...... 47.66 per cent

The hoist motor input was measured directly, and the output was obtained by deducting the losses which were based on factory test results.

The power input to the motor-generator set when running light as measured by the 30-in. per hour curve-drawing wattmeter, and checked by the indicating wattmeter was 80 kw. at 512 r.p.m. For the average speed of the set during the test this was taken at 78 kw.

The segregation of the losses in the set was made from results of tests made in the factory. The running light input to the set includes:

Flywheel bearing friction and windage

Generator bearing friction and windage.

Induction motor bearing friction and windage.

Induction motor core loss and running light copper loss.

Hoist motor shunt field (with economy resistance in series).

Exciter loss with load of motor field.

The same total loss in the equipment is obtained by adding to the running-light loss of the set, the increase in losses while under load, these being readily calculated. On this basis, the result is as follows:

Motor shunt field (increase)	0.248 kw-hr.
Ind. motor copper loss (increase)	0.223 kw-hr.
Exciter loss (increase)	0.060 kw-hr.
Generator losses (exclusive of friction and windage)	3.019 kw-hr.
Motor losses (exclusive of shunt field)	4.440 kw-hr.
Regulator losses	2,120 kw-hr.
Running light loss of set	12.250 kw-hr.
Friction in mech. parts of hoist	4.1 kw-hr.
Total	26.460 kw-hr.

An item not included in the above segregation consisting of approximately 0.25 kw-hr., used in operating the accumulator oil pump and the brake solenoid is also included in the running light input.

The total energy accounted for is therefore 50.81 kw-hr., as against 50.5 shown by the wattmeter.

The energy output of the generator, as obtained from the d-c. power curves by the aid of a rolling planimeter was 32.64 kw-hr., and the input 38.17 kw-hr. The input to the generator was at the rate of 243 kw., so that during the trips, approximately 27.5 kw-hr., were required from the flywheel. The average speed reduction of the set during hoisting was 10.6 per cent on the basis of which, the energy given up during the five cycles was 96,500 kw-sc. or 26.8 kw-hr., which checks fairly well with the figure given above.

In general, the test results check very well with the estimated performance. The friction losses in the hoist, sheaves, rope and guides proved unexpectedly low, but the shaft guides are in very good repair, and the cage rides almost as smoothly as a passenger elevator. Also, the hoist drums run true and with no interference with the brake shoe blocks; the head sheaves and idlers are well lubricated and easy running.

The efficiency of hoisting exceeded that anticipated, even with the light loads, the load per skip being but 80 per cent of that considered normal. With heavier loads, as when hoisting high grade copper ore, the efficiency would be further increased. Hoisting was done at slightly less than 50 per cent of the maximum rate for this level and the power consumption was 2.49 kw-hr. per ton as compared with 2.83 kw-hr., expected.

The tendency should be for the efficiency to increase at the greater depths, the maximum probably being reached at the intermediate levels.

The time for retardation is considerably longer than that used in calculating the duty cycles, and is the result of the rather close setting of the Welch safety device. At present there is no particular reason for rapid hoisting, and the management being inclined to a policy of safety, require the slower rate of retardation. A reduction in the retardation period would further tend to a betterment of the efficiency of hoisting.

The standby losses are considered particularly low for an equipment of this capacity. It is believed that by decreasing the loading time so as to obtain a more uniform input to the power set, decreasing the retardation period and bringing the load up to normal, the hoisting efficiency of this outfit will reach 50 per cent at this level.

It is believed that the results of these tests give fairly accurate information as to the operating characteristics of the hoist at Elm Orlu, and indicate, in general, the results to be expected of the performance of similar equipments in similar service.

PHOTOMETRIC TESTS OF FLOOD LIGHTING PROJECTORS

By S. L. E. Rose

Illuminating Engineering Laboratory, General Electric Company

The author outlines the commercial tests essential to the determination of the beam candle-power distribution of flood lighting apparatus, and tabulates constants necessary for calculating beam candle power in lumens under various conditions.—Editor.

So many different uses are being made of flood lighting apparatus today that it may be of interest to learn how the beam candle-power distribution curve of this type of lighting unit is obtained.

The ordinary photometer room is too short to permit of testing this class of apparatus on the standard photometers. The photometric readings on these units are usually made at a distance of 50 to 100 feet or even more, and where this distance is not available indoors the tests must be made outside after dark. It is much better, however, to make these tests indoors where possible, and by using shades to exclude external light the tests may be made during the day. Screens must also be used to prevent wall, floor and ceiling reflections from reaching the test plate of the photometer.

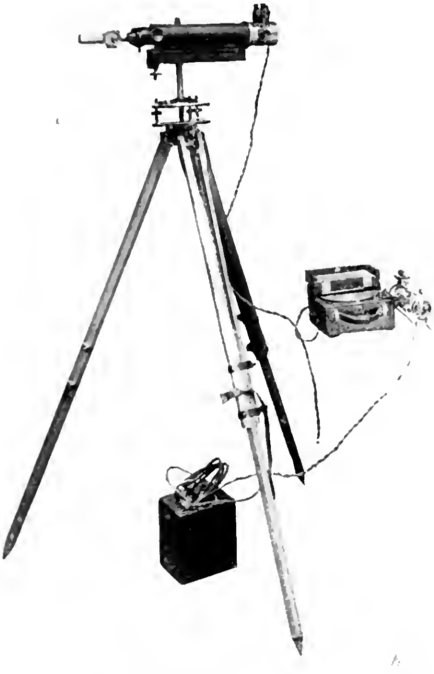


Fig. 1. Portable photometer and accessories

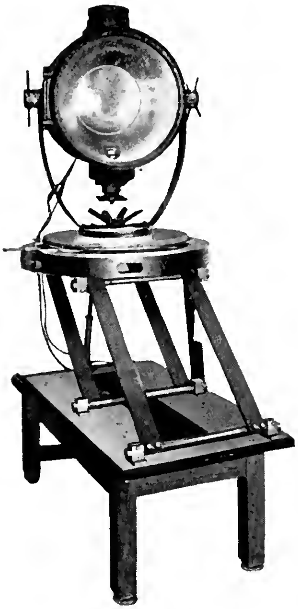


Fig. 2. Adjustable test table with flood light

There are two methods that may be used to obtain the distribution of candle-power across the beam. First, the projector may be kept stationary and the photometer moved across the beam from one side to the other. Second, the photometer may remain stationary and the projector turned on a vertical axis through the light source until the beam has traversed the photometer test plate.

Either method will yield the desired results, and which one to use will depend on local conditions, such as the number of tests to be made, whether tests are to be made indoors or outdoors, the available space, etc.

Where frequent tests will be required, and especially indoors, the second method will be found preferable, and is the one used at the Illuminating Engineering Laboratory.

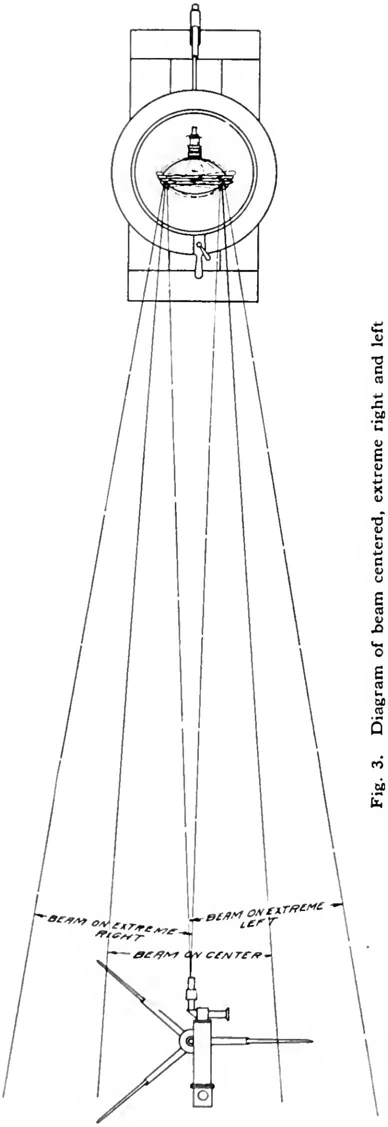


Fig. 3. Diagram of beam centered, extreme right and left

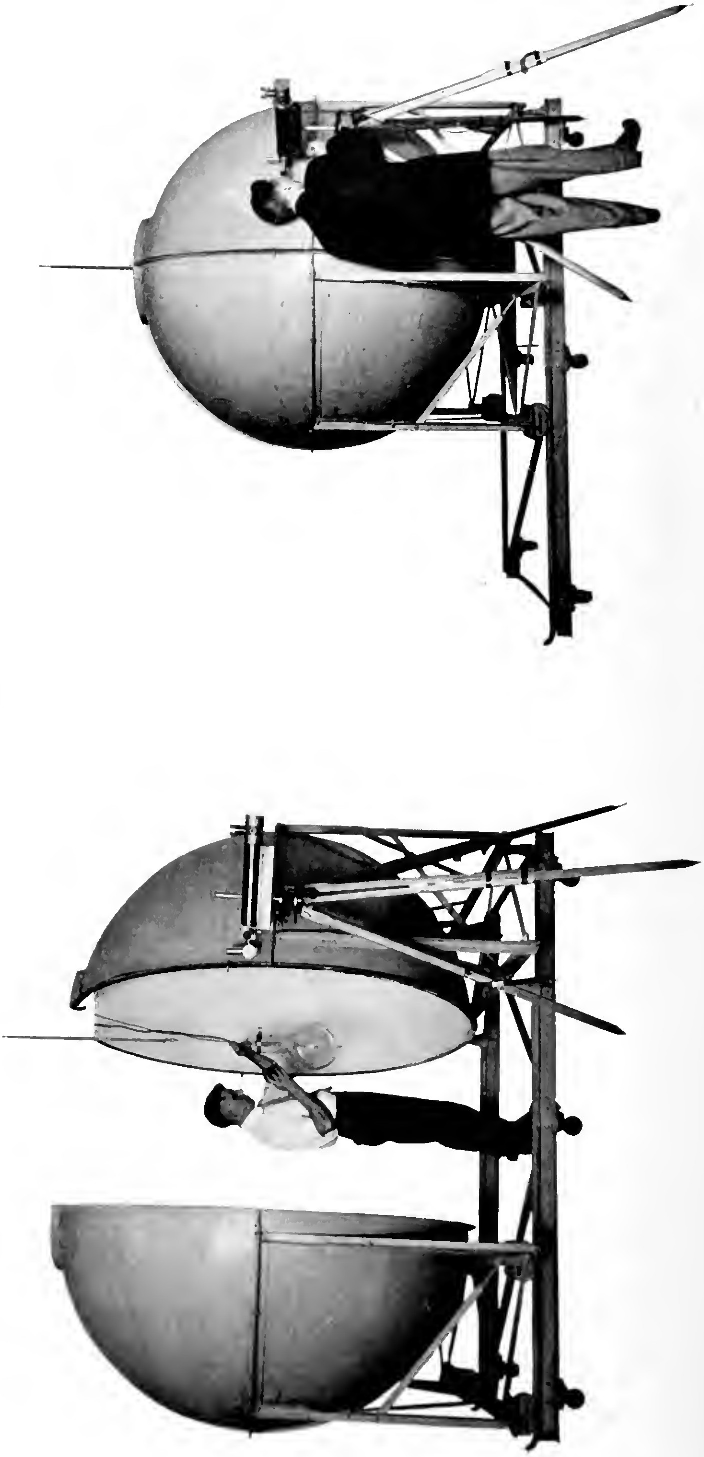


Fig. 4. Two views of sphere

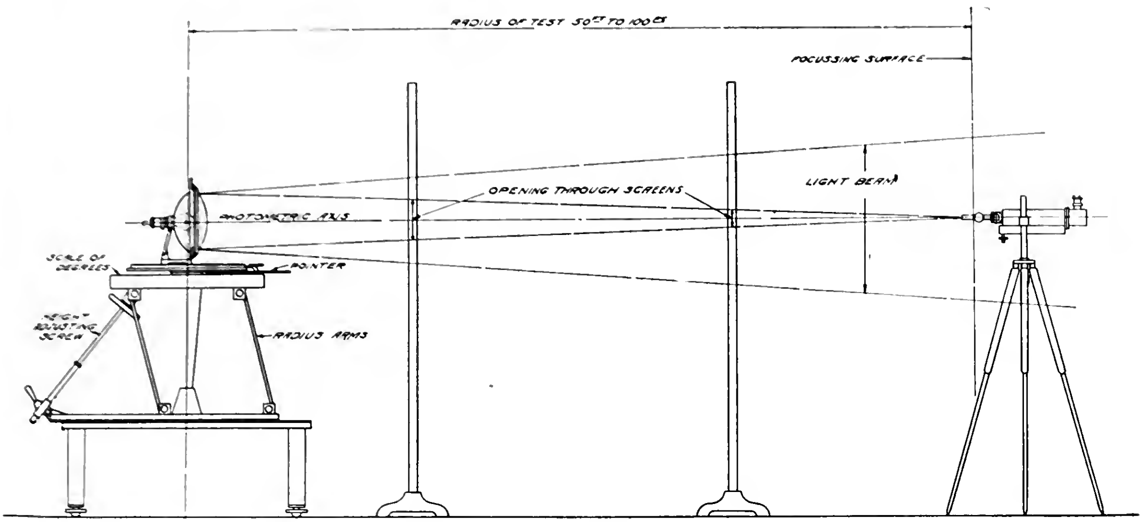


Fig. 5. Diagram of set up for test

TABLE I

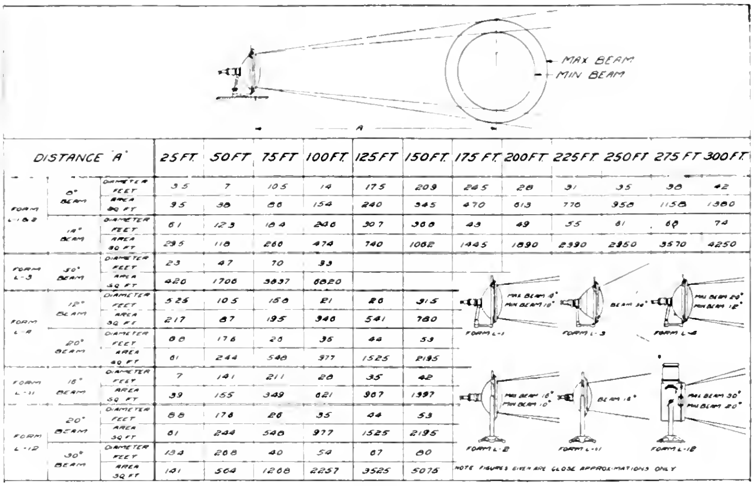
SPHERICAL CANDLE AND LUMEN CONSTANTS, ONE-DEGREE ZONES

Candles at	ZONE From	ZONE To	CONSTANT Hemispherical	CONSTANT Spherical	CONSTANT Lumen
0°	0	0° 30′	0.00004	0.00002	0.00025
1°	0° 30′	1° 30′	0.00030	0.00015	0.00188
2°	1° 30′	2° 30′	0.00061	0.00030	0.00383
3°	2° 30′	3° 30′	0.00092	0.00046	0.00578
4°	3° 30′	4° 30′	0.00121	0.00060	0.00760
5°	4° 30′	5° 30′	0.00152	0.00076	0.00955
6°	5° 30′	6° 30′	0.00183	0.00092	0.01150
7°	6° 30′	7° 30′	0.00213	0.00106	0.01338
8°	7° 30′	8° 30′	0.00242	0.00121	0.01521
9°	8° 30′	9° 30′	0.00273	0.00137	0.01715
10°	9° 30′	10° 30′	0.00304	0.00152	0.01910
11°	10° 30′	11° 30′	0.00333	0.00166	0.02092
12°	11° 30′	12° 30′	0.00362	0.00181	0.02275
13°	12° 30′	13° 30′	0.00393	0.00197	0.02469
14°	13° 30′	14° 30′	0.00422	0.00211	0.02652
15°	14° 30′	15° 30′	0.00452	0.00226	0.02840
16°	15° 30′	16° 30′	0.00481	0.00240	0.03022
17°	16° 30′	17° 30′	0.00510	0.00255	0.03204
18°	17° 30′	18° 30′	0.00540	0.00270	0.03393
19°	18° 30′	19° 30′	0.00568	0.00284	0.03569
20°	19° 30′	20° 30′	0.00597	0.00298	0.03751
21°	20° 30′	21° 30′	0.00625	0.00313	0.03927
22°	21° 30′	22° 30′	0.00654	0.00327	0.04109
23°	22° 30′	23° 30′	0.00682	0.00341	0.04285

TABLE II

SPHERICAL CANDLE AND LUMEN CONSTANTS, TWO-DEGREE ZONES

Candles at	ZONE From	ZONE To	CONSTANT Hemispherical	CONSTANT Spherical	CONSTANT Lumen
0°	0°	1°	0.00015	0.00008	0.00094
2°	1°	3°	0.00122	0.00061	0.00767
4°	3°	5°	0.00244	0.00122	0.01533
6°	5°	7°	0.00364	0.00182	0.02287
8°	7°	9°	0.00486	0.00243	0.03054
10°	9°	11°	0.00606	0.00303	0.03808
12°	11°	13°	0.00726	0.00363	0.04562
14°	13°	15°	0.00844	0.00422	0.05303
16°	15°	17°	0.00963	0.00481	0.06051
18°	17°	19°	0.01078	0.00539	0.06773
20°	19°	21°	0.01194	0.00597	0.07502
22°	21°	23°	0.01308	0.00654	0.08218
24°	23°	25°	0.01419	0.00710	0.08916
26°	25°	27°	0.01530	0.00765	0.09613
28°	27°	29°	0.01639	0.00820	0.10298
30°	29°	31°	0.01745	0.00872	0.10964
32°	31°	33°	0.01850	0.00925	0.11624
34°	33°	35°	0.01952	0.00976	0.12265
36°	35°	37°	0.02051	0.01025	0.12887
38°	37°	39°	0.02149	0.01075	0.13503
40°	39°	41°	0.02244	0.01122	0.14100
42°	41°	43°	0.02336	0.01168	0.14678
44°	43°	45°	0.02424	0.01212	0.15230
46°	45°	47°	0.02511	0.01255	0.15777



DISTANCE "A"			25 FT.	50 FT.	75 FT.	100 FT.	125 FT.	150 FT.	175 FT.	200 FT.	225 FT.	250 FT.	275 FT.	300 FT.
FORM L-1 & 2	0° BEAM	DIAMETER FEET	3.5	7	10.5	14	17.5	20.9	24.5	28	31	35	38	42
		AREA SQ FT	9.5	38	86	154	240	345	470	613	776	958	1158	1380
	14° BEAM	DIAMETER FEET	6.1	12.3	18.4	24.6	30.7	36.8	43	49	55	61	68	74
		AREA SQ FT	29.5	118	266	474	740	1062	1445	1890	2390	2950	3570	4250
FORM L-3	50° BEAM	DIAMETER FEET	23	47	70	93								
		AREA SQ FT	420	1706	3837	6820								
FORM L-4	12° BEAM	DIAMETER FEET	5.25	10.5	15.8	21	26	31.5						
		AREA SQ FT	21.7	87	195	346	541	780						
	20° BEAM	DIAMETER FEET	8.8	17.6	26	35	44	53						
		AREA SQ FT	61	244	548	977	1525	2195						
FORM L-11	16° BEAM	DIAMETER FEET	7	14.1	21.1	28	35	42						
		AREA SQ FT	39	155	349	621	967	1397						
FORM L-12	20° BEAM	DIAMETER FEET	8.8	17.6	26	35	44	53						
		AREA SQ FT	61	244	546	977	1525	2195						
	30° BEAM	DIAMETER FEET	13.4	26.8	40	54	67	80						
		AREA SQ FT	141	564	1268	2257	3525	5076						

NOTE FIGURES GIVEN ARE CLOSE APPROXIMATIONS ONLY

Fig. 7

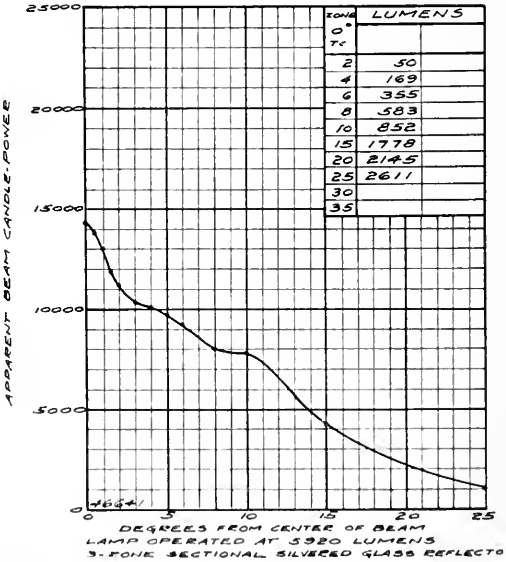
The equipment necessary is a portable photometer with accessories (Fig. 1), a test table adjustable for height and fitted with a revolving top upon which to mount the projector (Fig. 2), a curtain or light colored surface upon which to focus the beam; and necessary screens, ammeter and voltmeter.

TABLE III

SPHERICAL CANDLE AND LUMEN CONSTANTS, FIVE-DEGREE ZONES

Candles at	ZONE		CONSTANT		
	From	To	Hemispherical	Spherical	Lumen
0°	0	2° 30′	0.00095	0.00048	0.0060
5°	2° 30′	7° 30′	0.00761	0.00380	0.0478
10°	7° 30′	12° 30′	0.01514	0.00757	0.0951
15°	12° 30′	17° 30′	0.02258	0.01129	0.1419
20°	17° 30′	22° 30′	0.02984	0.01492	0.1875
25°	22° 30′	27° 30′	0.03687	0.01844	0.2317
30°	27° 30′	32° 30′	0.04362	0.02181	0.2741
35°	32° 30′	37° 30′	0.05004	0.02502	0.3144
40°	37° 30′	42° 30′	0.05607	0.02803	0.3523
45°	42° 30′	47° 30′	0.06169	0.03085	0.3876
50°	47° 30′	52° 30′	0.06683	0.03341	0.4199
55°	52° 30′	57° 30′	0.07146	0.03573	0.4490
60°	57° 30′	62° 30′	0.07555	0.03778	0.4747
65°	62° 30′	67° 30′	0.07907	0.03954	0.4968
70°	67° 30′	72° 30′	0.08197	0.04098	0.5150
75°	72° 30′	77° 30′	0.08427	0.04214	0.5295
80°	77° 30′	82° 30′	0.08591	0.04295	0.5398
85°	82° 30′	87° 30′	0.08691	0.04345	0.5461
90°	87° 30′	90°	0.04362	0.02181	0.2741

The screens should be arranged so that they can be moved out of the way for focusing or for observation of the beam for evenness of intensity, proper centering on photometer, etc.



ZONE 0° TO	LUMENS
2	50
4	169
6	355
8	583
10	852
15	1778
20	2145
25	2611
30	
35	

Fig. 6. Curve showing the initial distribution of candle-power in a horizontal plane from a Form L3 flood light projector with 400-watt Mazda C flood lighting lamps

The focusing surface in use at this Laboratory is a wooden partition painted white, with a small hole on the photometer axis through which the tube of the photometer projects. This arrangement has several

TABLE IV

SPHERICAL CANDLE AND LUMEN CONSTANTS, TEN-DEGREE ZONES

Candles at	ZONE		CONSTANT		
	From	To	Hemispherical	Spherical	Lumen
5°	0	10°	0.0152	0.00760	0.095
15°	10°	20°	0.0451	0.02256	0.284
25°	20°	30°	0.0737	0.03683	0.463
35°	30°	40°	0.1000	0.05000	0.628
45°	40°	50°	0.1232	0.06162	0.774
55°	50°	60°	0.1428	0.07140	0.897
65°	60°	70°	0.1580	0.07899	0.993
75°	70°	80°	0.1684	0.08418	1.058
85°	80°	90°	0.1736	0.08682	0.091

advantages, viz.; it enables the test to commence immediately after focusing without having to roll up a curtain or move the photometer into position; the test plate of the photometer is in the same vertical plane as the surface used for focusing; and the photometer operator's eyes are protected from the intense light of the beam at all times.

On the adjustable stand at the top is a pointer which can be rotated independently of the top or clamped to it so that they turn together. Under this pointer on the stationary part is a scale graduated in degrees both ways from zero. The scale is divided in one-quarter degrees from 0° to 20°, and every 5° from 20° to 90°. This is done so readings may be made at very small angular intervals near the center of the beam where the

TABLE V

LUMEN CONSTANTS FOR PROJECTOR BEAMS, SPECIAL SPACING

Candles at	TEN-DEGREE BEAM			Candles at	TWENTY-DEGREE BEAM		
	Zone		Lumen Constant		Zone		Lumen Constant
	From	To			From	To	
0° 15′	0°	0° 30′	0.00024	0° 30′	0°	1°	0.0010
0° 45′	0° 30′	1°	0.00072	1° 30′	1°	2°	0.0029
1° 15′	1°	1° 30′	0.00120	2° 30′	2°	3°	0.0048
1° 45′	1° 30′	2°	0.00168	3° 30′	3°	4°	0.0067
2° 15′	2°	2° 30′	0.00215	4° 30′	4°	5°	0.0086
2° 45′	2° 30′	3°	0.00263	5° 30′	5°	6°	0.0105
3° 15′	3°	3° 30′	0.00311	6° 30′	6°	7°	0.0124
3° 45′	3° 30′	4°	0.00359	7° 30′	7°	8°	0.0143
4° 15′	4°	4° 30′	0.00407	8° 30′	8°	9°	0.0162
4° 45′	4° 30′	5°	0.00455	9° 30′	9°	10°	0.0181

Candles at	THIRTY-DEGREE BEAM			Candles at	FORTY-DEGREE BEAM		
	Zone		Lumen Constant		Zone		Lumen Constant
	From	To			From	To	
0° 45′	0°	1° 30′	0.0022	1°	0°	2°	0.0038
2° 15′	1° 30′	3°	0.0065	3°	2°	4°	0.0115
3° 45′	3°	4° 30′	0.0108	5°	4°	6°	0.0192
5° 15′	4° 30′	6°	0.0152	7°	6°	8°	0.0266
6° 45′	6°	7° 30′	0.0194	9°	8°	10°	0.0343
8° 15′	7° 30′	9°	0.0236	11°	10°	12°	0.0419
9° 45′	9°	10° 30′	0.0279	13°	12°	14°	0.0493
11° 15′	10° 30′	12°	0.0321	15°	14°	16°	0.0568
12° 45′	12°	13° 30′	0.0363	17°	16°	18°	0.0641
14° 15′	13° 30′	15°	0.0405	19°	18°	20°	0.0714

intensity is usually changing rapidly. The angular intervals may be increased as we get farther away from the center. The foregoing arrangement also offers a quick and accurate means of centering the beam horizontally on the photometer. This is accomplished in the following manner: With the pointer loose, the beam is centered as close as possible by the eye; the pointer is then moved to zero and clamped to the revolving top. Next, turn the revolving top both ways and note the angles when the edge of the beam is at the photometer tube. If they are equal, the beam is centered; if they are not equal, loosen the pointer and move it one half the difference, keeping the edge of the beam on the photometer tube; then clamp it. Repeat this operation if necessary to check the centering (see Fig. 3).

After the unit to be tested is properly set up and focused, the screens are moved into position (see Fig. 5), and readings taken at the center of the beam, i.e., with the pointer at 0°. The unit is then turned to the right and readings taken at predetermined angular interval, until the edge of the beam is reached. Then go back to zero and again turn the projector to the left until the edge of the beam is reached. In order to get a good average, it sometimes is desirable to make tests in at least three planes 120° apart, in which case some means must be provided for turning the unit about the photometric axis. Then all of the readings at the same angle each side of the center are averaged for the final curve.

If the efficiency of the unit is desired the total lumens of the bare lamp must be obtained, and for this purpose a sphere is used, Fig. 4. The lumens in the beam can be calculated from the beam candle-power test and the ratio of the latter to the former gives the efficiency. Tables 1 to 5 give constants for calculating lumens of beams of different angular widths.

The results of beam candle-power tests are usually plotted on rectangular co-ordinates and other necessary data for applying the results should also be given on the same sheet (see Fig. 6).

A table of data giving areas covered by the beams of various flood lighting projectors, when striking a surface normally at different distances, is given in Fig. 7 and may prove of value in using this class of apparatus.

HIGH TEMPERATURE MEASUREMENT WITH THE OPTICAL PYROMETER

By W. E. Forsythe

Nela Research Laboratory, National Lamp Works of General Electric Company

The adaptability of the research facilities of a large manufacturing company to the need for commercially practicable equipment is aptly illustrated by this article. The various methods employed in the measurement of very high temperatures are discussed and the practical utility of one of these methods is illustrated by results secured by the employment of relatively unskilled assistants.—Editor.

In measuring ordinary temperatures the measuring instrument, or a portion of it, is generally placed in very close contact with the body whose temperature is desired. However, if the temperature of the source is continually raised, a point is soon reached where no known substance will, in general, remain constant in any of its temperature measuring properties if placed in direct contact with the source at this high temperature. Also, it is occasionally necessary to measure the temperature of a source that is so small or so situated that it would be very hard to determine the temperature by bringing the measuring instrument into direct contact with the source. When the above conditions exist, advantage is taken of the well known fact that all bodies when at sufficiently high temperatures send out radiation in amounts readily measurable. This radiation has been found to be related to the temperature.

The temperatures of very hot bodies have probably always been judged by the color or the intensity of the light given off. With practice, one can give an estimate that will probably be within 50 to 100 deg. C. of the correct value. However, if judgment is left to the eye alone, very much larger errors are sometimes apt to be made due to the use that has been made of the eye just previous to the time the estimate is made. If any attempt is made to secure accurate estimates by eye observations, a comparison source is necessary. The introduction of a comparison source is the first step towards an optical pyrometer; an optical pyrometer consists of a comparison source and some convenient arrangement for matching this source, either in brightness or in color, against the source studied. Optical pyrometers may differ either in the method of introducing the comparison source or in the method used in matching the comparison source against the source studied.

In Fig. 1 is shown diagrammatically the arrangement used in one form of the Le Chatelier optical pyrometer. The light from the comparison source at *C* is reflected into the eyepiece by the mirror *E* so arranged

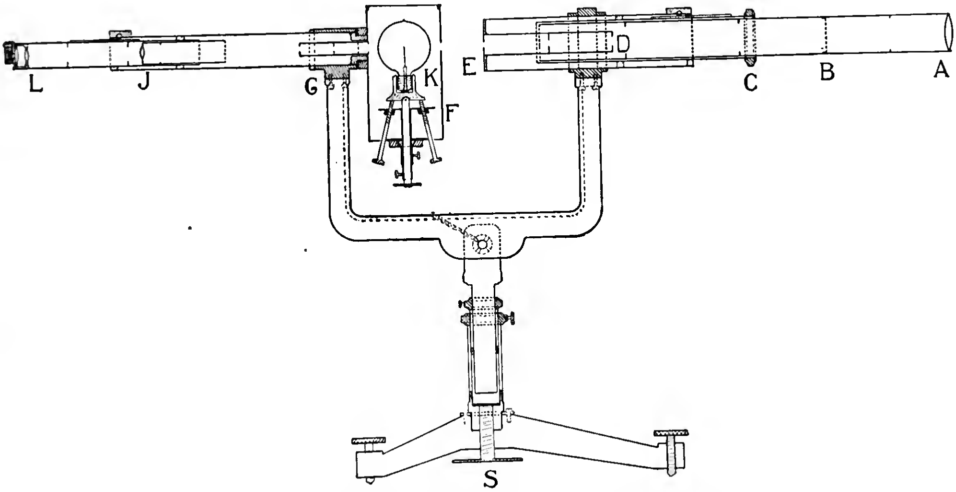


Fig. 1. Diagram showing arrangements used in one form of LeChatelier optical pyrometer

that one-half of the field is illuminated by light from the comparison source and the other by light from the source studied. The match is obtained either by varying the intensity of the comparison source or by varying the size of the opening before the objective lens *D*. In the Wanner optical pyrometer, the beams of light from the comparison source and the source studied are so arranged that, by the use of a polarizing device, the two beams as viewed through the eyepiece are polarized in a plane at right angles to each other. By rotating another nicol located in the eyepiece, the two sources can be made to appear the same in brightness.

The Holborn-Kurlbaum form of the Morse Optical pyrometer arrangement is shown diagrammatically in Fig. 2. The comparison source in this case is the lamp filament *D* which is placed in the plane where the image of the source studied is brought to a focus by the objective lens. Brightness matches are obtained by varying the current through the pyrometer filament *D*.

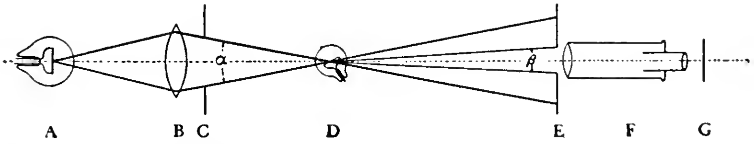


Fig. 2. Diagram showing arrangements used in the Holborn-Kurlbaum optical pyrometer

The LeChatelier pyrometer, as it is generally constructed, requires a comparatively large source in order to be able to make temperature measurements. If the brightness of the image of the source is varied by changing the size of the opening before the objective lens, the calibration of the instrument must take account of this change in the size of the cone of rays used.

In working with the Wanner pyrometer almost all the troubles due to polarizing instruments are encountered. The scale is not uniform for the entire range of the instrument. If for any reason the light from the source is polarized a very great error may be made. A third difficulty is that there is no possibility of seeing, through the instrument, the object whose temperature is being measured.

The Holborn-Kurlbaum optical pyrometer is not free from difficulties, but most of the difficulties are quite well understood and various methods have been devised for either overcoming or avoiding them. The first fact to be noted is that there must be two limiting diaphragms; one located between the pyrometer lamp and the eyepiece, the other between the pyrometer lamp and the objective lens. The first fixed limiting diaphragm is necessary in order that the light from the source studied and the pyrometer lamp will be limited to the same cone. The second fixed diaphragm, limiting a larger cone than the first, is necessary in order to avoid errors due to diffraction (1) at the pyrometer lamp filament. By the use of this diaphragm the observed brightness of the source studied will not depend upon the distance it is from the pyrometer; in other words, upon the position of the pyrometer objective lens. In using the pyrometer, care should be taken to have both of these diaphragms filled with light from the point of the source studied.

If a rotating sector is used to extend the scale beyond that of the standard furnace, care must be taken as to the location of the sector. It has been shown (2) that this sector must be located as near the pyrometer lamp as possible. If a rotating sector of small transmission is placed near the objective lens, the definition will be poor and also the value of the temperature obtained for a small source will be less than if the rotating sector is located near the pyrometer lamp.

This pyrometer has the great advantage that it is possible to observe directly, through the instrument, the source whose temperature is being determined. Thus the temperature can be measured at almost any point of the source desired.

The temperature of a radiating solid may be determined by a measurement of the intensity of the radiation for a particular wave-length interval or by a determination of the relative distribution of energy for the entire visible spectrum. Neither of these measurements will in general give the true temperature, the difference depending upon

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(1) Physical Review N.S. Vol. IV, No. 3, 1914; p. 163.
(2) Astrophysical Journal, Vol. XLII, No. 4, 1915; p. 303.

the radiating properties of the body under consideration. Measurements on the relative distribution or "color" of the emitted radiation may give a value higher or lower than the true temperature, depending upon the relative emissivity from one end of the visible spectrum to the other. Values obtained from such measurements are called color temperatures. Thus, the color temperature of any source is the temperature at which it is necessary to operate a black body in order to obtain radiation of the same color as that given by the source studied.

A true temperature cannot be determined from measurements with an optical pyrometer of the brightness of a source for a particular wave-length interval, unless the emissivity of the substance studied is known for this wave-length.

If a temperature is calculated from the values of the emitted radiation for a particular wave-length interval, a value for the temperature will be obtained that is in general lower than the true temperature. This temperature has been called the "black-body-brightness (3) temperature," meaning by this that a black body must have that temperature in order to have the same intensity of emitted radiation or brightness for the particular wave-length interval. Thus, in general, different black-body-brightness temperatures would be obtained for different wave-lengths.

The temperature scale for optical pyrometers is based upon the relation between the temperature and the intensity of the radiation emitted for a particular wave-length interval. This relation is represented for the visible spectrum for the black body by Wein's equation

$$E_\lambda = c_1 \lambda^{-5} e^{-c_2/\lambda T}$$

Theoretically, it is necessary to use some method of obtaining monochromatic radiation. In practice, it has generally been found sufficient to use a so-called monochromatic glass before the eyepiece of the pyrometer. For the most part a red glass has been used as the monochromatic screen. In general, red screens have been used rather than blue screens or those having a transmission band near the central part of the visible spectrum because for sources at low temperatures it is the red radiation that first becomes visible. Another good reason for using the red screen is that there exists better red glass screens than green or blue screens. A colored glass to be suitable for a monochromatic screen must have a somewhat narrow transmission band. This is necessary in order that there will not be enough color difference between the source studied and the comparison source to prevent accurate comparisons from being made. As there may be at times more than a thousand degrees difference in temperature between the two sources compared, it will be seen that this is very important.

When the monochromatic glass is used, it is the brightness from the source for a rather wide range of wave-length that is compared with the brightness through the same screen from the standard source. An optical pyrometer can be so calibrated and so used as to make unnecessary a knowledge of the transmission of the screen used. To do this, it is necessary to have a standard furnace that can be operated up to the highest temperature that it is desired to measure with the optical pyrometer. However, if an attempt is made either to calibrate the pyrometer from a standard source (4) held at a single temperature or to extend the temperature scale beyond that of the standard source used in calibration, a knowledge of what is called the effective wave-length is necessary. A knowledge of the effective wave-length is also convenient in some cases if the optical pyrommeter is used to measure the temperature of a source other than the black body.

By the effective wave-length (5) of a screen is meant a wave-length such that the ratio of the intensities of the emitted radiation for this wave-length from a black body at two particular temperatures is the same as the ratio of the brightnesses of the black body through the screen used for the same temperatures.

When the black-body-brightness temperature of a source is measured with an optical pyrometer with a so-called monochromatic screen before the eyepiece, what is really measured is the brightness of the source through the screen. The value of the brightness thus obtained corresponds to a certain temperature, say T, if the same brightness were obtained from a black body. Therefore, call the temperature of the source a black-body-brightness temperature S, where S equals T. As this is a black-body-brightness temperature, to what wave-length shall it be ascribed(6)? The brightness temperature S must be ascribed to a wave-length such that the energy emitted by a

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(3) A discussion of this term will be given in a paper on "An Announcement of the Temperature Scale Adopted for Use in the Laboratories of the General Electric Company." The paper will appear in an early number of this magazine.

(4) Mendenhall, Physical Review, 33, 1911; p. 74.

(5) Astrophysical Journal, Vol. XLII, No. 4, 1915; p. 294.

(6) Physical Review, November, 1917.

black body per unit area at temperature T for this wave-length will equal that emitted per unit area by the source for the same wave-length. Thus there are two sources with different spectral distributions that have the same brightness when observed through the red screen, a black body at temperature T and the source being studied which is at a brightness temperature S. Call the color temperature of the source studied T_c. As these two distributions are different and yet the sources have the same brightness, the curves representing these distributions must cross if they are plotted with energy emitted per unit area against wave-length. The point at which these two curves cross evidently gives the wave-length to which the brightness temperature S is to be ascribed.

It will now be shown that this brightness temperature is to be ascribed to the effective wave-length for the screen used between the black body at a temperature T_c and at T. The effective wave-length λ_e between a black body at T_c and T is so defined that

$$\frac{B_T}{B_{T_c}} = \left(\frac{J_T}{J_{T_c}}\right)_{\lambda_e}$$

where B_T and B_{T_c} represent the brightnesses for the black body at temperatures T and T_c, through the screen used and J_T and J_{T_c} represent the energy emitted at temperatures T and T_c for the wave-length interval whose center is at λ_e.

Now if the source studied is considered, it will be seen from the definition of color temperature that its distribution of energy corresponds to that of a black body at T_c, the difference being that each ordinate of the curve representing this distribution bears a constant ratio to the corresponding ordinate of the black body at temperature T_c. As each ordinate of the curve representing the distribution of energy from the source studied is a certain fraction $\frac{1}{K}$ of that for a black body at temperature T_c it can easily be seen that the brightness will be reduced the same amount. Thus

(B_{T_c}) black body $= K$ (B_S) source studied from which it follows

$$\frac{B_T}{B_{T_c}} = \frac{B_T}{KB_S} = \left(\frac{J_T}{J_{T_c}}\right)_{\lambda_e} = \left(\frac{T}{KJ_S}\right)_{\lambda_e}$$

or

$$\frac{B_T}{B_S} = 1 = \left(\frac{J_T}{J_S}\right)_{\lambda_e}$$

where B_S and J_S correspond to the brightness through the screen and the energy from the source studied.

Thus, the effective wave-length between the two distributions does not depend upon the absolute value of the radiation but upon the distribution. From this it follows that the brightness temperature S previously discussed is to be ascribed to the effective wave-length between temperatures T and T_c of a black body.

As the brightness temperatures of a source are measured using a particular screen before the eyepiece, there will be a variation in the wave-length to which these temperatures are to be ascribed. Sometimes it is desirable to know the brightness temperature over quite a range for the same wave-length. If the color temperature of the source is known, the brightness temperature can be calculated for any wave-length when it is known for one wave-length. Thus for a source at a temperature T, using Wien's equation and the conditions that hold for color match, the following relation between two brightness temperatures (S_1 and S_2) for two wave-lengths (λ_1 and λ_2) can be derived.

$$\frac{1}{S_2} = \frac{\lambda_2}{\lambda_1}\left[\frac{1}{S_1} - \frac{1}{T_c}\right] + \frac{1}{T_c}$$

If a double thickness (6.8 mm.) of the kind of red glass known as Jena Rotfilter No. 4512 is used before the eyepiece of the pyrometer, this correction when applied to the brightness temperature of tungsten will be small. It has been shown that the effective wave-length changes from 0.6657μ for the range between brightness and color temperature of tungsten at a brightness temperature of 1600 deg. K to 0.6626μ for this range for a brightness temperature of 3000 deg. K. If the brightness temperatures are corrected to a wave-length 0.6657μ, this correction will amount to about -2 deg. K at a brightness temperature of 3000 deg. K. It is thus seen that for most work when using this screen this correction will be negligible.

In Fig. 3 is shown a diagram of a form of the Holborn-Kurlbaum pyrometer that has been constructed for use in the Nela Research Laboratory(7).

Tungsten filament pyrometer lamps have a very long life as they are used in this kind of work. They are seldom operated at a brightness above that necessary to match that of a black-body at the temperature of melting palladium (1828 deg. K). (3) A particular pyrometer lamp that has been in use for about two years, and has during the

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(7) Astrophysical Journal 43, 1916; p. 295.

(3) A discussion of this term will be given in a paper on "An Announcement of the Temperature Scale Adopted for Use in the Laboratories of the General Electric Company." The paper will appear in an early number of this magazine.

greater part of that time been used almost every day, shows an exceptionally good performance. When it was first calibrated, about two years ago, it required 0.4573 amperes to apparently match the black body at the temperature of melting palladium. A recent calibration of this lamp in the same pyrometer showed that it now requires 0.4578 amperes to apparently match the black body at the same temperature. The difference corresponds to less than 2 deg. *K*. As this lamp has been operated for over 400 hours in all, it is seen to be very satisfactory.

If an optical pyrometer is to be used to measure high temperatures, it is important to know what agreement may be expected in the results obtained by different observers. To test this, the temperature of a wide flat filament tungsten lamp was measured by a number of observers using a Holborn-Kurlbaum optical pyrometer. The instrument was the laboratory form of the Holborn-Kurlbaum pyrometer in which the conditions were very good. The resistance that controlled the current through the pyrometer lamp was so chosen that the sliding contact had to be moved quite a distance in order to change the apparent brightness of the filament by an appreciable amount. The current was measured by means of a potentiometer. Observers *1* and *2* were high-school graduates who had had several months experience as laboratory assistants but had had no experience in using the pyrometer. Observer *3* was a man who had had several years' experience in shop work but no previous experience with the pyrometer. Observer *4* was a man who had had several year's experience in a lamp factory where he was working with various lamps but no experience with an optical pyrometer. Observers *5* and *6* were girls from the lamp factory. No. *5* had not had previous experience with this kind of work while No. *6* had had experience with the photometer. In Table I are given the results of the test.

TABLE I

OBSERVER	VALUE OBTAINED FOR TEMPERATURE		Variation of Single Reading from Mean
Std.	1438 deg. *K*	1643 deg. *K*	
1-L.C.	1439	1643	4 deg. K
2-H.W.	1438	1642	3
3-F.G.	1439	1642	2
4-E.H.	1436	1644	3
5-E.W.	1436	1636	5
6-L.R.	1436	1640	2

To avoid operating the black body furnace every time that it is necessary to check the calibration of the pyrometer lamp, a large filament tungsten lamp has been standardized so as to have the same brightness when observed through the red screen as that of the black body at the temperature of melting palladium. Experienced observers in calibrating a pyrometer lamp on different days make settings that do not vary on the average by more than 3 or 4 parts in 4500 in the current through the pyrometer lamp. This corresponds to a fraction of a degree at 1800 deg. *K*., and gives the accuracy that is to be expected from observations by experienced observers.

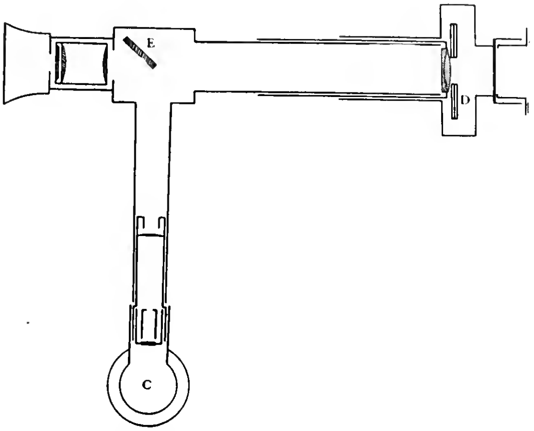

Fig. 3. Diagram of a Holborn-Kurlbaum optical pyrometer

A reference to Table I will show that no observer made an error greater than 3 deg. *K* in the temperature as obtained from the average of six readings. In no instance was a value of temperature obtained from a single reading that differed more than 5 deg. from the mean of the set of readings. These results are thought to be very good and to indicate the character of results that could be obtained with this form of pyrometer in industrial works. The pyrometer as used probably enabled the observers to make much more accurate observations than is possible with a commercial form of the instrument. However, even a commercial instrument could be so constructed that very good observations could be obtained. In this work, as in almost all work depending upon eye observations, a small amount of training makes a very great improvement in the accuracy of the results.

LIFE IN A LARGE MANUFACTURING PLANT

Part II

THE PREVENTION OF ACCIDENTS

In our August issue we published a description of the system of physical examination and the emergency hospital service that have been instituted by the General Electric Company at its various plants. The wisdom of the adage, "An ounce of prevention is worth a pound of cure," is forcefully obvious in welfare work; and while the prevention of accidents cannot entirely be eliminated—and hence the need for the emergency hospital service—some surprising results can be accomplished by a systematic study of the causes of accidents and the means of minimizing them. An important element is the instruction of the employee, which amounts practically to an education in safety habits. In this installment we have outlined the work that has been done by the General Electric Company, a pioneer in these activities, to protect its employees from bodily injury.—Editor.

One million men crippled annually in the factories of the U. S.! This is the statement made by the United States Department of Labor in their latest comprehensive report on industrial accidents.*

In these days of war when the conservation of manpower as well as that of all our National resources is given serious thought by all true lovers of America, such figures as these are calculated to inspire even the most indifferent citizens to do what they can to obviate this shocking waste.

It is the purpose of this article to point out the methods pursued and the results of the educational campaign by which the Safety Committee of the General Electric Company has reduced the percentage of accidents to employees.

While complete figures are not available for all of the factories of the Company at this writing, an indication of the results accomplished by the campaign for accident prevention is afforded by the adjacent figures.

The growing tendency of the employee to have minor injuries treated at the emergency hospital, in order that the danger of blood-poisoning may be lessened, has resulted in a large increase in the number of first aid cases treated, with a corresponding decrease in the number of infections. The large number of new employees in 1916, many of whom were inexperienced, resulted in many injuries which in all probability would not have happened to older and more experienced workmen working under normal conditions.

HOW THE RESULTS WERE ACCOMPLISHED

A blank form was provided, on which particulars of all accidents, however slight, were reported to the Safety Committee by the foreman. These reports showed that most accidents resulted from a few causes.

The study of these records was supplemented by a check on individual cases, until it was established beyond doubt that the statistics represented general conditions.

PITTSFIELD WORKS

Year	No. of Employees	No. of Lost Time Accidents	Percentage of Employees Meeting with Accidents
1912	4913	1850	.376
1913	5852	1353	.231
1914	4385	573	.1306
1915	3904	353	.0904
1916	5378	721	.134

Decrease from November 1912 to 1916, 64 per cent.

SCHENECTADY WORKS

Year	No. of Employees	No. of Lost Time Accidents	Per Cent
1913	19977	1284	.64
1914	16823	829	.49
1915	15347	662	.43
1916	20985	1355	.67

Note.—A "lost time" accident is one causing a loss of time of 5 hours or more.

The methods of preventing specific kinds of accidents will be discussed extensively later; but some interesting high lights revealed by these statistics will be mentioned first.

Interesting Facts Developed

The most careful age was found to be 37 years.

The ages showing most accidents in proportion to number of employees were between 22 and 26 years, and 50 years and over.

The hour showing most accidents was from 9 to 10 a.m.

50 per cent of the accidents occur to new employees, i.e., those who have been with the company less than six months.

Contrary to general belief, the foreign born employees are exceptionally quick in acquiring the safety habit, if taught.

More accidents occur on Monday than on any other day.

More accidents occur in the hot season than in the cold.

Eighty per cent of the accidents are due to carelessness.

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*Industrial accident statistics—Bulletin No. 157 U.S. Department of Labor, March, 1915.

Having obtained this knowledge the officials of the Company organized a central safety committee whose duties were to analyze the working conditions in the factories with respect to their effect on health, and from the standpoint of hazards. This committee was to study the causes of accidents, adopt means for preventing them, and make recommendations for the guidance of the local safety committee in each branch of the organization. The local safety committee at each Works is selected from the various departments, the chairman of the local committee being the representative on the central committee. The local committees are the medium through which recommendations of the central committee are carried out, and their duties include a practically continuous inspection of the Works with which they are connected.

It is their further duty to maintain such factors as sanitation, ventilation, and lighting at the highest standard.

At the Schenectady Works all matters pertaining to the protection of employees are directed by the safety department, which is the general clearing house for all information and data relative to these activities in the entire organization. Under the direction of the safety department various educational campaigns were planned.

THE EDUCATIONAL CAMPAIGN

A competent executive was engaged to instruct the employees inside the Works, as well as to extend the propaganda to the entire population of the city.

Inside the Works

While collecting the statistics, photographs were taken, showing the causes and results of specific accidents. Lantern slides were made from these photographs, and these together with the data collected formed the bases for lectures. The last half of the noon hour was frequently employed to give these lectures, and the "horrible example" of those who had been injured either through their own carelessness or that of others was forcibly shown by the photographs and description.

The foremen served to radiate the general information, as well as to personally instruct employees in certain processes which had been found hazardous. Employees were urged to report carelessness in others, and those who showed habitual carelessness were encouraged to seek less dangerous fields of work, and if they failed to improve were discharged.

A magazine containing items of general interest but always some article about safety is printed at each of the factories and distributed gratis among the employees. These articles are made to supplement the lectures, and in some of the factories the head of the safety work is editor of the paper.

Safety literature is distributed among the men, and a series of posters, almost half of them illustrated with photographs or artists' drawings, are designed and posted in prominent places throughout the Works. These posters are changed semi-monthly, and are written in strong, simple English, in many cases the pictures telling the story.

Outside the Works

The local newspapers gave prominence to the safety worker's activities, and even commented editorially upon the value of his services to the community.

Lectures were given in halls and schools and to the Boys Scouts, so that the habit of carefulness could be instilled in the youth as well as the skilled workman. The Y. M. C. A. co-operated generously, donating its auditorium as a meeting place for many of these lectures, discussions, and demonstrations.

MECHANICAL AND ELECTRICAL SAFEGUARDS

Supplementing the educational activities, the Company's engineers and production experts, upon authority of the safety committee, spent large sums for safeguards. A lengthly discussion of these will be omitted because of their technical nature, but in general, wherever a machine could be instantly stopped by an electrical pushbutton or otherwise, and human life and limb thus made safer, the appropriation was forthcoming for these devices.

Those responsible for the safety work in the various factories give their first attention to providing proper safeguards on those machines which present the greatest hazard to the workmen. For instance, punch presses are recognized as dangerous machines unless properly guarded. Accidents are likely to occur with this class of machinery from the press repeating while the hands of the operator are under the die, in the act of either placing or removing the work. Special attention was given to eliminating this danger, in many cases the presses being changed from foot tripping operation to a mode of operation which requires that both hands be removed

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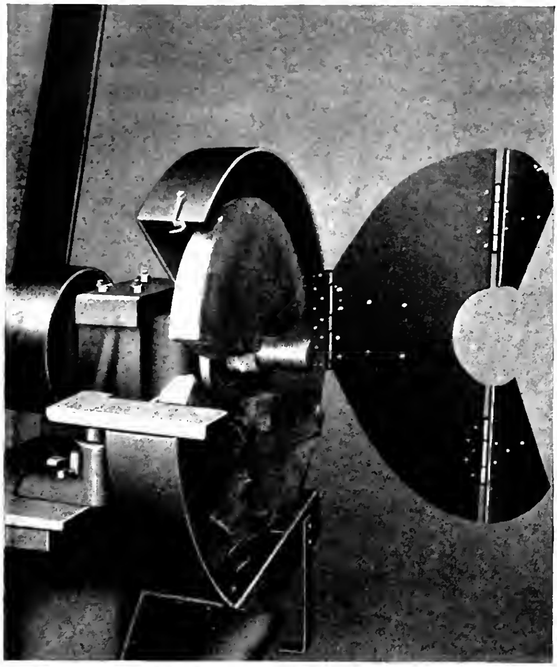

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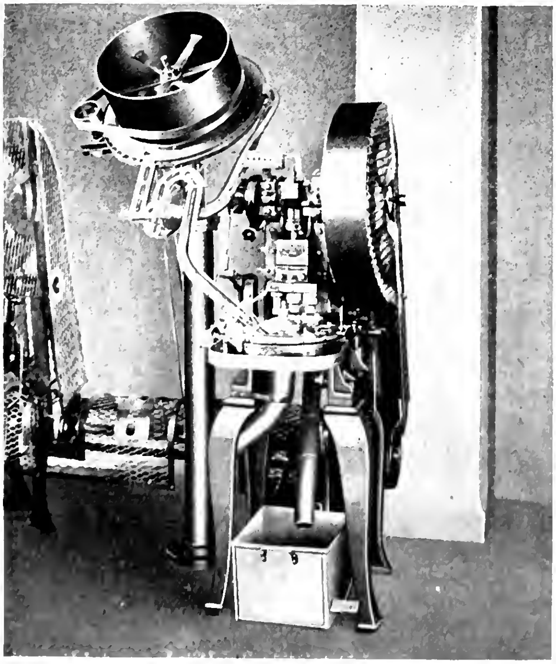

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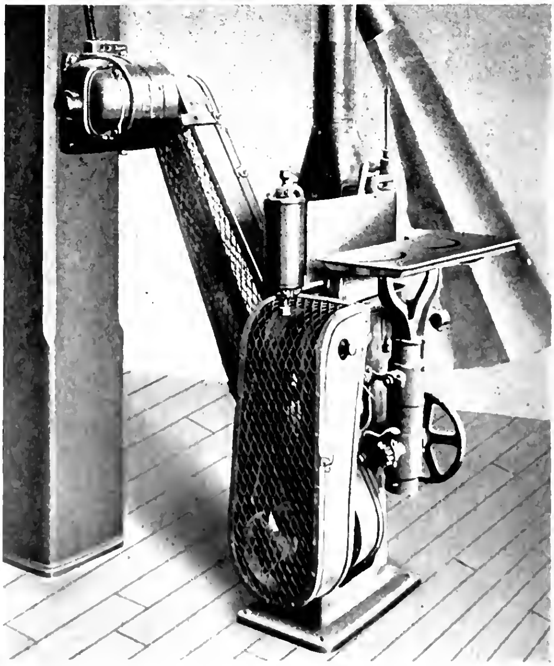

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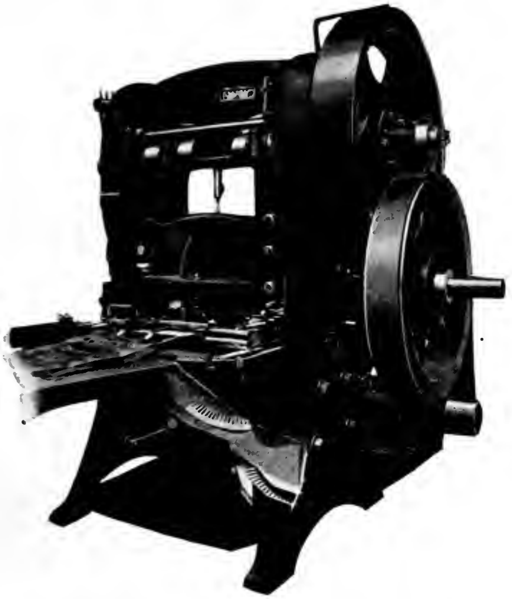
1. Grinding wheel in foundry which burst when running at 5,372 feet per minute. It will be noted that the pieces were prevented from flying and doing damage by a guard made of $\frac{3}{8}$-inch boiler plate.

2. Battery of punch presses equipped with "simplicity" guard in operation. Press cannot be operated while guard is up.

3. Punch press with dial feed for the forming operation of small parts. The attention of the operator is not required except to keep hopper filled.

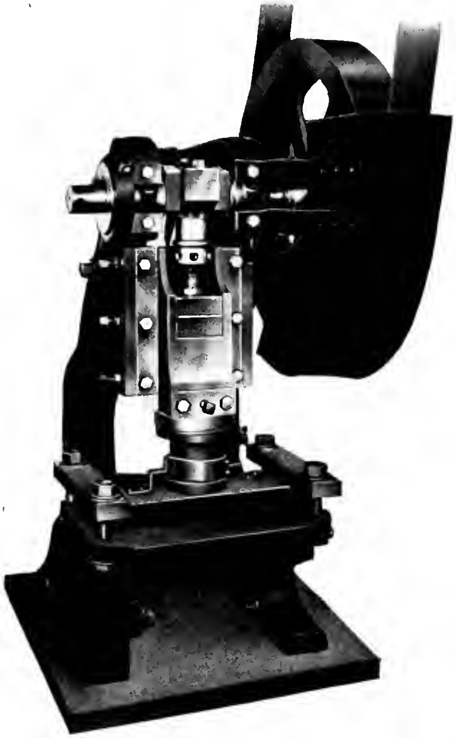
4. Belt guards on spindle sander.

from under the die before the press can be operated. In other cases non-repeating tripping devices were attached which would only permit one stroke of the press at a time. Automatic, mechanical and pneumatic feeding devices have been developed for presses working on long strips or rolls, which make it unnecessary to place the hands under the die. Where large numbers of small pieces are required, a magazine feed has been developed, so that the operator has only to feed a large hopper. In fact, wherever the work will permit some rearrangement of the work or of the machines is made, or some type of guard is used which will obviate the necessity of the hand being placed under the die, or the press is made inoperative while the hand is there. Where guards are not practical, pliers are used for placing the work and a jet of air is employed for removing it. The care which has been taken to eliminate the danger incident to the use of this class of machinery has reduced the number of accidents to a minimum.



Automatic mechanical feed for punch press which makes it unnecessary for operator to put his hands anywhere near the die while machine is in motion

The majority of protective devices for machines consists of belt and gear guards of great variety, and much constructive ingenuity has been displayed in avoiding interference with the operation of the machines and at the same time affording adequate protection to the operator. It was found that in numerous cases where it was necessary to remove the guard to make adjustments to the machine, the operator would neglect to replace it, with the result that accidents occurred from this form of carelessness. To obviate accidents of this kind, the belt and gear guards are made part of the machine. They are rigidly constructed, and doors are placed so that the removal of the guards is unnecessary for making adjustments.

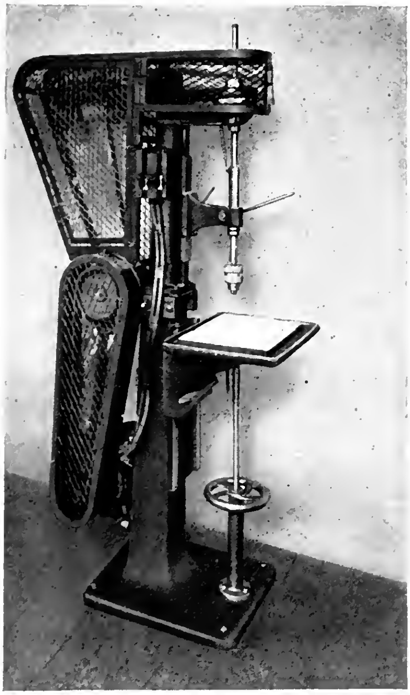


Guard on press for punching mica washers. Front of guard is covered with transparent mica which permits the operator to see the work but prevents the fingers being put under die

The operation of grinding wheels would be dangerous, due to bursting from excessive speed or to a fracture in the wheel, if proper precautions were not taken to safeguard them. Experiments were made which resulted in a reduction of the grinding speeds, and the wheels have been completely enclosed, except that portion actually necessary for performing the work. The results obtained by these precautions have been very gratifying, as accidents from grinding wheels have been entirely eliminated.

OTHER SCHEMES FOR ACCIDENT PREVENTION

In one building at the Schenectady Works three million screws are made, and two million are used every week in wiring devices. Most of the screw-driving is done by power, and in this building over three hundred electrically driven screw drivers are being operated by girls. The principal feature of this device is the auto-start and auto-stop mechanism. The screw driver does not begin to rotate until the work has been brought in contact with it, and after the screw has been driven home the screw driver ceases to rotate, through the operation of a cleverly devised slipping clutch.



Type of expanded metal guard used on drill presses

In metal spinning, spring making, and on kick presses for light punching and perforating, metal saws, milling machines, and a score of other types, all dangerous moving parts are completely enclosed. This has been done so thoroughly that one girl voiced her appreciation in the following comment: "Everything that is movable cannot be touched, and anything that can be touched is not movable."

In walking through the Schenectady Works one is impressed with the miles of ventilating pipes which convey dust, offensive odors, and injurious gases to the external air. These ventilating systems are motor driven, and they give the observer a new appreciation of electricity, for little motors hardly bigger than a quart bottle are faithfully protecting the health of hundreds of workers. Many rooms in which manufacturing processes are being carried on, such as melting wax, spraying lacquer, or handling powders, were found to be entirely free from odors or dust. This result was accomplished by the location of large metal hoods into which the objectionable materials were carried by the inrushing air of the ventilating system.

A thing of interest was a metal finger used to indicate the precise point at which melted sealing wax was being dropped from a melting pot. As one man remarked: "That one metal finger has saved many a burned thumb."

Belt Guard on Profiler

On many of the small kick-presses for light perforating work, a metal finger attached to a swivel guard automatically pushes aside the hand of the operator before the ram descends to pierce the metal. One girl operator said:

"This machine is almost human, for if I were to forget and leave my hand in danger I would not only be saved from injury, but likewise slapped on the wrist for my carelessness."

Some of the processes involve the cutting of millions of little strips of metal from ribbons of zinc. These ribbons are fed into the machine through a narrow slot scarcely larger than the metal itself, and no part of the operator's body can get into the danger zone by accident.

On the stamping machines which are power driven this method of protection is used, as well as another which makes it necessary for both of the operator's hands to be clear of the material being worked before the ram descends upon it. The trigger releasing the machinery is also the safety device itself, for in order to make the machine operate it is necessary to pull down the guard. This is not a case of adding a safety device to a machine, but of redesigning a machine so that a vital portion of the operating mechanism is the safety device.

Operator wearing respirator which is used in places where ventilating or exhausting systems can not successfully remove injurious dust

An interesting variation of punch press operation consists in having a revolving table carry the work under the punch press; sometimes the metal is worked upon by the tool at as great a distance as eighteen inches from the operator's hand.

A general principle observed by the safety experts of the General Electric Company is: "Bring the work to the tool and not the tool to the work." By this means the number of possible combinations of movements is materially lessened; because with a moving tool and a moving hand the possibility of lack of co-ordination is increased. This practice has been specially followed in tapping machines where a jig holds the work secure and the jig is then brought to the tap.

Helmet used by arc welders, provided with windows of special glass which shield the operator not only from injurious light rays but also from the heat rays

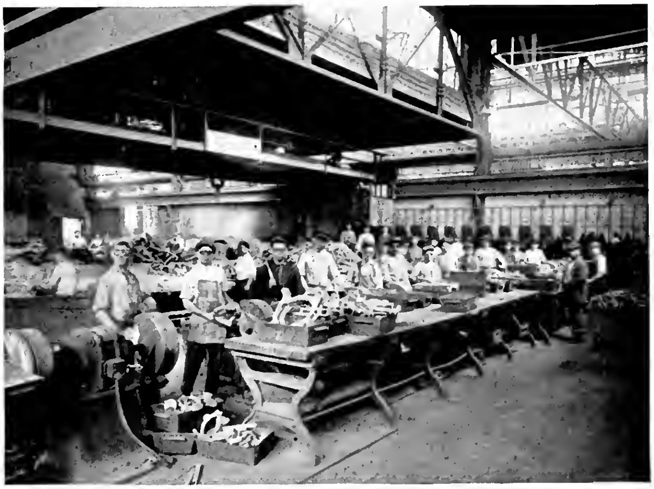
The same practice is followed in most soldering processes and has prevented numerous burned fingers. The electrically heated soldering iron is permanently fixed at the proper angle and the parts to be soldered are brought into contact with the hot point. Identical methods are employed for melting sealing wax.

In a few cases where a variety of soldering is to be done, the weight of the soldering iron is carried by a helical spring—taking advantage of the well known fact that if the strength of the operator is conserved and fatigue is lessened, inaccuracies are minimized. Where intermittent soldering processes are performed, a rack is provided to hold the iron when not in use—thus preventing fires and needless damage and interruptions. One young lady solders 7000 electric light sockets every day.

Any one who has handled solder is familiar with the fact that the metal when melted has practically the same appearance as when cold. To guard against burns from this cause each electrically heated soldering pot is provided with a pilot light; when the light is burning it serves as a warning that the metal is hot.

The Company provides the girls with becoming caps to be worn when operating machinery having exposed moving parts which might entangle the hair and cause an accident.

One of the details in safety work consists in fixing a plate of sheet iron to the inside rim of an exposed "flying" pulley, thus shielding the spokes and making it impossible for metal rods or clothing to be drawn into the machinery.



Safety Work at the Erie Plant. The grinding machines are fitted with guards and the men are impressed with the need for wearing Goggles to shield the eyes from flying particles

Safety and efficiency are sometimes closely related: when one man with a machine can drive thousands of nails by electricity every hour and never touch one of the nails it is obviously a safe process as well as an efficient one.

The same thing can be said of electric motor trucks which go all through the buildings, up and down the elevators—they need no rails or trolley wires, carry very heavy loads, and require but one man to operate. When we consider that 47 per cent of the accidents which occurred in 1916 were due to handling of materials, it is again evident that safety and efficiency can be made natural running mates.

Elaborate automatic electric stops have been devised for overhead cranes, and large sums spent for fire prevention, detection and fighting, and both automatic and hand apparatus is supplied extensively in all buildings. An organized fire department is maintained in all the Works.

The devices designed to prevent electric shock have been so successful that only one quarter of one per cent of the major accidents in Pittsfield in 1916 were due to this cause.

FIGHTING SPECIFIC ACCIDENTS

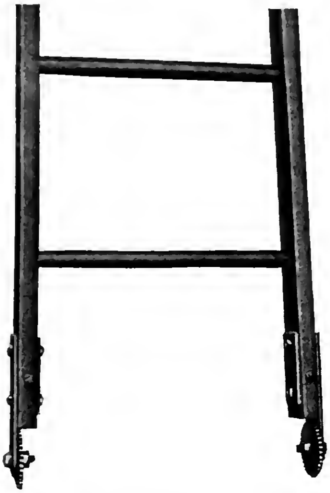
The study and ingenuity displayed in the Pittsfield campaign, which reduced accidents by 64 per cent in 1916, will be of interest to all welfare workers and altruists.

A machinist is shown what kind of a cravat he should *not* wear, and a foundryman what kind of shoes he *should* wear. Raw labor is taught just how to pile pipes, castings, heavy timbers, etc; special methods are devised for preventing blindness by acids, metal, sawdust, stone dust, and by the injurious "ultra-violet and actinic" light rays. Instruction is given in how to avoid burns from steam, molten metal, gas, acids, and electricity; how to handle a ladder; how to keep tools in condition; how to choose a hammer; how to protect the lungs from dust; how to prevent nail punctures of the feet—a wealth of detail which to those with an interest in his fellowman reads like a revelation. Think of grown men being taught how to lift so as to avoid ruptures; how to drink water; how often to bathe in warm water; how to attend to a scratch on his finger; why he should clean up rubbish; how to carry tools up a ladder; what kind of sleeves he should have; and whether his jacket should be on the inside or outside of his overalls!

Surprising as these statements may sound to the laymen, they are nevertheless some of the problems with which the captains of industry are grappling, and in the solution of which they are engaging able executives whose entire time is spent in teaching safety habits.

THE MAIN CAUSES OF ACCIDENTS

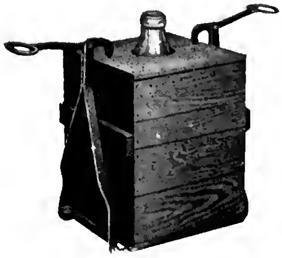
The duties of the safety committee are becoming more and more of an educational nature, as the factories are now generously equipped with mechanical and electrical safeguards. This is clearly pointed out in a report recently issued in which an analysis is made of the causes of accidents at the Schenectady Works in 1916:



Non-slip device for ladders. Sharp toothed wheel may be adjusted when teeth become worn

"A little less than ten per cent of the Schenectady Works accidents last year were classed as "machine" accidents, and only about two and one-half per cent of that number might have been prevented by guards or were due to worn-out or defective apparatus or equipment.

"Forty-seven per cent were due to handling of materials; twelve per cent to the slipping of hand tools, such as wrenches, chisels, hammers, etc.; twelve and one-half per cent to stepping on chips, scrap, nails, etc., or striking some part of the body against some object; ten per cent to machine accidents; about four per cent to slipping and falling; one per cent to locomotives, cars, or cranes; one per cent to electrical shocks and burns; and the remainder to miscellaneous causes."



Devices for handling acid carboys. The destructive action of acid may lead to the case becoming rotten, so tongs are provided which reach under the box and would prevent the bottle falling even if the bottom came away entirely. When small quantities are required, the carboy is held in an inclinator which is easily tipped without danger

TIME LOST IN 1916

"Exclusive of two fatal cases, the aggregate amount of time lost on account of accidents in 1916 at Schenectady Works was two thousand six hundred and forty-seven weeks, or fifty years and forty-seven weeks, divided as follows:

Shield for Foundry Ladle

888 weeks or about 17 years due to cuts and bruises.
507 weeks or about 9¾ years on account of fractures.
338 weeks or about 6½ years on account of infections.
287 weeks or about 5½ years due to amputations or loss of eyes.

179 weeks or about 3½ years due to burns of various kinds such as acid, electric, emery wheel, flame, friction, gas, metal, oil, pitch, potash, soda, solder, vitriol and hot water.
136 weeks or about 2⅔ years on account of sprains.
130 weeks or about 2⅔ years on account of ruptures.
120 weeks or about 2⅓ years due to miscellaneous eye injuries, other than loss of eyes or sight.
62 weeks or a little over a year on account of miscellaneous causes.

"During 1916 there were 1490 accidents which resulted in loss of time or required attention other than could be given by the Emergency Hospital. Those were classified by causes as follows:

975 accidents, 1553 weeks or about 30 years, accidental.
255 accidents, 513 weeks or about 10 years, carelessness on part of injured.
57 accidents, 147 weeks or about 2½ years, carelessness on part of other than injured person.
118 accidents, 172 weeks or about 3 years, failure to have slight injuries treated promptly, resulting in blood poisoning.
34 accidents, 37 weeks or about three-quarters of a year, failure to wear safety goggles.
13 accidents, 62 weeks or a little over a year, defective and wornout apparatus or might have been prevented by guards.
38 accidents, 163 weeks or about 3 years, miscellaneous causes, for most of which it was impossible definitely to decide.

"Based on experience it is reasonable to expect that this record can be materially improved."

It is the study of such statistics as these that indicates to the safety committee along what lines they should conduct their educational campaign so as to bring the greatest return to corporation and employee alike.

Now that the safety work of the General Electric Company has become chiefly educational in nature, in order to outline the main present activities a digest is given of some of the bulletins which tell their story every day to sixty-one thousand employees. These are classified according to the specific types of accidents which are being combated.

Falls from Elevations

The safety committee directed that all old style ladders should be replaced with those having iron shoes or shoes of special design to prevent slipping on wooden, iron, brick, and other flooring. This precaution, supplemented by regular inspection, has materially curtailed accidents. The bulletins continually remind the men that they should examine the ladders for structural defects, nails, or sharp projections; and further, that the ground support of the ladder should be tested and all made secure before ascending.

Other bulletins show how scaffolding should be made, and even the details of the sizes of planks and the number of timbers have been carefully worked out. The story is emphasized by statistics taken from the building trade, showing the number of men killed and injured because of defective scaffolding.

Things Falling on Men

Photographs show how to pile material neatly and so as not to obstruct passageways. The men are warned not to pile these materials too high.

Improper Clothing

Eight posters and eight illustrations are devoted to showing the dangers from burns and nail punctures due to improper shoes; men are warned not to wear four-in-hand or flowing neckties about machines. It is pointed out that jumper sleeves should be tight fitting at the wrist, and that the jumper should be worn inside of the overall-bib, because loose clothing is dangerous. They are reminded that the wearing of gloves and finger rings is dangerous when working about machines, and that such superfluous things should be removed.

In one poster a striking photograph shows how an accident was luckily avoided by a young man who wore a dangling necktie which caught in the rolls of his machine, drawing him closer and closer. Fortunately the machine was stopped in time to prevent a serious injury; as it was, his tie and shirt were caught and torn off his body.

Celluloid collars are made the subject of a separate poster, and a case is mentioned where a man narrowly missed serious injury when this composition of guncotton caught fire and could not be removed.

Infection of Small Injuries

The importance of this subject may be judged from the fact that seven posters and two illustrations were devoted to explaining the necessity for going to the Work's physician for immediate treatment. One case in particular was described, in which a man tried to dig a speck of dirt out of another's eye. Blood poisoning resulted and the eye had to be removed. Newspaper clippings were reproduced on the bulletin, recounting how citizens in different parts of the country had suffered from blood-poisoning and lockjaw as a result of neglecting slight injuries such as scratches, pricks of the skin, nail punctures, and small cuts.

Burns

In addition to foot burns in the foundry, which were previously discussed, the educational campaign deals with burns by steam, gas, gasolene torches, acid, and electricity. To prevent steam burns large red tags are tied to steam valves which, if opened, would scald a man at work near the outlet of the pipe. On the tag are the words "Danger! Do not open this valve without permission of the foreman."

One poster shows the photograph of a badly burned arm, and the incident was told of a man who "was told to get an extension light from a work bench, but lit a match instead. The gasolene tank he was cleaning exploded."

Regarding gasolene torches: Other posters instruct the men to examine torches for leaks before lighting, pointing out that they should never loosen the filling plug while any flame can be seen. Others are warned, "If you do not use torches, keep away from them."

Burns by acids are the subject of other posters. The handling of acids, especially in large quantities, presents hazards if proper precautions are not taken. The destructive action of the acid on the wooden containers housing the carboys is likely to cause a carboy of acid to be dropped and broken, with disastrous results. Experience has taught that the best preventive measure is such work is the provision of tongs for handling the carboys, of such a construction that they will reach under the boxes, so that if the wood is entirely rotted the carboy of acid will not drop to the ground. Where only small quantities of acids are being handled, the carboy is placed in an inclinator which permits it being tipped without danger of spilling the acid. Rubber gloves and rubber mounted goggles are provided for employees handling acid where there is a chance of the acid spattering on the hands or in the eyes.

In general, the precautions taken to guard against electrical hazards are the placing of all live parts in such positions that no employee can inadvertently come into contact with them, the provision of grounded metal guards, and ample insulation wherever necessary.

The most practical way of guarding against electrical burns is to keep all unauthorized people away from every danger zone. Warning signs are therefore placed near any locality where dangerous voltages exist, and all passages, etc., leading to such places are marked with danger signs.

Blindness

Blindness due to flying particles of metal, wood, emery, etc., can be almost eliminated by the use of goggles. These are furnished by the Company wherever needed; as are also gloves, helmets, leggings, etc. Nevertheless it requires considerable advertising sometimes to persuade a man to use them. Some posters show photographs and give the names of men whose eyes have been saved by goggles, as well as other photographs and names of men who have become partially or totally blind because of the neglect of this simple precaution. As soon as goggles become broken from any cause whatsoever the Company replaces them with a new pair without expense.

Goggles of scientifically colored glass, which make it impossible for ultraviolet and actinic rays emanating from electric or oxy-acetylene work from injuring the optic nerve, are especially valuable. In some cases complete helmets are provided for this purpose.

Nail Injuries

Four posters and two illustrations tell strikingly the danger of stepping on protruding nails. The men are urged to turn down the nails and prevent lockjaw.

Rupture

How to lift heavy weights is shown in two posters and two illustrations. Men are cautioned not to try muscular feats beyond their strength, but to await the service of the electric cranes and hoists when very heavy objects must be moved. They are also warned not to wear tight belts, and considerable discussion is given to personal hygiene and exercises that have a tendency to prevent hernia.

Accidents from Machinery and Tools

Fourteen posters and nine illustrations point out the necessity of extreme care in handling machine tools and choosing hand tools. Repairing or oiling machines and adjusting work while machines are in motion, are shown to be dangerous. Actual incidents are mentioned, and the loss in wages of men who have been injured through neglect of these rules is shown. Men are warned not to start a machine when it is tagged "Out of order—do not start."

They are urged to keep the protecting guards in place and to immediately report when damages are repaired. Statistics are given of the number of men in one state who were injured while cleaning their machines while in motion.

Other posters remind the men that they should never sling a hammer or sledge which is loose on the handle. Likewise, a photograph is shown on 1000 bulletin boards illustrating how a man should stand when using a sledge so as to avoid injuring his companion who holds the bar or cold chisel.

It is pointed out that when striking case hardened material, such as drills, reamers, cutting tools, etc., only lead or copper hammers should be used so as to prevent chipping of the hardened metal and injury of fellow workmen.

Tripping over Rubbish and Junk

Two posters and two illustrations emphasize the danger of obstructing floors and passageways with refuse, waste material, and junk. A disorderly workshop contributes to accidents.

Insanitary Habits

A fairly complete course in personal hygiene is contained in a series of posters. These treat of headache, eyestrain, hunger, bad ventilation, etc., and urge plenty of sleep, good care of the teeth, adequate bathing, plenty of fresh air, and even cleanliness of the hands. Spitting on the floor is forbidden, and even such details as how to drink out of the fountain come in for their share in the educational campaign.

Alcohol

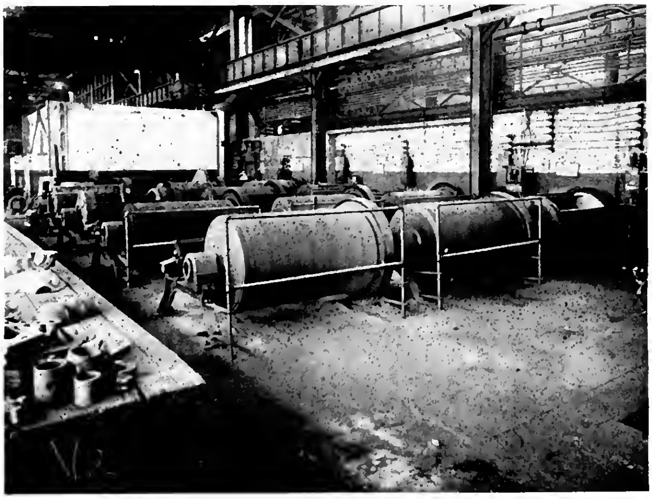
One poster shows the extravagance of the drinker, and by suggesting a plan by which a married man shall appoint his wife as his exclusive bar tender, illustrates how she could make money which would go far toward paying the household expenses. This argument shows the saloon as a public nuisance.

Careless Men

Fifty-one posters and eighteen illustrations are directed against the chance taker and the practical joker who deals in "horse play." Examples are shown where men have lost their lives, or have caused the death of another because of foolish scuffling.

Special appeals are made to lodge men, and in every possible way the doctrine of carefulness is taught, whether it be going up and down a ladder carelessly, or throwing shovels, brooms, and tools where others might be damaged by them.

Arguments against hurry and extravagance and in favor of deliberation and thrift show the range of the educational campaign.



Guards Erected in Front of Rotating Machinery

SAFETY EXTENSION

The Company has extended the idea of safety to the benefit of the users of the electrical apparatus manufactured by the Company, as well as that of the employees of the Company in its factories. Safety switchboards, safety switches, safety controllers, "fool-proof" motors, transformers, etc., have been devised, and while definite statistics are not available it is quite reasonable to assume that accidents from electric shock are being minimized in public service corporations, and among the general public who operate electrical devices in the home.

GENERAL ELECTRIC REVIEW

A MONTHLY MAGAZINE FOR ENGINEERS

Manager, M. P. RICE Editor, JOHN R. HEWETT Associate Editor, B. M. EOFF
Assistant Editor, E. C. SANDERS

Subscription Rates: United States and Mexico, $2.00 per year; Canada, $2.25 per year; Foreign, $2.50 per year; payable in advance. Remit by post-office or express money orders, bank checks, or drafts, made payable to the *General Electric Review*, Schenectady, N. Y.

Entered as second-class matter, March 26, 1912, at the post office at Schenectady, N. Y., under the Act of March, 1879.

VOL. XX, No. 10 OCTOBER, 1917

CONTENTS

FIRE DRILL AT PITTSFIELD WORKS OF GENERAL ELECTRIC COMPANY

Fires in our manufacturing plants result in loss of buildings and equipment to the owners, delayed deliveries to customers, and loss of wages to employees. Adequate fire-fighting facilities in the larger plants require an elaborate system of water distribution to sprinklers, hose connections, and outdoor hydrants, and a well organized fire crew. A description of a large industrial fire department appears in this issue, beginning on page 829

GENERAL ELECTRIC REVIEW

CONTRACTS FOR PUBLIC WORKS, BUREAU OF YARDS AND DOCKS, NAVY DEPARTMENT

To assist the Bureau of Yards and Docks of the Navy Department in securing bidders on its Public Works' contracts, we are in this issue endeavoring to place in the hands of prospective bidders general information which is of vital import concerning such contracts. The "General Provisions Forming Part of Specifications for Contracts for Public Works," such contracts to be awarded by the Bureau of Yards and Docks of the Navy Department, contain provisions and specifications which are specific and require careful study in order to ascertain their true meaning and intent.

During the time the work is in progress, it is under the supervision of an officer of the Government who has full charge of the work as to details; and in case of dispute between the contractor and the officer in charge, appeal may be made first, to a Senior Naval Officer; second, to the Chief of Bureau of Yards and Docks; and third, to the Secretary of the Navy. Notwithstanding the fact that the Government has an officer in charge of the work as it progresses, this does not relieve the contractor from the responsibility for the full performance of the contract in accordance with its terms and conditions.

It should be noted that the Government has the power to decide as to the competency of the workmen employed; and the form of contract provides that if at any time it shall appear to the Government officer in charge that any person is incompetent, such person shall be immediately discharged by the contractor. Even if the contractor does not agree with the officer in charge that any individual should be discharged, the contractor is, nevertheless, required to discharge such employee immediately, but then may appeal from the decision of the officer of the Government in charge of the contract.

It should be noted that time is the essence of the contract. If the contract is not completed within the time specified the contractor is liable to pay in liquidated damage the amount provided in the contract for failure to complete any work within the time specified in the contract. However, an extension of time for the completion of the work may be allowed, provided proper application is made for such extension and the delay results from causes beyond the control of the contractor or in cases where the delay is caused by acts of the Government. In case it develops that the contractor will probably be unable to complete the contract according to the terms thereof, the Government reserves the right to annul the contract. Upon the annulment of any contract it is provided that the Government shall appoint a Board to ascertain and determine the value of all material delivered and work done, including a fair and reasonable amount of profit thereon; and upon the approval of the findings of the Board by the Chief of Bureau of Yards and Docks such findings become conclusive upon the contractor. In this connection it should be noted that the contractor is expected to rely largely upon the good faith of the Government, because matters in dispute are not submitted to the ordinary arbitration tribunal, but to a Board representing the Government, the contractor having no representative upon such Board.

It is also provided in case the Government desires to make changes in the contract, the cost of such changes shall be ascertained by the Board representing the Government and shall be conclusive when approved by the Bureau of Yards and Docks. It is provided, however, that the findings of the Board in regard to the cost of changes shall be the actual cost to the contractor plus a profit of ten per cent.

There is the usual provision that oral modifications cannot in any way change the terms of the written instrument.

A unique provision is that concerning inspection, the officer in charge having full power to reject any material and workmanship not in accordance with the contract. If he shall deem it advisable for the purpose of inspection to remove or tear out any of the work completed, the contractor shall furnish the necessary labor or material; and if the work is found to be defective in any respect due to the fault of the contractor, he is required to pay all expenses of the examination and satisfactory reconstruction. If, on the other hand, when the work is torn out or removed it is not found to be defective the cost of examination plus ten per cent is allowed the contractor, and a suitable extension of time to cover the delay caused by the tearing out or removing of the work completed.

METHODS FOR MORE EFFICIENTLY UTILIZING OUR FUEL RESOURCES

PART IV

PULVERIZED FUEL IN A POWER PLANT ON THE MISSOURI, KANSAS & TEXAS RAILWAY*

By H. R. Collins
Fuller Engineering Co., Allentown, Pa.
and
Joseph Harrington
Advisory Engineer, Chicago

Previous experience with the burning of pulverized coal under boilers has been acquired in connection with single boilers where the cost of preparing the fuel is high, and it is difficult to show relative economy in operation. This is the first instance in which an entire boiler plant has been equipped for utilizing pulverized fuel. Moreover, the fuels used are low-grade fuels which can be burned to better advantage by this method than in any other way. Complete records are given of boiler tests with three kinds of fuel. Also the cost of pulverized Kansas coal, as compared with natural gas and fuel oil which were previously used.—Editor.

During the winter of 1912, when the natural gas supply was limited in quantity and fuel oil hard to obtain in Kansas, the officers of the Missouri, Kansas & Texas decided to investigate other methods for generating steam in the boilers at the power house of the shops at Parsons, Kan. There were at this point, eight 191-h.p. boilers of the Heine water tube type, equipped for using natural gas and oil as fuel. Some of the other fuels available in the district, which would be within an economical range as to cost delivered at the plant, were soft coals from the Mineral mine in Kansas, the McAlester and Lehigh mines in Oklahoma, and lignite from Texas, with the following analyses:

Kind of Coal	Fixed Carbon	Volatile	Ash	Moisture	B.t.u.
Mineral	45.22	26.39	20.38	8.01	10,640
McAlester	47.07	32.37	14.29	6.27	11,837
Lehigh	41.40	31.28	19.29	8.03	11,200
Lignite	25.50	33.95	7.58	32.97	7,548

The sulphur, separately determined, ranged from approximately 3 to 5 per cent in the various soft coals.

Owing to the ash and moisture content of these fuels, it was determined to investigate methods of using them in pulverized form, as it was known that pulverized bituminous coal has been in successful use in the cement industry in a major portion of the plants throughout the country. This investigation resulted in the placing of a contract for the necessary equipment at the Parsons power house with the Fuller Engineering Company, Allentown, Pa., and the material and machinery were delivered in the fall of 1913. Owing to financial conditions, it was thought unwise to make the change at that time, but in the early part of 1916, owing to the abnormal price of fuel oil, orders were given to proceed with the work. The equipment was installed and the plant was placed in successful operation on August 1, 1916.

Pulverizing and Drying Equipment

The equipment for pulverizing and drying the fuel is contained in a separate building which is located near one end of the boiler house, and the coal is dumped from the cars directly into a concrete track hopper of 50 tons capacity adjoining this building. The plant is designed to handle either mine run or slack coal and immediately below the track hopper is placed a set of 24-in. by 20-in. Jeffrey double spike-tooth rolls, which will reduce lumps up to 12 in. by 18 in. to 5-in. cubes or less in one operation. As the coal passes through this crusher, it drops onto a 20-in. inclined belt conveyor, which discharges directly into a set of Lehigh 24-in. by 18-in. corrugated rolls. The upper end of the belt conveyor passes over a 24-in. by 22-in. Cutler Hammer magnetic separator pulley, the function of which is to remove any pieces of iron or steel which may be in the coal and retain them on the belt until the latter passes off the underside of the pulley, the metal then dropping to the floor behind the crusher. This crusher reduces the coal to pass through a ¾-in. mesh or less and delivers it into a dust-tight elevator, from which it is distributed by a 12-in. screw conveyor into a storage bin of 50 tons capacity over the coal dryer.

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* The description of the plant is based on an article which appeared in the Railway Mechanical Engineer, October 1, 1916. The detailed tests have been made since that time. A brief account of this installation is given in Part I of this series (August, 1917).

The equipment throughout the pulverizer plant is operated by three-phase, 60-cycle motors at 440 volts. The first crusher is driven by a 10-h.p. belt connected motor, while the inclined belt conveyor and the second crusher are operated by one 15-h.p. belt connected motor, this arrangement obviating any possibility of choking the crusher. The elevator and screw conveyor by means of which the coal is taken from the rolls and delivered to the storage bin are operated by one 10-h.p. back-geared induction motor.

Coal may be drawn from any part of the storage bin and delivered by means of a screw conveyor to the indirect fired dryer, a chute from the conveyor being provided for the delivery of coal to the floor for firing the dryer furnace. The dryer is driven by a 10-h.p. induction motor and will evaporate the moisture from coal containing 10 per cent moisture, to ½ per cent at the rate of eight tons per hour. In order that lignite, containing from 30 to 50 per cent moisture may be handled, the dryer is arranged so that the material may be passed through as many times as may be necessary to reduce the moisture to the desired maximum before the coal is delivered to the pulverizer.

From the dryer the coal is discharged directly into a second dust-tight elevator, delivering to a 12-in. screw conveyor, both of which are driven by a 10-h.p. back-geared induction motor. The conveyor discharges the fuel into two bins of 40 tons capacity each, which feed two 42-in. Fuller-Lehigh pulverizing mills. The material to be reduced is fed to the mill by means of a feeder mounted on top of the mill. This feeder is driven direct from the mill shaft by means of a belt running on a pair of three-step cones, which permits the operator to accommodate the amount of material entering the mill to the nature of the material being pulverized. In addition, the hopper of the feeder is provided with a slide, which permits the operator to increase or decrease the amount of material entering the feeder hopper.

The pulverizing element of the mill consists of four unattached steel balls which roll in a stationary, horizontal concave grinding ring. The balls are propelled around the grinding ring by means of four pushers attached to four equidistant horizontal arms forming a portion of the yoke, which is keyed direct to the mill shaft. The material discharged by the feeder falls between the balls and the grinding ring in a uniform, continuous stream, and is reduced to the desired fineness in one operation. Fan discharge mills are fitted with two fans; one of these fans operates in the separating chamber immediately above the pulverizing zone, whereas the other fan operates in the fan housing immediately below the pulverizing zone. The upper fan lifts the fine particles of pulverized material from the grinding zone into the chamber above the grinding zone, and passes it through the surrounding screen. The material leaving the separating chamber is drawn into the lower fan housing, from which it is discharged by means of the centrifugal action of the lower fan. All the material discharged is the finished product which requires no subsequent screening.

The current of air induced by the action of the lower or discharge fan passes over the pulverizing zone and out through the screen surrounding the separating chamber, thus insuring cooler operation and maximum screening efficiency. This current of air keeps the screen clean and enables the mill to handle material containing a considerable amount of moisture without affecting the efficiency of the machine. As soon as the material is reduced to the desired fineness, it is lifted out of the pulverizing zone and discharged. Each pulverizer is belt driven by a 60-h.p. vertical motor, and reduces the fuel so that 95 per cent of it will pass through a 100-mesh screen and 85 per cent through a 200-mesh screen at the rate of four tons per hour, the plant having a maximum capacity of eight tons per hour.

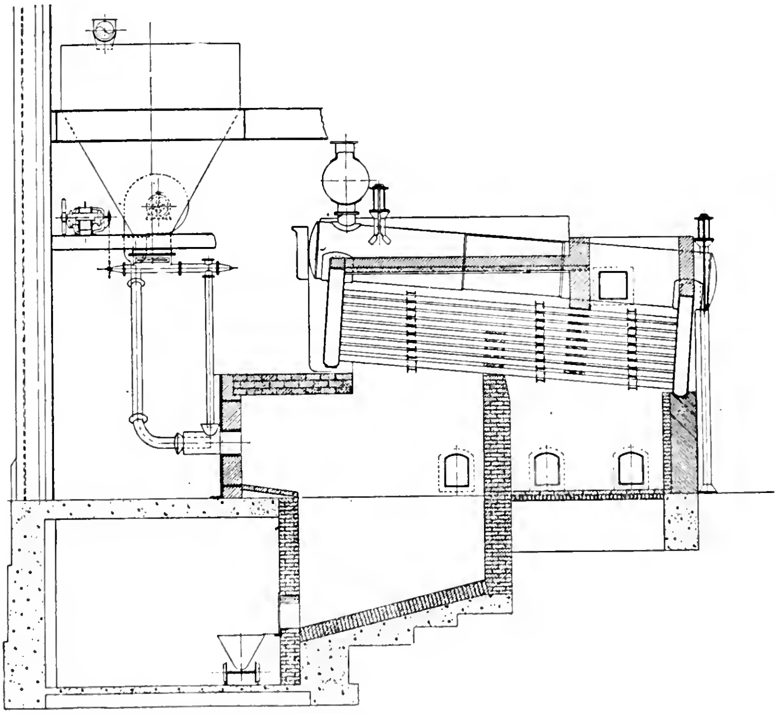
The grouping of the drives for the various parts of the equipment makes possible a maximum utilization of the power consumed, as only such parts of the plant as are in actual use need be running at any time. When fully loaded the actual power consumed is within about five per cent of the rating of the motors, according to observations taken since the plant has been in service.

As the fuel leaves the pulverizer, it is discharged into a third dust-tight elevator and delivered to a 12-in. screw conveyor for transfer to the bins in front of the boilers. This elevator and screw are driven by a 15-h.p. induction motor, the conveyor passing from the pulverizer building to the power house through a steel bridge covreed with corrugated sides and roof. This is the only connection between the pulverizing plant and the power house.

The capacity of the pulverizer plant is 180 tons in 24 hours and the requirements of the power house are at present about 96 tons in 24 hours. Arrangements are being made for the trial of pulverized coal in locomotive service, one engine now being in process of equipment, and an outside storage bin will be added to the plant to supply fuel directly to the locomotive.

The Boilers and Furnaces

The boilers are arranged in batteries of two each and, as equipped for burning gas and oil, the combustion takes place in the furnace directly under the heating surface of the boiler. For pulverized fuel, however, a Dutch oven furnace has been built on the front of the boiler setting, it having been found that the best results are obtained in this manner. The equipment for burning the fuel is simple. Each pair of boilers is provided with a blower, driven by a 10-h.p. constant speed direct current motor, the blast pipes from this blower entering the rear end of an induction tube which extends through the wall of each furnace. Each blast pipe is fitted with a gate for controlling the air jet to the combustion tube. The fuel from the bin passes through a 4-inch screw feeder, which accurately determines the rate at which the coal is delivered to the furnace, each feeder being driven by a 2-h.p. variable speed motor. The fuel from the feeders is fed by gravity through a pipe entering the top of the induction tube near the front of the furnace. The action of the high velocity jet from the blast pipe induces a large volume of air at lower velocity through the induction tube; the fuel is caught by this current with which it is thoroughly mixed, and enters the furnace at a low velocity, burning with a lazy flame which practically fills the combustion chamber.



Boiler in the Shops of the Missouri, Kansas & Texas Railroad Company, Parsons, Kansas. Converted from oil firing to low-grade pulverized coal firing

The fuel bins in front of the boilers have a capacity equivalent to 16 hours' service at boiler rating. The bins and supports are of steel and the bins are closed with steel covers which are dust-tight. Each bin is hoppered and is equipped with a hand-operated agitator, the purpose of which is to prevent the bridging over of fuel in the hopper.

Early Tests

Considerable experimental work has been done in order to secure the best furnace arrangement and to provide an effective control of combustion to meet the requirements of varying loads on the boilers. As installed for the use of gas, the boilers were provided with three-pass horizontal baffles. In the pulverized fuel fired boilers these baffles have been replaced by a vertical three-pass arrangement from which excellent results have been obtained, as the following list of temperatures indicates. These temperatures were taken starting at the bottom of the first pass and proceeding in the direction of the flow of the gases over the heating surface of the boiler.

Location	Temp., Deg. F.
Bottom of first pass	1650
Top of first pass	1260
Top of second pass	1180
Bottom of second pass	960
Bottom of third pass	800
Top of third pass	705
Stack temperature (average)	508

These temperatures were taken under operating conditions with a draught averaging 0.26 inch of water.

Various tests have been made with the different fuels mentioned and all of them were burned with entire success, giving an effective distribution of the heat throughout the heating surface of the boiler with low stack temperatures. No deposit of ash settled anywhere in the boiler but what was readily dislodged with an ordinary air blast.

The normal coal feed is arranged to develop about the rated capacity of the boiler. At maximum feed, however, the boilers may be forced to 186 per cent of rated capacity. No difficulty has been experienced from abnormal furnace temperatures, which would tend to destroy the furnace walls. Even under forced conditions the furnace temperature does not much exceed 2400 deg. F., and under normal conditions it is about 2100 deg. F.

With Texas lignite and an output of 145 per cent rating, an equivalent evaporation of 7.26 lb. of water was obtained per lb. of coal fired, an equivalent evaporation of 8.81 lb. being obtained per lb. of combustible. The coal as fired had a heating value of 11,250 B.t.u. and contained 7 per cent moisture, the dryer not being designed to handle this class of fuel regularly. The efficiency of the boiler was 67.3 per cent, the losses being as follows: 0.7 per cent due to evaporation of moisture in the coal; 4.8 per cent due to steam from hydrogen combustion; 11.8 per cent carried away by dry flue gases, and 15.4 per cent due to radiation and unaccounted for.

With the boiler operating at about 120 per cent of rated capacity an equivalent evaporation of 8.38 lb. of water per lb. of coal fired was obtained with Mineral slack (Cherokee Co., Kansas), the fuel as fired containing one per cent of moisture and having a heating value of 11,580 B.t.u. The equivalent evaporation per lb. of combustible was 10.9 lb. In this case the boiler showed an efficiency of 71.5 per cent, the losses being: 0.3 per cent due to evaporation of moisture in the coal; 3.8 per cent due to steam from hydrogen combustion; 10.8 per cent in dry flue gases, and 13.6 per cent radiation and unaccounted for. In neither case was there any CO loss.

Cost of Fuel

Including the cost of pulverizing, which is about 35 cents per ton, the cost of Mineral coal delivered to the bins was $1,795. The cost of evaporating 1000 lb. of water as determined by this test was 11.6 cents. Using natural gas, the heating value of which is about 940 B.t.u. per cu. ft., the cost of evaporating 1000 lb. of water is 16 cents, with gas at 12.5 cents per 1000 cu. ft.

Later data is given in Table I, which cover the cost of fuel for February and March, 1917, together with the equivalent cost of oil.

TABLE I

	FEBRUARY		MARCH	
	Tons	Cost	Tons	Cost
Coal	1,758.25	$2,285.73	1,850.85	$2,406.11
Pulverizing		685.72		721.83
Total for coal		$2,971.45		$3,127.94
Equivalent cost of oil		4,923.10		5,182.40
Saving		$1,951.65		$2,054.46
Saving		39.6 per cent		39.6 per cent

Coal cost $1.30 per ton
Pulverizing 0.39 per ton
Total coal 1.69 per ton

Oil, contract price $0.80 per barrel
Equivalent price $2.80 (for 3½ barrels = 1 ton coal).

Recent Tests

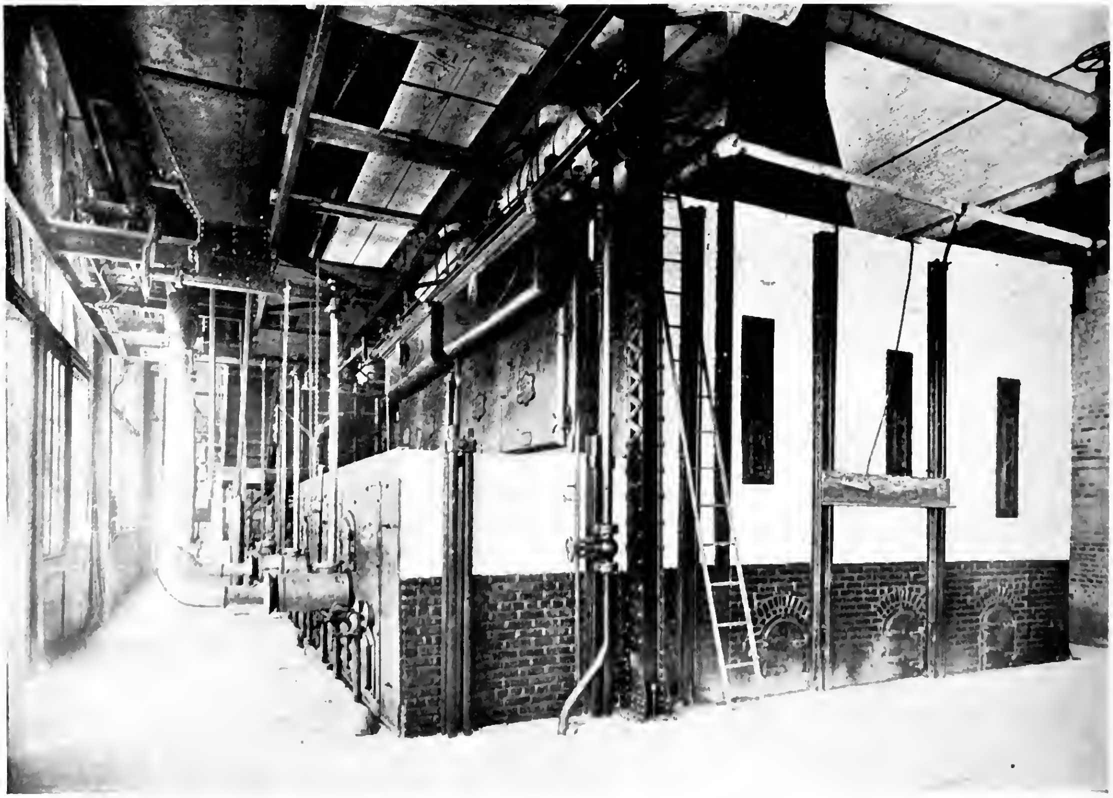
A series of detailed boiler tests were made in June, 1917. It is interesting to refer to a few of the more important items and add to these references some comments on the peculiarities of the tests.

These tests were made in the usual manner, the boiler being given such attention as it was possible to give it, and the coal being prepared in the usual way just previous to the test. Three different fuels were tested having a considerable range in quality. The first test was of Texas lignite, which had been stored in the open air over six months, and subjected to freezing and thawing, and the influence of the sun and wind all this time. It was not necessary to dry this lignite to the same degree that the other coals were dried, and the 17 per cent of moisture in the coal, as fired, did not affect its apparent quality at all. To all appearances, it was as fluid as the semi-anthracite coal containing only 0.3 per cent of moisture. The second coal was a fairly high ash, high sulphur coal from Southern Kansas, and is the coal which is usually burned at this plant.

For the last test a car load of semi-anthracite screenings was obtained. This coal was very fine when received, and was stated to be of a kind which is unsalable on account of its size.

The first question presented for settlement was the proper method of weighing the coal. Under the conditions surrounding this installation, it was not practical to actually weigh the coal on scales, and it was decided, therefore, to determine the weight from the revolutions of the feed screw. The discharge pipe was accordingly disconnected from the burner, and another one substituted, which reached to a large galvanized iron can which was placed on a pair of accurate platform scales on the floor in front of the furnace. There was a revolution counter attached to this screw, which made it possible to accurately count the revolutions.

After determining the weight of the empty can, the feed screw was started and allowed

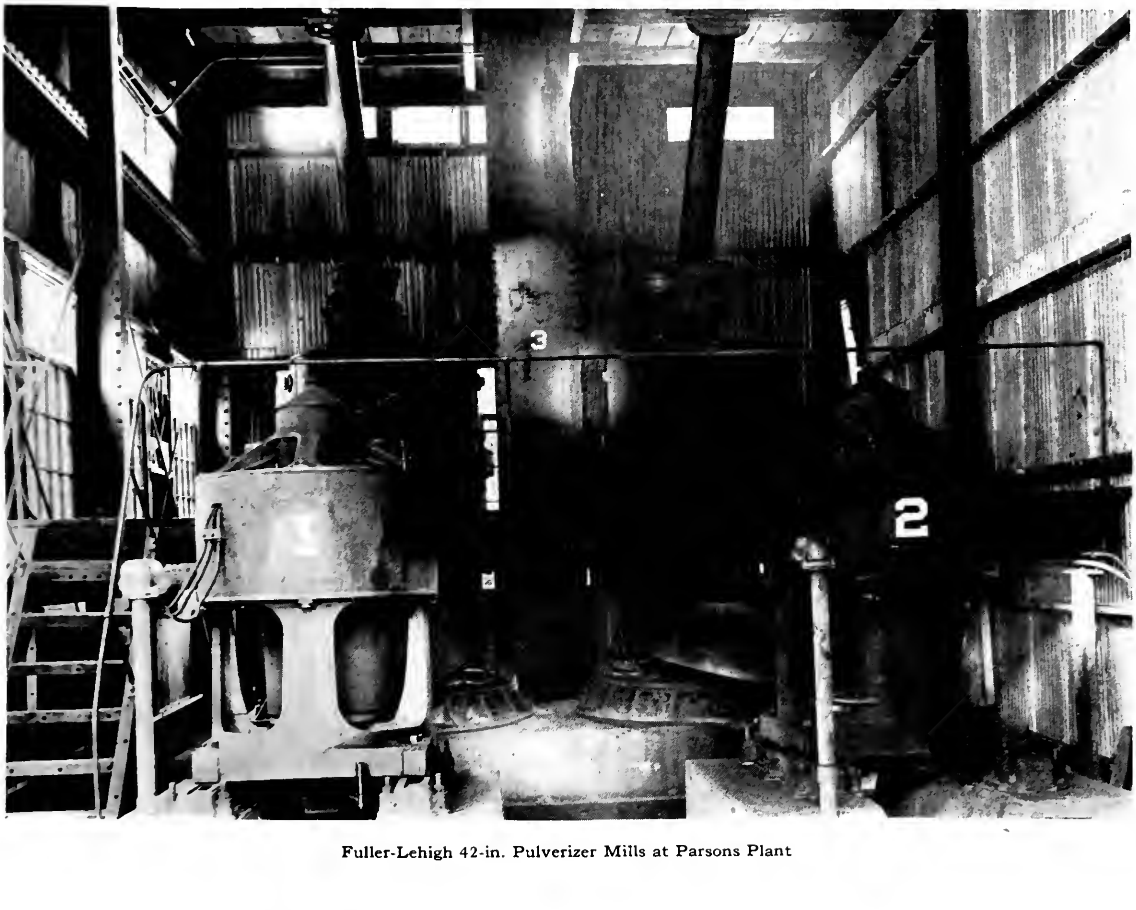


Heine Type Horizontal Tubular Boilers Burning Pulverized Fuel at the Parsons, Kansas, Shops of the M., K. & T to run until the can was substantially filled. The spout was then disconnected, the can and its contents weighed, and the net weight of coal thereby determined. In all cases three tests were made, and the average taken. The average of the three readings was taken as the carrying capacity of the screw per revolution, and is very nearly the correct figure. A separate determination in this manner was made for each of the three tests.

It was not possible under the conditions obtaining at the time to conduct tests even as long as eight hours, so that tests of shorter duration were made. Particular care was taken that the level of the water in the boiler was exactly the same at the end as at the beginning, and the rate of the steaming was kept as constant as possible throughout each test. While these tests may appear to be short as compared with the accepted practice in mechanical stoker testing, it must be remembered that the amount of fuel actually in the furnace at any one time, is represented by a very few pounds, and that when the feed screw is suddenly stopped, the combustion as suddenly ceases. It is possible to cut off the fuel supply instantly, and before the feed screw has fairly stopped turning the fire is out, there being absolutely no question of piling up fuel in the furnace and having unequal conditions at the beginning and end of the test. It was felt that even a four hours' test did not introduce any serious error on this account.

The water was weighed in one thousand pound lots on a carefully calibrated scale, and the water level was as nearly the same at the beginning and end as it was possible to get it.

One point of particular interest is the heat balance, which indicates conditions unusual in boiler testing. The boilers themselves were O'Brien boilers, which had been rebaffled to provide three cross passes for the gases, and inability to clean the heating surface of these boilers by hand resulted in one-half of the heating surface being particularly dirty. To this may be ascribed



Fuller-Lehigh 42-in. Pulverizer Mills at Parsons Plant much of the inefficiency of the boiler. Gas temperatures nearly 200 deg. in excess of what could properly be expected were obtained at the stack.

The next item of interest is the very high furnace and grate efficiency. The analysis of this section shows a loss due to combustible in the ash of zero, and this is worthy of especial comment. The ash pit in this case had a sloping bottom, and was visible throughout its extent from the door in the basement. Previous to these tests the pit was substantially clean and the condition noted. In the case of the Cherokee slack, the ash fused and ran down the bottom in molten streams, being removed partially in liquid form and, particularly, by being broken away from the bottom with a bar after it had somewhat cooled.

Practically no dust in the ash pit was encountered with this fuel, all of the ash remaining appeared to be liquefied or at least deposited in a plastic condition. An examination of a piece of cold slag shows an appearance like that of black glass, without the slightest sign of any combustible. Under the ordinary operating conditions of this plant using this coal and operating at times at low ratings, there is produced a mixture of fine sandy looking ash and melted slag. Examination of a car load of this refuse standing on the side track of the plant failed to reveal any traces of unburned coal or coke. It was, therefore, assumed that the loss due to combustible in the ash was negligible, and it has been recorded as zero.

This car was being loaded with ash at the time. A representative sample was secured by taking a little from various parts of the car to the amount of a quart bottle full. This sample has been analyzed by the Commercial Testing and Engineering Company. The analysis is as follows:

Per cent moisture	13.00
Per cent ash, dry basis	97.40
Per cent combustible matter, dry basis	2.60

This could vary 100 per cent without there being enough ash pit loss to cut any serious figure in a boiler test. This coal (Cherokee slack) had 18.02 per cent ash on the dry basis. If all of the refuse could have been collected and weighed the weight would have been equal to 18.50 per cent of the dry coal fired. There would have been, therefore, 0.48 per cent ash pit loss. The ash pit loss with stokers will run from 2 to 5 per cent so that there is in stoker practice from four to ten times as much ash pit loss as with powdered coal. This confirms in a very satisfactory manner the assumption made in figuring the test, that the ash pit loss was substantially a negligible quantity.

During these tests there was a light gray haze apparent at the top of the stack. The question arose as to the possible loss of combustible matter from the stack and through the boiler and breeching. To determine this point a sample of this dust was obtained from the breeching which was very fine in size, and of a gray color. Analysis showed that there was 2 per cent of combustible matter in the fine dust, proving quite conclusively that the loss here was exceedingly small.

Another matter bearing on the high furnace efficiencies is the item of heat absorbed by excess air. It was without the slightest difficulty that the CO_2 in the flue gases was carried up to 16 per cent, readings frequently going to 17 per cent, and but few readings being less than 15 per cent. Considerable care was exercised in making the analysis for CO, there being the natural thought that with the high CO_2 that some loss from incomplete combustion might occur. It will be noted from the report that the CO loss was in direct proportion to the length of the flame. Some relation, therefore, between the proportion of volatile matter in the fuel and the CO loss becomes apparent.

The loss of combustible matter from the furnace appears to be the item upon which turns the entire discussion of unaccounted for loss which appears in these tests. Without doubt the furnace conditions with the semi-anthracite coal, so far as they could be determined, without exception were as nearly ideal as one could imagine. The flame did not reach the tubes at any time, and it was possible to count the bricks on the opposite side of the combustion chamber. The furnace gases were completely burned and transparent. The unaccounted for loss in this test is also the least, and the furnace efficiency is the greatest of any of the tests.

A point which has always been in controversy whenever the burning of powdered coal under steam boilers was under discussion, is the control of the furnace temperature and consequent fusing of the brick walls. To determine the exact temperature in this setting a Fery Radiation Pyrometer that had just been calibrated by the United States Bureau of Standards, was obtained from the Armour Institute of Technology.

Two sets of Seger Pyrometric Cones were placed in the furnace after the test had been going on for a couple of hours, and constant furnace temperature obtained. It will be noted in item eleven that the temperature of the furnace was between 2300 deg. and 2400 deg. under which conditions brick work may be maintained indefinitely, and which is above the fusing point of the ash from a great many coals. It was pleasing to note that the pyrometric cones checked the indications of the Fery Pyrometer within 20 deg. It is probable, therefore, that the temperatures given are very nearly correct. There was no apparent fusing of the brick work which might occur if the ash had a fluxing effect thereon. This furnace has been in constant service for nine or ten months, and the interior seems to be in perfectly good shape.

The ash from the lignite and semi-anthracite coals did not fuse, and there was a small deposit in the ash pit of a yellow sandy looking ash which appeared to be entirely free of combustible matter.

Another and most interesting phase of these tests is the draft loss in the boiler. A drop in draft between the top of the third pass and the furnace of around 0.05 inches, in a boiler ten tiers of tubes in height, operating at 25 or 30 per cent above its rating, does not seem natural, but the draft readings throughout all three tests were checked and repeatedly verified. These boilers are equipped with 60-ft. stacks, and were operated with the stack damper partially closed in order to get the furnace draft nearly neutral. This opens up a very interesting line of thought as to the draft requirements in this type of installation. The small loss is probably due to the small gas volume and consequent low frictional resistance in the boiler.

Summing up the entire matter, it may be stated without hesitancy that these tests give promise of a future for powdered coal in this service which is indeed bright. It is possible to burn in this manner qualities of coal which are not ordinarily classed as of commercial value. Moreover, it is entirely possible to provide space adequate for the complete combustion of fuel in this form, and to control the temperature of the furnace so as to make it possible to burn, with-

TABLE II

Report of Tests at M., K. & T. Railway Shops, Parsons, Kansas; 191 h.p. O'Brien water tube boiler, vertical baffle, equipped for burning pulverized coal

1.	Test number	1	2	3
2.	Date, 1917	4 p.m to 8:30 p.m. June 12	8 a.m. to 12 noon June 13	2 p.m. to 5:30 p.m. June 13
3.	Duration of test, hours	4.5	4.0	3.5
4.	Atmospheric pressure, lb.	14.5	14.5	14.5
5.	Boiler pressure, gauge lb.	137.5	136.0	135.5
6.	Boiler pressure, absolute lb.	152.0	150.5	150.0
7.	Draft at damper, inches water	0.092	0.055	0.000
	Top 3rd pass water	0.148	0.083	0.075
	Bot. 2nd pass water	0.119	0.105	0.070
	Top 1st pass water	0.039	0.021	0.010
	Furnace water	0.082	0.051	0.038
8.	Blast, pilot differential water	0.55	0.41	0.4
9.	Boiler room temp. deg. F.	102.1	90.3	104.5
10.	Air blast temp. deg. F.	106.0	94.0	109.0
11.	Furnace temp. deg. F.	2352.0	2329.0	2408.0
12.	Stack temp. deg. F.	597.9	534.6	624.3
13.	Feedwater temp. deg. F.	166.9	165.8	178.1
14.	Calorimeter temp. deg. F.	232.1	229.1	229.5
15.	Gas at end of flame CO_2	16.67	15.1	16.5
	O_2	1.93	2.9	1.9
	CO	0.24	0.1	0.0
	N	81.16	81.9	81.6
16.	Gas at stack CO_2	14.75	14.8	15.8
	O_2	5.05	3.5	3.0
	CO			
	N	80.20	81.7	81.2

	Test number	1	2	3
17.	Kind of fuel	Lignite from Texas	Cherokee Slack, Mineral Mine, So. Kansas	Semi-Anthracite from Kansas
18.	Proximate analysis of coal:			
	Moisture	17.06	1.06	0.30
	Volatile, dry	61.52	32.41	22.29
	Fixed C., dry	24.72	49.57	59.94
	Ash, dry	13.76	18.02	17.77
	Sulphur (separately determined)	0.98	5.14	4.09
	B.t.u. per lb. as fired	8854.0	12056.0	12587.0
	B.t.u. per lb. dry coal	10675.0	12185.0	12625.0
	B.t.u. per lb. combustible	12378.0	14863.0	15352.0
19.	Ultimate analysis of dry coal:			
	Carbon	62.69	66.41	70.60
	Hydrogen	4.49	4.46	3.51
	Oxygen	16.96	4.88	2.69
	Nitrogen	1.15	1.09	1.34
	Sulphur	0.95	5.14	4.09
	Ash	13.76	18.02	17.77
20.	Size—Over 100-mesh sieve	7.25	8.44	8.08
	Through 100-mesh sieve	92.75	91.56	91.92
	Over 200-mesh sieve	17.67	18.06	14.44
	Through 200-mesh sieve	75.08	73.50	77.48
21.	Coal burned total run actual lb.	6748.0	4692.0	3500.0
22.	Coal burned per hour actual lb.	1500.0	1173.0	100 .0
23.	Coal burned per hour dry lb.	1244.0	1161.0	997.0
24.	Coal burned per revolution feed screw, lb.	0.3703	0.4024	0.3865
25.	Ave. feed screw revolutions per min.	67.4890	48.5830	43.1190
26.	Total ash and refuse from ash pit			
27.	Per cent ash and refuse in dry coal	13.76	18.02	17.77
28.	Weight of combustible fired from analysis	4825.00	3808.00	2868.00
29.	Weight of combustible in ash	0	0	0
30.	Weight of combustible actually consumed	4825.0	3808.0	2868.0
31.	Water evaporated total run act.	33420.0	32018.0	30300.0
32.	Water evaporated per hour act.	7427.0	8005.0	8657.0
33.	Factor of evaporation (including moisture)	1.0562	1.0559	1.0434
34.	Equi. evap. per hr. f & a 212 deg. lb.	7844.00	8482.00	9034.00
35.	Per cent moisture in steam	3.92	4.07	4.04
36.	Horse power builders rating	191.2	191.2	191.2
37.	Horse power developed	227.4	245.9	261.9
38.	Per cent of rated horse power developed	119.0	129.0	137.0
39.	Water evap. actual per lb. coal as fired, lb.	4.953	6.824	8.657
40.	Water evap. actual per lb. dry coal, lb.	5.970	6.895	8.683
41.	Water evap. f & a 212 deg. per lb. coal as fired, lb.	5.229	7.231	9.034
42.	Water evap. f & a 212 deg. per lb. dry coal, lb.	6.305	7.306	9.061
43.	Water evap. f & a 212 deg. per lb. combustible, lb.	7.311	8.912	11.019
44.	Water evap, f & a 212 deg. per sq. ft. H.S. per hr., lb.	4.102	4.436	4.725
45.	Theoretical wt. dry gas per lb. dry coal, lb.	8.603	9.692	9.986
46.	Actual wt. dry gas per lb. dry coal, furnace, lb.	9.498	11.116	10.952
47.	Actual wt. dry gas per lb. dry coal, uptake, lb.	10.825	11.408	11.412
48.	Theoretical wt. air per lb. dry coal, lb.	8.139	9.267	9.472
49.	Actual wt. air per lb. dry coal, furnace, lb.	9.115	10.838	10.579
50.	Actual wt. air per lb. dry coal, uptake, lb.	10.328	11.109	10.995
51.	Wt. air leakage in lb. dry coal	1.213	0.271	0.416
52.	Wt. excess air per lb. dry coal, furnace, lb.	0.976	1.571	1.107
53.	Wt. excess air per lb. dry coal, uptake, lb.	2.189	1.842	1.523
54.	Per cent excess air per lb. dry coal, furnace per cent	11.99	16.97	11.69
55.	Per cent excess air per lb. dry coal, uptake, per cent	26.89	19.88	16.08

Heat Balance per Pound Coal as Fired

56	Heat per lb. coal as fired	8854	12056	12587

	B.t.u.	Per Cent	B.t.u.	Per Cent	B.t.u.	Per Cent
57. Heat absorbed by water in boiler	5073	57.32	6992	58.00	8765	69.64
Necessary Losses						
58. Heat absorbed by moist. and burned H up to to temp. steam	581	6.56	473	3.92	365	2.90
59. Heat absorbed by theo. amount dry gas up to temp. steam	441	4.98	618	5.13	607	4.82
60. Heat available for unit	7832		10965		11615	
61. Highest theoretical efficiency		88.46		90.88		92.27
Furnace and Grate Losses						
62. Heat loss due to combustible in ash	0	0.00	0	0.00	0	0.00
63. Heat absorbed by excess air up to temp. steam	50	0.57	100	0.83	67	0.53
64. Heat loss due to production of CO	75	0.86	44	0.37	0	0.00
65. Heat available for boiler	7707	87.05	10821	89.68	11548	91.75
66. Furnace and grate efficiency		98.40		98.69		99.44
Boiler Losses						
67. Heat loss due to theo. gas, moist. and H above temp. steam	465	5.25	438	3.64	675	5.36
68. Heat loss due to air leakage through setting	120	1.36	29	0.24	52	0.41
69. Heat loss due to radiation and unaccounted for	2049	24.27	3362	27.89	2056	16.33
70. Boiler efficiency		65.82		64.61		75.90
71. Combined efficiency		57.32		58.00		69.64
72. Ratio: Comb. eff. to highest theo. efficiency		64.80		63.90		75.49
73. Cu. ft. capacity of furnace	874.0		874.0		874.0	
74. Cu. ft. per lb. coal per min	35.0		43.7		51.4	
75. Cu. ft. per lb. of Vol. Comb. per min	48.5		54.6		70.5	

out objectionable fusing, those coals having low ash fusing temperatures. This also answers the problem of the maintenance of the refractory furnace linings. It is probable that by determining in advance the analysis and melting point of the ash of the coal to be used, and with a knowledge of the character of the fire-brick to be used in the setting, a design can be made which will produce conditions under which the furnace walls will last indefinitely.

There is without doubt a certain amount of the ash dust which adheres to the furnace walls, and if such ash has a fluxing effect on the brick, ultimate destruction will occur. On the other hand, if it is desirable to liquefy the ash the furnace can be designed to produce a temperature which will be above the fusing point, and the substantially complete removal of the ash in this form thereby affected.

One of the questions which heretofore has frequently been asked is relative to the slagging of the tubes from fused ash adhering thereto, and forming an objectionable coating on the exposed surfaces. During the three days when these boilers were under observation there was no sign of any formation of this nature. It would not have been expected with the lignite and semi-anthracite coals, which did not produce any fused ash whatsoever, but when the Cherokee slack was burned, and the ash formed in the pit in molten form, it was noted particularly that there was no accumulation on the tubes.

The controllability of the fuel feed and the cleanness of the combustion produced, make it appear that before long powdered coal will be accepted as not only highly economical, but as a commercially satisfactory form of fuel.

ELECTRIC RANGE CAMPAIGNING BY THE CENTRAL STATION

By Hartwell Jalonick

Commercial Manager, Texas Power and Light Company

Most people have no adequate conception of the magnitude of the electric range business today noi of its certain rapid growth tomorrow. To them, the following article will be a revelation. The author's valuable experience in electric range campaigning renders him particularly capable of speaking with authority on the subject. He combines the giving of instructions, descriptions, and recommendations for initiating and prosecuting a successful range campaign with a history of the campaign of the Texas Power and Light Company.—Editor.

A central station cannot expect to attain any degree of success in electric range sales without the hearty co-operation of every department of its organization. The securing of enthusiastic co-operation will likely prove to be the most difficult task of the range manufacturer's salesmen. The General Manager as an individual, or Sales Manager as an individual, or the Superintendent as an individual, may not be difficult to interest in the range business; but the big problem is to secure the enthusiastic interest of the General Manager, the Superintendent, the Chief Engineer, and the Chief Accountant as a co-operative unit. One individual in the central station's organization cannot make the range business; two individuals in the central station, who are not enthusiastic, can break the range business.

Co-operative Consideration and Planning

When considering entrance into the field of electric cooking business, a conference of the department heads should be called to survey the situation. The Commercial Organization should be instructed to investigate the possibility of sales, using as data the information gathered in a preliminary canvass of the people in the towns under consideration. The Accounting Department should be asked to determine how much could be safely spent in the promotion of the range business and, furthermore, to advise an accounting system which would satisfactorily keep the actual expenditures. The Operating Department should be required to take up the study in conjunction with the Engineering Department and find out just what the effect on operating costs would be, and just what modifications would have to be made in existing distributing operating conditions. Together, the departments should report what might be the results to the stockholders.

Attention is called to the fact that, by following this program of co-operation, the Sales Department would avoid the great mistake of endeavoring to press sales propositions on the Operating Department, with the possible result of forcing the latter into furnishing service and facilities unwillingly and perhaps unprofitably.

Co-operation Based on Conviction

In the case of the Texas Power & Light Company, the Accounting Department saw all good in the range campaign; the Engineering and Operating Department saw great possibilities; and consequently the Commercial Organization felt encouraged and enthusiastic.

Lack of co-operative planning and looking ahead involves one of the possible risks in the range business among central stations; and, consequently, the manufacturer's range salesmen should not fail to impress upon the various departments of the central station the necessity for looking into the future.

Importance of Engineering Department Co-operation for Future Growth

Suppose that a "new-business" man of a central station places a 5 or 15 h.p. piece of business on the books; he does not notify the Engineering Department, he merely takes the order and puts it through. That particular piece of business simply involves the installation of a transformer suitable for it, and some more coal will be burned in the furnaces to take care of the additional load. But, with the electric range the situation is different; the Engineering Department has to be advised not only with regard to the present year but as to future years. If the Engineering Department does not thus plan for several years ahead and many ranges should be installed, the central station will not be able to render proper cooking service.

The importance of this forecasting the future cannot be emphasized too strongly. When a central station undertakes to serve the public with "fuel" for cooking, and anything disturbs the service or interferes with the cooking, the Company is striking the customer "under the belt." With several thousands of residence customers in the United States depending directly or indirectly upon the central station for daily meals, it becomes a rather serious matter to fail. If the manufacturer's salesmen sell one, two, five hundred, or one thousand ranges to a central station, and then do not in addition sell the electric cooking idea to the Engineering and Operating Departments, so that the ranges will remain sold through the adequate service which these departments must provide, the salesmen are inviting trouble six months later, and they will be called upon to adjust it. The duties of the manufacturer's salesmen are not so much to sell ranges as to sell the electric cooking "idea" to the central stations; and to do this successfully they must, in the long run, sell it to the entire organization and see to it that the business becomes established upon a "service-first" basis.

Prospecting for Prospects

While there may be many good methods of preparing the prospectus for the engineers, that employed by the Texas Power & Light Company resulted in such thorough satisfaction as to warrant a detailed description of its operation and a favorable consideration of its adoption by other central stations about to enter the field.

Before the Commercial Organization attempted to sell electric ranges it sent one of its salesmen to each town served by the company, giving him a blueprint map of the town. He made a preliminary canvass through all the streets of his town, putting a red dot on the map to represent the residence which, in his judgment due either to his findings or due to outward appearance, should be a range prospect, no matter whether for next month, or for 1918, 1919, or 1921. It was not absolutely necessary for him to go to the door to find this out. The proposition was this: If the home has a nice-looking front with lace curtains, a telephone, etc., it is a $140 range prospect, and as such will be represented by the little red dot on the map and will be followed "for life"—or until a range is bought. Everyone with a telephone and electric lights is a range prospect.

Information for the Engineering Department

This map becomes a very convenient record for the guidance of the Engineering Department in making provisions for even 1922 activities, and therefore there should be no excuse for not giving the customer, when ultimately secured, that good and reliable service to which he is entitled.

To take care of the range load, the proper transformer is placed at the intersection of two streets and feeds one-half block each way in all four directions along these streets. The secondaries supply 110/220-volt three-wire service. In special cases, however, secondary service may be run 400, 500, or even 600 feet.

In constructing the secondary line in conformity with this map, it is not necessary that each zone or distribution center be constructed complete upon the installation of the first range; on the contrary, this map enables the Engineering Department to plan ahead. They may put up No. 2 wire as an extension to No. 4 wire which may remain in service next to the transformer, in which event they are merely building for the future and ultimately (when each red dot becomes a customer instead of a prospect) the distribution system will be found to be complete, even though this may not be for several years to come.

Preliminary Exploitation

The first allotment of ranges distributed by the Texas Power & Light Company numbered 273; these were located "maliciously" so as to scatter them throughout the territory, the customers selected being those who were believed to be most friendly to the Company. A record of these installations was kept and the statistics compiled from 260 installations which remained in service (see compilation at the end of this article) were used as the basis for further calculations and also as information wherewith to induce other customers to cook electrically.

In this work a salesman was placed at headquarters in every district as the local sales representative operating under the District Office Manager.

Classifying the Prospects

Inasmuch as cooking by electricity was new to Texas, it was found desirable to obtain some specific information concerning the probable prospective customers before attempting to campaign aggressively for electric cooking business. Accordingly, the salesmen were given "Prospect Cards," these cards being very simple, as shown by the illustrated form on the following page.

Only a few questions were asked. The salesmen were not instructed to try particularly to make sales, but to visit each residence that appeared as though its occupants could afford to buy a range, and then fill out the card and rate the prospect "A," "B," or "C." By making this card record as a preliminary step, the salesmen secured a great deal of valuable information; the new men on the job who had no experience, or had never seen an electric range before, received a liberal education on how (not) to sell an electric range. They soon learned what they were "up against." After these cards were classified according to the salesmen's idea as to the "A," "B," or "C" standing of the prospects, they were filed for use at a future date as "follow-up's."

ELECTRIC RANGE PROSPECT
Town..
Name ....
Address...
Is coal, wood, or gas used for fuel........ Number in family.......
Cook, yes, no................ Number of rooms..............
............A—Waiting Rate quoted ....
.... B—Receptive Type range favored by prospect........
............C—Active
Salesman's initials............... Date.......................................
Remarks on reverse side

Card (6 by 4 inches) used by the Texas Power & Light Company in its preliminary electric range campaign.

Following the Prospects

Arrangements were made for securing a series of three booklets, corresponding to the "A" (Active), "B" (Receptive), and "C" (Waiting) classification of the prospect cards.

If the prospect was ready to talk particulars regarding a range she was handed a "Matchless Kitchen," which is an attractive catalogue of the various types of ranges, giving full details and prices.

If the prospect was not an active one, but still was receptive to the idea of electric cooking, the salesman left one of the booklets which tells of "Brighter and Happier Hours in the Kitchen," prepared by the Society for Electrical Development to sell the idea of electric cooking rather than sell the electric range itself.

However, if the prospect was "from Missouri" as to the electric cooking proposition and had not a spark of enthusiasm, she was handed a booklet gotten up by the Texas Power & Light Company. This booklet gives just a few plain facts on the number of homes in Texas using electric cooking, and a few pointed paragraphs to create interest and indicate that the reader's skepticism could be overcome by actual data if she cares to look further into the proposition.

Among other advantages resulting from the use of the cards and the corresponding literature, the salesman is enabled to adapt his own mood to the disposition and degree of receptivity displayed by the prospect, and thus secure for himself the highest degree of efficiency. If the card indicates that the prospect is "grouchy" and the salesman does not that morning feel in the mood to argue with anyone, he does not call on one who is antagonistic but selects an "A" prospect instead, and thus has a good possibility of success. On being encouraged by landing this order he might then feel in the mood to talk to the "grouchy" one.

How it Worked

As proof of the success of the preliminary exploitation and campaign, it is to be noted that to July 20th a total of 1112 ranges had been sold, this representing eight months of exploitation work and four months of actual campaign work. During the initial eight months of exploitation only 260 ranges were sold, the remaining 854 having been sold during the four months of campaign.

It has been found from experience that the most essential thing in selling electric cooking is vested in maintaining a perpetual prospect list. If points of merit were to be given to the salesman, they should be on the basis of 90 points for ability to "prospect for prospects" and 10 points for his ability to close.

Why the Central Station Should Enter the Range Business

At the meeting of the Range Committee of the N.E.L.A. in St. Louis in 1916, it was the consensus of opinion of those in attendance, particularly those of the Northwest who had gone into the question, that the range business offered the greatest possibilities for the central station of any undeveloped field. There must have been very good reasons for considering the proposition so favorably.

Furthermore, inasmuch as the officials of the General Electric Company and other large manufacturers believed in the successful future of the range business, it seemed that there must be sound reasons for it—reasons capable of demonstration. If the General Electric Company committed itself to the expense of the development of this business, it must certainly have convinced itself of the possibilities.

Therefore, when the Texas Power & Light Company handled General Electric Ranges during the exploitation period of the campaign, it felt that the value of the range business was capable of being demonstrated to be sound. It was not sufficient that the range business should "look good" to the Commercial Organization. It was necessary that it should be proved to the satisfaction of the Accounting Department, the Engineering Department, and the various other departments of the Company that it was good.

To prove that the range business was sound and that the central station should aggressively enter the field for electric cooking load, endeavor was made to analyze the situation in the following manner.

Decreasing Price of Current and the Investigator

We know by data which have been compiled, and many times published, that in contrast with the general cost of living, electricity is the only commodity which has steadily decreased in price since 1896. Such necessities of life as foods, fuel, taxes, clothing, and rents have increased since 1896 about 50 per cent while on the other hand during the same period the cost of electric lighting is the only important commodity relating to the home that has not increased. It has suffered a very substantial decrease.

This is very good advertising indeed for the central station; but the people who are putting money into public utility stocks and bonds might well be very much concerned regarding this continual dropping off in the selling price of the product which they are marketing through their central stations.

One may well say that these reductions are often voluntary, but on the other hand central stations are continually facing drastic legislation, commission rulings, and municipal ownership agitation, all of which tend to force down still further the already low prices being secured for current.

Central-station managers are alive to the effect this may have upon the security market, and that the situation can become serious unless some good way can be found to offset it. The attitude of the investing public is highly important to central stations which are continually in a state of development and expansion, and must seek from time to time additional capital in the financial markets. In other words, their securities must be attractive.

New Revenue from the Range Business Attractive to Stockholders

Now that electric cooking is a proven commercial success, the central station is in a position to secure the $3.00 to $3.50 per month (or about $40 a year) which each electric range will earn, transferring this money from the customer's account with the coal man to that of the central station without increasing the living expenses of the customer. To add $40 a year per customer to the present residential earnings—which now average only $18 to $20 per year—will increase the central station's revenue 210 per cent, with proportionately very little increase in expense. Thus, the range business must appeal as a very attractive proposition to the stockholders.

Turning Unprofitable Accounts Into Profitable Ones

Practically every central station has on its lines a large number of residential customers who are unprofitable—who do not pay more than the minimum monthly bill; e.g. 50 to 75 cents per month. It probably costs about 60 cents per month per residential customer to take care of his account in meter reading, accounting, and other general service expense; so that any customer who does not pay this amount is really a dead loss to the company, and there are usually many of them. The range business affords the means whereby these unprofitable accounts can be turned into very profitable ones and, as has been stated, this service can be secured by the customer without increasing his living expenses.

Adding Business Without Corresponding Additional Equipment

The central station can take on additional business of this character without materially increasing its station capacity. In the first place, the electric range will fill in the valleys of the residential load curve. In the next place, there is a large diversification in the range demand, It has been found that station capacity for one electric range (5 kw. connected load) is sufficient to take care of ten electric ranges (totalling 50 kw. connected load), due to the individual customer's demands on the range coming at different times and overlapping, and also due to the fact that the total rated capacity of the range is seldom, if ever, used. This diversification of demand also reduces the cost of the distribution feeders, transformers, and secondaries over that which would apparently be required to care for this class of business.

How It Figures Out

It is vitally necessary to any organization that the probable results of a new or extended venture be figured out as accurately as possible beforehand. Accordingly, as an indication of what results may be expected from the prosecution of an electric cooking campaign, the figures of the Texas Power & Light Company may be of interest.

By the end of this year it is anticipated that the company will have on its lines a total of 2807 ranges. Assuming an average monthly revenue of $3.34 per range (as secured from the company's records) the total annual revenue would be $112,504. The average monthly consumption is 125 kw–hr. per range. The total annual consumption, therefore, would be about 4,210,500 kw-hr.

Assuming the average connected load per range to be 4 kw. (which is low), this would mean a connected total of 11,288 kw. or approximately 15,000 h.p. This based on a demand factor of 10 to 1 (and assuming efficient line operation) would require only 1,128 kw. in plant capacity.

The company has on its lines 31, 986 residential customers, and it feels it can reasonably expect to serve 50 per cent of this total number of range prospects within the next few years, from which the estimated annual revenue to be derived would be $639,720, and the annual consumption would be 23,989,500 kw-hr.

As to the probability of inducing these 16,000 residence customers to become range users in any reasonable length of time, it should be borne in mind that the figures the company has obtained show that an individual can cook his meal at an average cost of less than one cent (9/10 of a cent) and he is a pretty mean sort of a fellow who is afraid to part with a cent for the service which can be rendered by an electric range. On the other hand, as has already been stated, a customer who cooks electrically does not increase his cost of fuel for cooking. He merely transfers his "fuel account" to the central station.

The cost to serve a range customer is expected to be about $75. This $75 will be spent for transformers, hardware, wire, wiring supplies, etc. In the aggregate, the Texas Power & Light Company plans to spend $210,525 this year in order to take care of this anticipated range business; and of this expenditure, the manufacturer will receive perhaps 50 per cent. The manufacturer's salesman should, therefore, be particularly interested in this fact, for it means that every time he sells an electric range he is creating $37.50 worth of business for his transformer and supply departments, in addition to the direct range sale.

In continuing the consideration of the range proposition, the cost of the central station capacity and operation is another important factor. Assume a hypothetical case: one which would take care of 2807 ranges with a connected load of 11,228 kw. having a diversity or demand-factor of 10 to 1. In this case we would require 1122 kw. additional station capacity which, on the basis of $100.00 per kw., represents an additional investment of $112,280. Thus, the investment would amount to $40 per range, which means station or plant investment of $40 to earn $40 per year in range revenue.

Adding $40 per range for station capacity to $75 for transformer and line equipment makes a total investment of $115 per range to bring in an annual average gross revenue of $40. On the other hand, consider the analysis on the basis of overhead and operating costs, overhead being taken at 12 per cent of the total, made up as follows: Interest 5 per cent; depreciation 5 per cent; taxes 1½ per cent; and insurance ½ per cent.

We have a total interest charge of $38,799 per annum, this interest having been figured on a total investment of $323,325 in plant and line, the plant cost being $112,800 and the line cost $210,525. With 2807 ranges installed, bringing in a revenue of $40 per range per annum, we have total gross earnings to the amount of $112,280. Subtracting from this the given overhead expenses at 12 per cent, viz., $38,799, there is remaining for operating costs a profit of $73,481 per annum, which amount, considering the diversity of the load, would repay the company handsomely for all range business secured.

It is to be noticed that in these figures involving plant and line expenditures for the installation of these 2807 ranges, we have considered in connection therewith the gross profits to be derived from the operation of the electric range only. This same installation which was made for the range, both as regards plant and line capacity, is serviceable for the operation of water-heater load, and we believe it is conservative to assume that each range installed should carry with it a water heater; and we furthermore believe it conservative that each water heater installed should return at least $30 gross revenue per annum. Therefore, to take on water-heater load in addition to range load would not increase either the plant or line costs, and yet, at the same time, would add $84,210 to the revenue which would be derived from the range business alone. Adding this revenue to the sum $73,481 previously derived from the range business, after 12 per cent fixed charges had been paid, gives us a total of $157,691 out of which to pay the operating cost for generating the power consumed and the resultant net divisible to the stockholders.

Range Data

Of the 273 ranges installed by the Texas Power & Light Company in its preliminary exploitation work last year, as has been stated, only 13 were removed on account of dissatisfaction for one cause or another, leaving 260, or 95 per cent in service. The average monthly bill figured from these 260 installations was $3.65, and the average consumption was 143 kw-hr. for cooking service exclusively, the average price per kw-hr. being 2.57 cents.

Of this total number, a "representative" group of 111 installations showed an average consumption of 125 kw-hr. each, at a monthly bill of $3.34, earning an average rate of 2.67 cents per kw., and the average number of persons served as 4.2 per range. These figures are believed to be conservative and were the ones used by us in estimating. The following tabulation is based on these 111 ranges.

Average consumption per month per person	29.8 kw-hr.
Average consumption per person per meal	332 watt-hrs.
Average cost of operation per month	$3.34
Average cost per kw-hr.	2.67 cents
Average cost per person per month	79.6 cents
Average cost per person per meal (approximately)	9/10 cent

GENERAL PROVISIONS FORMING PART OF SPECIFICATIONS FOR CONTRACTS FOR PUBLIC WORKS

BUREAU OF YARDS AND DOCKS, NAVY DEPARTMENT

Never before in the history of our Republic has it been more imperative that every one render his fullest service to the Government. By giving publicity to the general provisions now in force concerning contracts for public works to be awarded by the Bureau of Yards and Docks, Navy Department, it is our hope that the response to calls for bids by that Bureau will be both increased and quickened.—EDITOR.

1. *Contract.*—The contract to cover the work to be done will be based upon these general provisions, the detailed specification of the work, and the plans or other papers to which such detailed specification refers, all of which will be attached to and form a part of the contract. The successful bidder will be the party of the first part to the contract and will be known as the contractor, and the Navy Department will be the party of the second part and known as the Government.

2. *Government representatives.*—The work will be under the general direction of the Chief of the Bureau of Yards and Docks, acting under instructions of the Secretary of the Navy. A resident officer of the Corps of Civil Engineers, United States Navy, or other officer or representative of the Government, known as the officer in charge, will have immediate charge and supervision of the work and of all details thereof, including inspection. Appeals may be made to the resident senior naval officer, to the Chief of the Bureau of Yards and Docks and to the Secretary of the Navy, in the order named.

3. *Control of work.*—The Government, by its officer in charge, shall at all times exercise full supervision and general direction of all work under the contract so far as it affects the interests of the Government, and all questions, disputes, or differences as to any part or detail thereof shall be decided by such officer in charge, subject to appeal, provided that it shall be distinctly understood that the supervision and general direction of all work under the contract by the officer in charge shall not relieve the contractor of responsibility for the full protection of and responsibility for his work, both as regards sufficiency and time of execution.

4. *Omissions and misdescriptions.*—The omission from the contract or from the plans, specifications, or other papers attached thereto and forming a part thereof, or the misdescription of any details of work the proper performance of which is evidently necessary to carry out fully the general intention expressed in the detailed specification of the work shall not operate to release the contractor from performing such work, but the same shall be fully and properly performed in the same manner as if fully and correctly indicated, described, and required in and by the contract and without expense to the Government in addition to the contract price.

5. *Discrepancies.*—The specifications and plans forming part of the contract shall be considered as supplementary one to the other, so that materials and workmanship indicated, called for, or necessarily implied

by the one and not by the other shall be supplied and worked into place the same as though specifically called for by both. Should any discrepancy be found to exist between plans and specifications or any parts of either, or should the language of any part of the contract prove to be ambiguous or doubtful, the officer in charge will decide as to the true intent and meaning.

6. *Facilities.*—Unless otherwise specifically stated, the contractor shall be allowed reasonable space at the site of the work and access to the same for receiving, handling, storing, and working material. Employees, material, and plant shall be confined to the space assigned. Upon the completion of the work the contractor shall remove all of his surplus material, machinery, tools, etc. from the property of the Government, and upon failure so to do within 30 days from date of notice to remove they may be treated as abandoned property.

7. *Employees.*—The contractor shall employ only competent, careful, orderly persons upon the work; and if at any time it shall appear to the officer in charge that any person employed upon the work is incompetent, careless, reckless, or disorderly, or disobeys or evades orders or instructions or shirks his duty, such person shall be immediately discharged from and not again employed upon the work. Such discharge may be directed by the officer in charge, and if not acceptable to the contractor shall be nevertheless immediately effected preceding any appeal. No person undergoing sentence of imprisonment at hard labor shall be employed on the work. The contractor shall, in the prosecution of the work, take such measures for the safety of life and limb as will meet and satisfy the requirements of the laws of the State where the work is done.

8. *Time of commencement of work.*—The contractor shall commence work immediately after the delivery to him of a copy of the contract, and continue without interruption unless otherwise directed by the Government.

9. *Time of completion.*—Each bidder shall state the number of calendar days required to complete the work counting from the date a copy of the signed contract is delivered to him.

10. *Evaluation of bids.*—Bids will be evaluated on the basis of the agreed damages per day in each case where different times for completion are named by bidders, the shortest time being taken as the standard, and other bids increased at the per diem rate to cover the increased time required. Bidders are at liberty to submit as many bids as they desire, naming different periods of time for completion of the work.

11. *Continuance of work after time.*—It is mutually understood and agreed that in the event of the work not being completed within the time allowed by the contract, said work shall continue and be carried on according to all the provisions of said contract, unless otherwise directed by the Government, in writing, and said contract shall be and remain in full force and effect during the continuance and until the completion of said work, unless sooner revoked or annulled according to its terms: *Provided*, That neither an extension of the time beyond the date fixed for the completion of said work nor the permitting nor accepting of any part of the work after said date shall be deemed to be a waiver by the Government of its right to annul or terminate said contract for abandonment or failure to complete within the time specified or to impose and deduct damages as hereinafter provided.

12. *Extension of time.*—For causes of the character hereinafter enumerated extensions of time for the completion of the work may be allowed. Should the contractor at any time consider that he is entitled to an extension of time for any cause, he must submit in writing to the officer in charge an application for such extension, stating therein the cause or causes of the alleged delay. The officer in charge will refer the same at once with full report and recommendation to the Navy Department, Bureau of Yards and Docks, for consideration and for such action as the circumstances may warrant. The failure or neglect of the contractor to submit, as above provided, his claim for extension of time within 30 days after the happening of the cause or causes upon which his claim is predicted, shall be deemed and construed as a waiver of all claim and right to an extension of time for the completion of the work on account of the alleged delay, and the contractor agrees to accept the finding and action of the Navy Department, Bureau of Yards and Docks, in the premises as conclusive and binding.

13. *Damages for delay.*—In case the work is not completed within the time specified in the contract, or within such extension of the contract time as may be allowed, it is distinctly understood and agreed that deductions at the rate named in the specifications of the work shall be made as liquidated

damages and not as penalty from the contract price for each and every calendar day after and exclusive of the date within which the completion was required up to and including the date of completion, said sum being specifically agreed upon as a measure of damage to the Government by reason of delay in the completion of the work; and the contractor agrees and consents that the contract price, reduced by the aggregate damages so deducted, shall be accepted in full satisfaction for all work done under the contract.

14. *Unavoidable delays.*—Unavoidable delays are such as result from causes which are beyond the control of the contractor, such as acts of Providence, fortuitous events, inevitable accidents, abnormal conditions of weather or tides, or strikes of such scope and character as to interfere materially with the progress of the work. Delays caused by acts of the Government will be regarded as unavoidable delays. Delays in securing delivery of materials, or by rejection of materials on inspection, or by changes in market conditions, or by necessary time taken in submitting, checking, and correcting drawings or inspecting material, or by similar causes, will not be regarded as unavoidable. Should any delay in the progress of the work seem likely to occur at any time, the contractor shall notify the officer in charge in writing of the anticipated or actual delay, in order that a suitable record of the same may be made. (See par. 12.)

15. *Progress.*—The contractor, if so directed, shall furnish on a prescribed form a schedule of expected progress on the work under the contract, showing approximately the dates on which each part or division of the work is expected to be begun and finished. The contractor shall also forward to the officer in charge as soon as practicable after the first day of each month a summary report of the progress of the various parts of the work under the contract in the mills or shops and in the field, stating the existing status, rate of progress, estimated time of completion, cause of delay, if any, etc.

16. *Annulment of contract.*—If at any time the progress of the work shall have been such as to show that the work can not be completed within the time allowed, or should any provision of the contract be violated by the contractor, the Chief of the Bureau of Yards and Docks may, if in his opinion the interests of the Government demand it, declare the contract null and void without prejudice to the right of the Government to recover for default therein or violations thereof. Should the contract be declared null and void, the contractor agrees that the Government may hold all material delivered and work done under the contract and all machinery, tools, appliances, and accessories upon the site of the work or used in connection therewith pending the completion of the work covered by the contract unless allowed or directed to remove them in whole or in part. If the contractor is directed to remove the whole or any part of said machinery, tools, appliances, and accessories, and fails or neglects to do so within 30 days after notice, the Government shall thenceforth be free from any responsibility for the care or preservation thereof, and shall be entitled to reimbursement for any expense incurred in connection therewith. Upon the annulment of the contract a board of officers, or other representatives of the Government, shall be appointed, which shall ascertain and determine the value of all material delivered and work done, including a fair and reasonable margin of profit thereon, and upon the approval of the findings of said board by the Chief of the Bureau of Yards and Docks, the Government may proceed to complete the work according to the contract, with such changes as may subsequently be found necessary or desirable, in such manner and by such means as it may deem advisable, and may, if the interests of the Government demand it, use or employ any material, tools, machinery, appliances, and accessories belonging to or furnished by the contractor for use in connection with the work covered by the contract. Said board shall also inventory and estimate the value of said material, tools, machinery, appliances, and accessories, and said inventory and estimate shall, if approved by the Chief of the Bureau of Yards and Docks, be conclusive in any accounting between the parties to the contract: *Provided,* That the Government shall not be liable for depreciation by ordinary wear and tear, or injury or destruction by superior force, or for such material or articles as are consumed in use. Upon the completion of the work the cost of completing the same shall be ascertained and determined, and when approved by the Chief of the Bureau of Yards and Docks, shall be final, conclusive, and binding upon all parties; and should the total cost of the work, including payments made to the contractor, exceed the contract price, modified by the cost of any changes made before

or after annulment, determined as provided in the following paragraph, the difference shall be charged to the contractor, who undertakes and promises to pay the same upon demand. Should the total cost of the work be less than the contract price, the contractor shall be credited with the difference between the contract price, as modified by changes, and the total cost of the work, provided the amount so credited shall not exceed the amount found by the board above mentioned to be the value of the material delivered and work done by the contractor, less previous payments to him.

17. *Changes.*—The Government reserves the right to make such changes in the contract, plans, and specifications as may be deemed necessary or advisable, and the contractor agrees to proceed with such changes as directed in writing by the Chief of the Bureau of Yards and Docks. The cost of said changes shall be estimated by the officer in charge and, if less than $500, shall be ascertained by him. If the cost of said changes is $500 or more, as estimated by the officer in charge, the same shall be ascertained by a board of not less than three officers or other representatives of the Government. The cost of the changes as ascertained above, when approved by the Chief of the Bureau of Yards and Docks, shall be added to or deducted from the contract price, and the contractor agrees and consents that the contract price thus increased or decreased shall be accepted in full satisfaction for all work done under the contract: *Provided*, That the increased cost shall be the estimated actual cost to the contractor at the time of such estimate and that the decreased cost shall be the actual or market value at the time the contract was made, both plus a profit of 10 per cent.

18. *Extras.*—The contract price shall cover all expenses, of whatever nature or description, connected with the work to be done under the contract. Should the contractor at any time consider that he is being required to furnish any material or labor not called for by the contract, a written itemized claim for compensation therefor must be submitted by him to the officer in charge, who will refer the same at once with full report and recommendation to the Navy Department, Bureau of Yards and Docks, for decision and formal order covering approved items, if any. The failure or neglect of the contractor to present, as above, his claim for material or labor alleged to be extra within 60 days after being required to furnish or perform the same shall be deemed and construed as a waiver of all claim and right to additional compensation for the furnishing or performance of the alleged extra material or labor, and the contractor agrees to accept the finding and action of the Navy Department, Bureau of Yards and Docks, in the premises as conclusive and binding.

19. *Oral modifications.*—It is distinctly understood and agreed that no oral statement of any person whomsoever shall be allowed in any manner or degree to modify or otherwise affect the terms of the specifications, plans, or the contract. Changes shall be made only as herein elsewhere specified.

20. *Patents.*—The contractor shall forever protect and defend the Government in the full and free use and enjoyment of any and all necessary rights to any invention, machine, or device which may be applied as a part of the work, either in its construction or use after completion, against the demands of all persons whomsoever.

21. *Contractor's responsibility.* — The contractor shall be responsible for the entire work contemplated by the contract and every part thereof, and for all tools, appliances, and property of every description used in connection therewith. All methods of work, tools, appliances, and auxiliaries of all descriptions shall be safe and sufficient, and, if found by the officer in charge not to be so, shall be made satisfactory by the contractor without delay. The contractor shall specifically and distinctly assume all risks connected with the work, and shall be held liable for all damage or injury to property used or persons employed on or in connection with the work and all damage or injury to any person or property, wherever located, resulting from any action or operation under the contract or in connection with the work, and undertakes and promises to protect and defend the Government against all claims and to reimburse it for any outlay on account of any such damage or injury.

22. *Supervision.*—The contractor shall give the work his personal attention and shall be present on the site of the work continually during its progress, either in person or by duly authorized representative, to receive directions or instructions from the officer in charge. The name of such authorized representative shall be communicated in writing to the officer in charge.

23. *Eight-hour law.*—Special attention is called to the provisions of the laws relating

to hours of labor upon public works. Any violation of said laws coming to the notice of the Government officers or employees will be reported to the Navy Department for such legal action as may appear warranted.

Subject to the provision of section 2 of the eight-hour law of June 19, 1912, no laborer nor mechanic doing any part of the work contemplated by the contract in the employ of the contractor or any subcontractor contracting for any part of said work contemplated shall be required or permitted to work more than eight hours in any calendar day upon such work. For each violation of this provision a penalty of $5 shall be imposed for each laborer or mechanic for every calendar day in which he shall be required or permitted to labor more than eight hours upon said work, and the amount of any such penalties shall be withheld for the use and benefit of the Government from any moneys becoming due under this contract, whether the violation of this provision is by the contractor or any subcontractor.

24. *Special plans.*—Wherever it shall be necessary, the contractor shall make special or detail plans in amplification of the contract plans, or in furtherance of the specifications, before proceeding with the execution of the work. Such plans shall be submitted to the officer in charge or Chief of Bureau of Yards and Docks as may be directed, in the form of blue prints, in duplicate, for consideration, correction, or approval. When approved, one set of these prints shall be returned to the contractor so marked. When changes or corrections are necessary, one set shall be returned to the contractor so noted, and he shall proceed as before with the submission of duplicate prints. When any plan has been approved, the contractor shall furnish the officer in charge with additional blue-print copies, or with the tracing, or an equivalent as regards the facility for printing. If a tracing is submitted, the Government will make such prints as it may require and will return the tracing to the contractor. On the completion of the work the contractor shall, if so directed, furnish the Government with one complete set of Vandyke prints, on cloth, of all approved plans. When the work of the contractor is of a nature originating with him, full general and detail plans shall be furnished to the Government in the form of tracings, or the equivalent as regards facility for printing, which shall, upon approval, become the property of the Government, approved sets of prints being furnished to the contractor. The approval of the general and detail plans of the contractor shall in all cases be of a general nature relating to their sufficiency and compliance with the intention of the contract, and shall not relieve the contractor from errors, discrepancies, or omissions therein contained, which shall be made good whenever found.

25. *Checking plans and dimensions; lines and levels.*—The contractor shall check all plans furnished him immediately upon their receipt and promptly notify the officer in charge of any discrepancies discovered therein. Figures marked on plans shall, in general, be followed in preference to scale measurements, but the contractor must compare all plans and verify the figures before laying out the work, and will be held responsible for any errors therein that might have been avoided. Large-scale plans shall, in general, govern small-scale plans. In all cases where dimensions are governed by conditions already established the contractor must depend entirely upon measurements taken by himself, scale or figured dimensions to the contrary notwithstanding; but no deviation from the specified dimensions will be allowed unless authorized by the officer in charge. The contractor shall be held responsible for the lines and levels of his work, which upon completion shall fulfill the intention of the contract.

26. *Inspection.*—The contractor must afford every facility necessary for the safe and convenient inspection of the work throughout its construction. The officer in charge shall have power to reject material and workmanship which are not in accordance with the contract, and all such must be removed promptly by the contractor and replaced to the satisfaction of the officer in charge without extra expense to the Government. Should it be deemed advisable by the officer in charge to make an examination of work already completed by removing or tearing out the same, the contractor shall furnish all necessary facilities, labor, and material. If the work is found to be defective in any respect, due to the fault of the contractor, he shall defray all the expenses of such examination and of satisfactory reconstruction. If the work be found to meet the requirements of the contract, the actual cost of the examination plus 10 per cent will be allowed to the contractor, and the contractor shall be granted a suitable extension of time on account of the additional work involved, provided such extension of time is clearly

warranted. Provisional acceptance in the course of construction shall not preclude rejection upon the discovery of defects previous to acceptance of the completed work. All inspection of material and workmanship will be made, unless otherwise provided, after delivery at the site. When material is to be inspected at the factory the "Instructions relative to factory inspection of machinery and material, coming under the cognizance of the Bureau of Yards and Docks, Navy Department," will form a part of the contract. Material rejected at the place of manufacture or elsewhere shall not be delivered on the site of the work, and material rejected at the site of the work shall be at once distinctly isolated and, as soon as possible, removed from the Government reservation and not returned thereto.

27. *Order, protection, and completion of work.*—The contractor shall protect his materials and work from deterioration and damage during construction, and upon completion shall, without delay, remove his plant and all surplus material and rubbish from the site. The contractor will be required to carry on his work without interfering with the ordinary use of the streets or with the operations of other contractors, or delaying or hindering any work done by the Government, whether upon the site or not. He shall make good any damage to property of the Government caused by his operations. It is understood and agreed that the parties to the contract will, so far as possible, labor to mutual advantage where their several works in the above-mentioned or in unforeseen instances touch upon or interfere with each other. Mutual concessions under the direction of the officer in charge shall be made to secure this end.

28.—*Schedule of prices.*—Before the first payment becomes due the contractor shall submit to the officer in charge an itemized schedule of prices on prescribed forms furnished by the officer in charge. The officer in charge will check such schedule and forward it to the Bureau of Yards and Docks with his recommendation and the schedule, after it has been approved by the Bureau, will govern the preparation of monthly estimates. Allowance for non-perishable material delivered at the site of the work will be made only when it appears to the satisfaction of the officer in charge that such material will be worked into place within a reasonable time after date of delivery, and the officer in charge shall determine what period shall constitute a reasonable time after delivery. Allowance will be made for such temporary work as is of intrinsic value to the Government for the time being, such as cofferdam, sheet piling, cribwork, dikes, concrete forms, scaffolding, etc., when such work constructed in accordance with general plans submitted by the contractor is in place and completed and found by the officer in charge to be sufficient for the purpose for which it was constructed: *Provided, however,* That allowance in any payment on account of such temporary work shall not be disproportionate to the value of other work included therein, to be determined by the officer in charge, and that payment shall place no responsibility on the Government for the success or failure of the structure on account of which payment is allowed. The prices to be allowed for material for use in temporary work shall be the estimated actual value to the Government should the contractor fail to proceed with the contract to completion. The prices for material used in the permanent structure shall be the actual current market value as nearly as may be ascertainable. The difference between the total of the schedule of prices prepared as above indicated and the contract price shall be distributed among all the items of the schedule so that the total of the approved schedule shall in every case equal the total contract price. When the contract or any part thereof is based on unit prices and estimated quantities, these quantities and unit prices shall be employed in the schedule. Whenever the contract price is increased or decreased by supplementary agreement or order, the schedule of prices shall be amended to conform to the increased or decreased contract price.

29. *Payments and reservations.*—Vouchers will be prepared by the officer in charge of the work as soon as practicable after the end of each month, covering his estimate, according to the schedule of prices, of all material delivered, material worked into place, and work done to date. From such gross estimate will be deducted the next previous gross estimate, if any, and 10 per cent of the difference unless otherwise specified. The contractor shall certify to the correctness, justness, and nonpayment of said vouchers, after which they will be forwarded to the Bureau of Yards and Docks for approval and for reference to the Paymaster General of the Navy for payment by check. Upon the completion of the contract the balance due

on account thereof will be covered by similar vouchers, subject to any credits in favor of the Government: *Provided*, That the contractor shall first execute and deliver a final release to the Government, in such form and containing such provisions as shall be approved by the Navy Department, of claims against the Government arising under or by virtue of the contract.

30. *Lien.*—The Government shall have a lien upon the material entering into the work under the contract for all moneys paid for and on account thereof, which lien shall begin with the first payment, and shall thereupon attach to the work done and materials furnished, and shall, in like manner, attach from time to time as the work progresses and as further payments are made, and shall continue until it shall have been properly discharged; and said lien hereby provided is, pursuant to the act of Congress, approved August 22, 1911, paramount.

31. *Subcontracts.*—The contractor shall furnish the officer in charge, for the information of the Bureau of Yards and Docks, immediately upon the execution of any subcontract, a statement showing the name and address of the subcontractor, the character and location of the work involved, date of contract, time limit, if any, and amount of money agreed to be paid. This does not include material men performing no labor nor persons employed individually.

INDEX

DISK-WHEEL STRESS DETERMINATION*

By S. H. Weaver

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This article describes and applies a simplified method for determining the centrifugal stresses in a disk wheel of given irregular shapes of section. Stodola's disk theory is assumed, together with his formula for disks of hyperbolic-section profile. The formulae are then transformed so as to give the tangential stresses at the inner and outer radii in terms of the radial stresses, ratio of radii, and shape constant of disk section.

For commercial work approximate equations are given which cover the practical disk proportions, and within the limits shown have a range of error of less than one per cent. As a further labor-saving device when a number of disks are to be estimated, the approximate equations have been placed in an alignment-chart form.

A practical example is included showing an actual application of the method to a disk wheel of the usual type.—Editor.

In high-speed machine parts a disk construction of the rotating element is often necessary, because a disk shape has a smaller maximum stress in the material used than any other construction; and to reduce the maximum stress still further, the section of the disk is given an irregular shape, which, however, makes the stress determination more difficult. The mathematical determination of the three stresses, radial, tangential, and axial, acting at a given point in the disk section, is impractical. But if there is no sudden change in the axial thickness of the disk, as at a hub, the axial stress is of negligible value, and the mathematical side is greatly simplified by considering only the radial and tangential stresses. This method is treated fully in Stodola's Die Dampfturbinen and Stodola's Steam Turbine, translated by Dr. L. C. Loewenstein, but the resulting formula is left in such a form that it is difficult to apply, even by those well acquainted with the theory and the mathematics.

In the following will be described a method of calculation which has resulted in reducing the time required for a stress computation of an irregular-shaped turbine disk wheel to about one-tenth of that required for previous computations.

While the profile of the radial sections of disk wheels is usually made up of straight lines and arcs of circles, the equations of such lines present mathematical difficulties in the solution. The outline of the disk section can be closely approximated by one or more hyperbolas with the equation $t=cr^a$, where t is the thickness at the radius r, c is a dimension constant, and a is a shape constant for the profile of the section; a has a negative value when the thickness decreases with a larger radius, a zero value for a constant or uniform thickness, and a positive value when the thickness increases with a larger radius. For a given disk profile, Fig. 1, the value of a may be found from

$$a=\frac{\log\ (t_2/t_1)}{\log\ (r_2/r_1)}\quad \text{or}\quad =-\frac{\log\ (t_1/t_2)}{\log\ (r_2/r_1)} \qquad (1)$$

the formula being chosen which gives one or more for the ratio of thickness numerically.

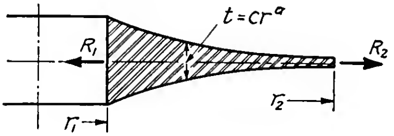

Fig. 1

The equations of the tangential and radial stresses as given in the above reference are as follows:

$$m_1=-\frac{a}{2}-\sqrt{\frac{a^2}{4}-Va+1},$$

$$m_2=-\frac{a}{2}+\sqrt{\frac{a^2}{4}-Va+1}$$

$$p=-\frac{(1-V^2)\ uw^2}{E_1\,[8+(3+V)\ a]}$$

$$R=\frac{E_1}{1-V^2}\,[\,(3+V)\ pr^2+(m_1+V)\ b_1r^{m_1-1}+(m_2+V)\ b_{11}r^{m_2-1}]$$

$$T=\frac{E_1}{1-V^2}\,[\,(1+3V)pr^2+(1+m_1V)b_1r^{m_1-1}+(1+m_2V)\ b_{11}r^{m_2-1}]$$

where m_1, m_2 and p are algebraic quantities

a = shape constant of profile of disk section
u = mass of disk material per unit of volume
w = angular velocity of rotation
V = Poisson's ratio of deformation = 0.3 for steel
E_1 = Young's modulus of elasticity
R = radial stress at radius r
T = tangential stress at radius r
r = any radius in disk section
b_1 and b_{11} = boundary-condition constants.

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* This article, except for the charts, was presented as a paper at the Spring Meeting (May, 1917) of the American Society of Mechanical Engineers, Cincinnati, Ohio.

To transform these equations, it will be necessary to know two stresses so as to determine the values of the condition constants b_1 and b_{11}. Assume a known radial stress R_1 at radius r_1 and R_2 at radius r_2, then from the above equations

$$R_1=\frac{E_1}{1-V^2}[(3+V)\,pr_1^2+(m_1+V)\,b_1r_1^{m_1-1}+(m_2+V)\,b_{11}r_1^{m_2-1}]$$

$$R_2=\frac{E_1}{1-V^2}[(3+V)\,pr_2^2+(m_1+V)\,b_1r_2^{m_1-1}+(m_2+V)\,b_{11}r_2^{m_2-1}]$$

Solving for b_1 and b_{11} gives, writing $K=\frac{r_1}{r_2}$,

$$b_1=-\frac{1-V^2}{E_1}\;\frac{[R_1-K^{m_2-1}R_2]+(3+V)\,pr_2^2\,[K^{m_2-1}-K^2]}{(m_1+V)\,(K^{m_2-1}-K^{m_1-1})\,r_2^{m_1-1}}$$

$$b_{11}=+\frac{1-V^2}{E_1}\;\frac{[R_1-K^{m_1-1}R_2]+(3+V)\,pr_2^2\,[K^{m_1-1}-K^2]}{(m_2+V)\,(K^{m_2-1}-K^{m_1-1})\,r_2^{m_2-1}}$$

Placing in the original equation for tangential stress the value of T_1 at r_1 and T_2 at r_2 with $K=r_1/r_2$, gives

$$T_1=\frac{E_1}{1-V^2}[\,(1+3V)\,pK^2r_2^2+(1+m_1V)\,b_1\,(Kr_2)^{m_1-1}+(1+m_2V)b_{11}(Kr_2)^{m_2-1}]$$

$$T_2=\frac{E_1}{1-V^2}[\,(1+3V)\,pr_2^2+(1+m_1V)\,b_1r_2^{m_1-1}+(1+m_2V)\,b_{11}r_2^{m_2-1}]$$

Substituting in these equations the values of b_1 and b_{11} as derived and remembering that

$$\frac{1+m_1V}{m_1+V}=-m_2,\qquad \frac{1+m_2V}{m_2+V}=-m_1,$$

$$m_1+m_2=-a,$$

gives

$$\begin{aligned}T_1&=Ar_2^2-BR_1+CR_2,\\ T_2&=Dr_2^2-ER_1+FR_2\end{aligned}\qquad(2)$$

where

$$B=\frac{m_1K^{m_2-1}-m_2K^{m_1-1}}{K^{m_2-1}-K^{m_1-1}},\quad E=\frac{m_1-m_2}{K^{m_2-1}-K^{m_1-1}},$$

$$C=\frac{E}{K^{a+2}},\quad F=B+a\qquad(3)$$

$$A=-\frac{uw^2}{8+(3+V)a}[\,(1+3V)\,K^2+(3+V)\,(K^2B-C)\,]$$

$$D=-\frac{uw^2}{8+(3+V)a}[\,(1+3V)+(3+V)\,(K^2E-F)\,]$$

The formulae for A and D can be further simplified by substituting numerical values for constant conditions in practice.

Disk wheels are usually made of cast steel or steel forging, the weight of material varying from 0.28 to 0.283 lb. per cu. in. Take the average value 0.2815, because it will result in an even numeral in the reduction; gravity is 32.16×12 in. per sec. per sec.; Poisson's ratio of deformation $V=0.3$. The stresses due to the external centrifugal load and the weight of disk itself vary as the square of the speed. One can then take a constant 1000 r.p.m. for all disks and, after finding stress values, reduce to any desired speed by multiplying by the square of the speed ratio.

With these values

$$\frac{uw^2}{8+(3+V)a}=\frac{\frac{0.2815}{32.16\times12}\left(\frac{2\pi\times1000}{60}\right)^2}{8+(3+0.3)a}=\frac{1}{1+0.4125a}$$

$$A=\frac{3.3\,(C-K^2B)-1.9K^2}{1+0.4125a},$$

$$D=\frac{3.3\,(F-K^2E)-1.9}{1+0.4125a}$$

Collect the formulae required for a solution of the stresses, Fig. 1.

$$\left.\begin{aligned}
&K=\frac{r_1}{r_2},\quad a=\frac{\log(t_2/t_1)}{\log(1/k)}\ \text{or}\ =-\frac{\log(t_1/t_2)}{\log(1/k)},\\
&m_1=-\frac{a}{2}-\sqrt{\frac{a^2}{4}-0.3\,a+1},\\
&m_2=-\frac{a}{2}+\sqrt{\frac{a^2}{4}-0.3\,a+1}\\
&B=\frac{m_1K^{m_2-1}-m_2K^{m_1-1}}{K^{m_2-1}-K^{m_1-1}},\\
&E=\frac{m_1-m_2}{K^{m_2-1}-K^{m_1-1}},\quad C=\frac{E}{K^{a+2}}\\
&F=B+a\\
&A=\frac{3.3\,(C-K^2B)-1.9\,K^2}{1+0.4125\,a},\\
&D=\frac{3.3\,(F-K^2E)-1.9}{1+0.4125\,a}
\end{aligned}\right\}\quad(4)$$

The tangential stresses at r_1 and r_2 are

$$T_1=Ar_2^2-BR_1+CR_2\qquad(5a)$$

$$T_2=Dr_2^2-ER_1+FR_2\qquad(5b)$$

These formulae are in a form more easily applied than the original ones. The factors A, B, C, D, E, and F are functions only of the shape constant a and the ratio of radii K; and when they are computed in a given disk for particular values of a and K, they may be preserved in tabulated form for future problems involving the same a and K and may be used even if the actual dimensions and speed of the wheel are entirely different.

As the determination of the values of the functions consumes the greater part of the time in a stress calculation, an attempt was made to place the tabulated values of the functions in a curve form with the function and a and K as variables. When plotted on rectangular coördinates, the curves covered so much space and some of the functions gave curves crossing each other in such a maze that it was impossible to read the values. For the form of an alignment chart the functions are so complicated that an accurately constructed chart would involve cumulative readings, and would introduce too large an error in the final values read. The conditions were finally met by using simple alignment charts based on approximate equations with known, negligible errors.

The approximate equations were found by a combination of mathematical and cut-and-try methods, and apply to the disks of practical proportions. The ratio of thicknesses is limited to a value not greater than 5. For values of a between 0 and -5 and K between 0.1 and 0.8 (except C where the K range is 0.4 to 0.8), the total range of error from the plus to the minus value is about 0.7 of one per cent. For the large plus values of a between 0 and $+40$ and K between 0.8 and 0.97, the total range of error is about 0.6 of one per cent.

These approximate equations, using common logarithms, are given in (6). On charts made from these equations one can read three numerals from the scales, which is close enough for commercial stress work.

Wheels usually have parts of uniform or constant thickness, and the values of the functions are then so simple that they can be calculated accurately as quickly as reading the values from the charts. For uniform thickness, the functions reduce to

$$\left.\begin{aligned}
&a=0, \quad K=\frac{r_1}{r_2}, \quad C=\frac{2}{1-K^2},\\
&B=F=C-1, \quad E=C-2\\
&A=6.6+1.4K^2, \quad D=6.6K^2+1.4
\end{aligned}\right\} \quad (7)$$

with A and D for 1000 r.p.m. and disk material of 0.2815 lb. per cu. in.

$$\left.\begin{aligned}
B &= \frac{\log\frac{1}{K}}{5.43}(a^2-1.2a)-\frac{a}{2}+\left(\frac{2}{1-K^2}-1\right),\\
F &= B+a\\
E &= \frac{\log\frac{1}{K}}{10}(a^2+10a)-\frac{a}{2}+\left(\frac{2}{1-K^2}-2\right)\\
&\quad \left[K\right]_{0.1}^{0.8} \quad \left[a\right]_{0}^{-5}\\
&= \frac{\log\frac{1}{K}}{7}(a^2+10a)-\frac{a}{2}+\left(\frac{2}{1-K^2}-2\right)\\
&\quad \left[K\right]_{0.8}^{0.97} \quad \left[a\right]_{0}^{40}\\
C &= \frac{\log\frac{1}{K}}{3.33}(a^2+4.8a)+\frac{a}{2}+\frac{2}{1-K^2}\\
&\quad \left[K\right]_{0.4}^{0.8} \quad \left[a\right]_{0}^{-5}\\
&= \frac{\log\frac{1}{K}}{4.65}(a^2+6a)+\frac{a}{2}+\frac{2}{1-K^2}\\
&\quad \left[K\right]_{0.8}^{0.97} \quad \left[a\right]_{0}^{40}\\
A &= 3.1(1-K)^{2.09}a+(6.6+1.4K^2)\\
D &= 1.25(1-K)^{1.75}a+(6.6K^2+1.4)
\end{aligned}\right\} \quad (6)$$

EXAMPLE

The application of the formulae and principle involved can be illustrated very clearly by an example. Fig. 2 shows the half-section of a disk wheel designed to run at 3600 r.p.m. The profile of the disk must be represented by a number of connecting hyperbolas whose a value can be found from equation (4). The disk section is divided into sub-sections or rings numbered *1*, *2*, *3*, *4*, and *5*, each subsection having a value of a, and the same thickness where they join the adjacent section. Rings *1* and *5* are of uniform thickness, hence a is zero. Ring *4*, the thickness of which increases very rapidly with the radius, has a large positive value for a. For the portion including rings *2* and *3*, two sections are used because the profile is better represented by larger values of K; and, since the thickness decreases as the radius increases, both values of a are negative.

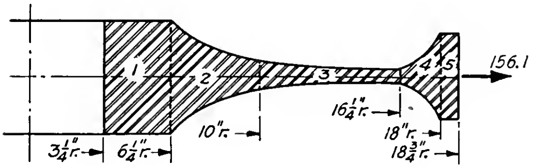
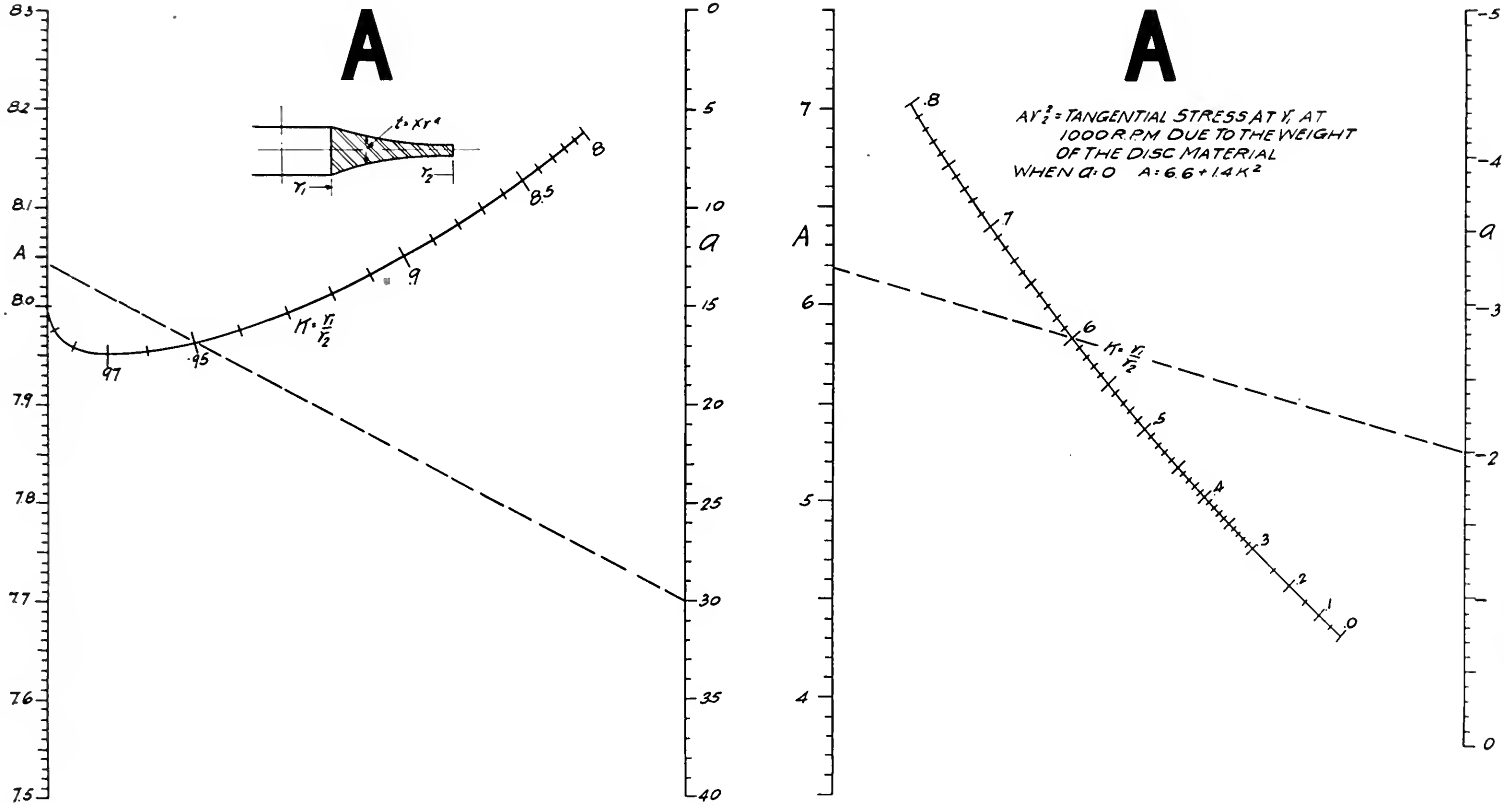
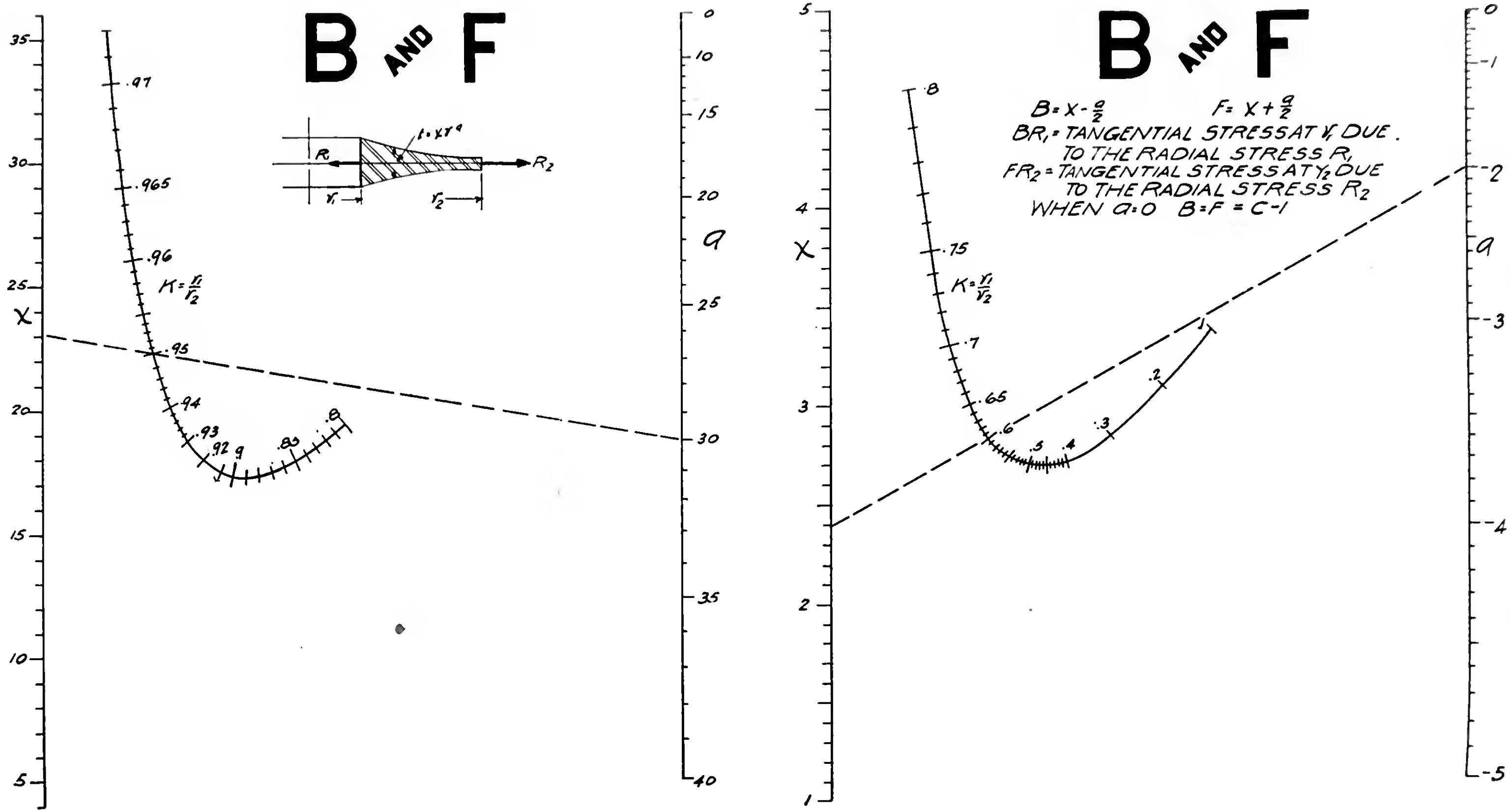


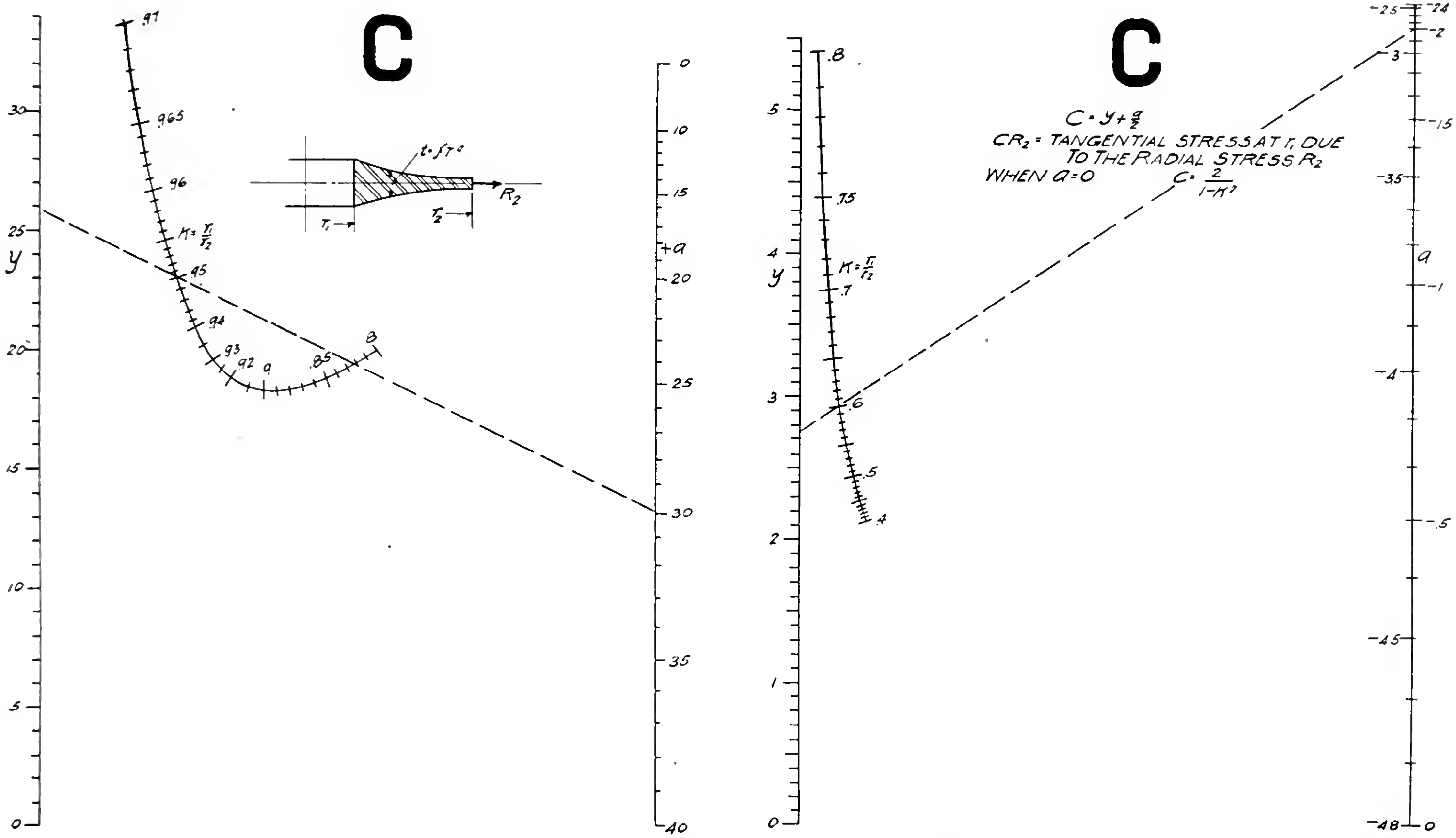
Fig. 2



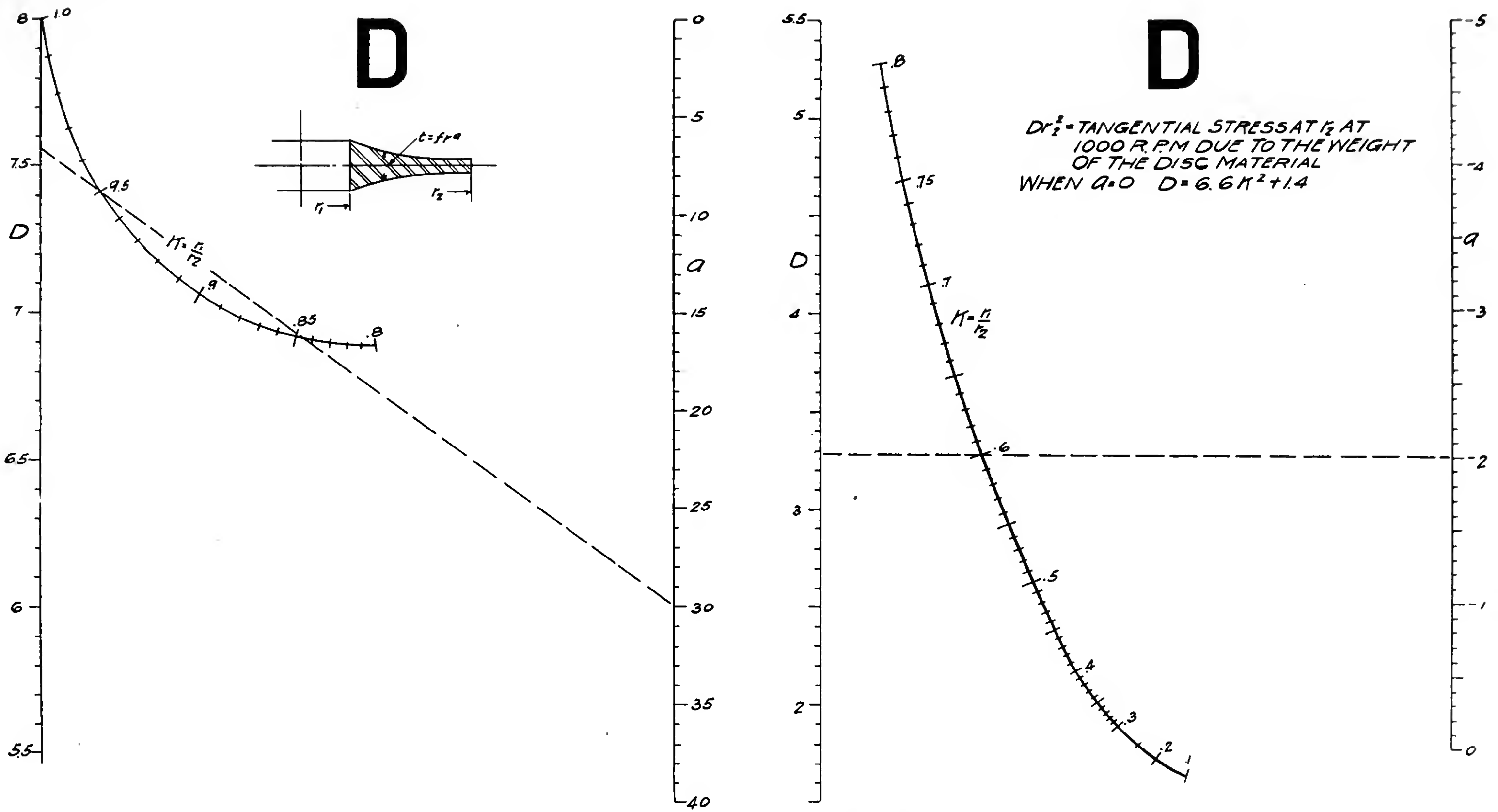
A—Disk-Wheel Stress: Any straight line, as the dashed lines shown, connects the corresponding values of the function *A* with the ratio of radii *K* and the shape constant of the disk *a*. $A\,r_2^2$ is the tangential stress at r_1 due to the weight of the disk material alone. *A* is for 1000 r.p.m. and material of 0.2815 lbs. per cu. in. and varies with the square of of the speed and with the specific weight of the material. Preferable to use value of *A* for 1000 r.p.m. and correct final results for the proper wheel speed. r_2 must be in inches then the stress is in pounds per square inch. See formula (5a).



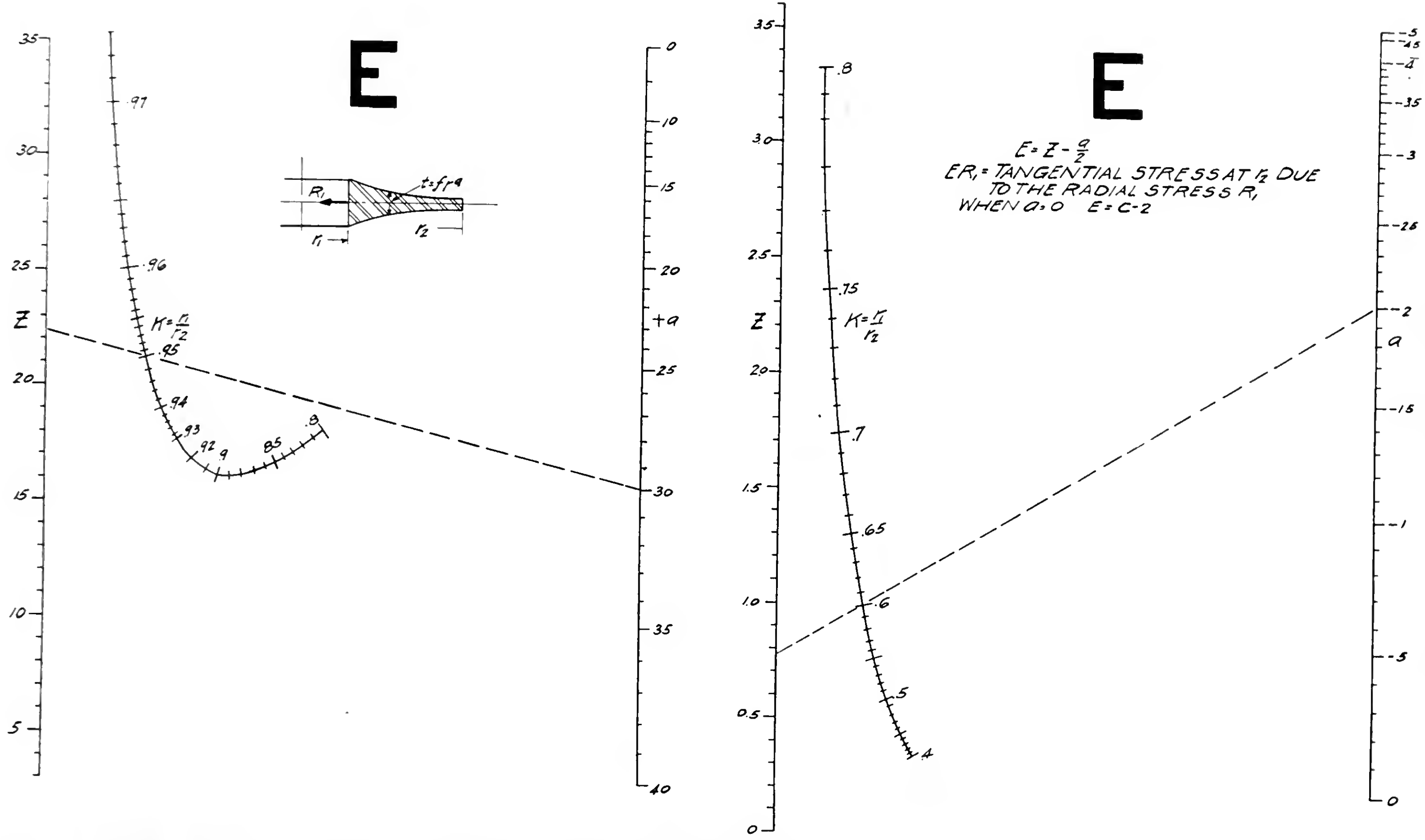
B and F—Disk-Wheel Stress: Any straight line, as the dashed lines shown, will connect the corresponding values of X, the ratio of radii K and the shape constant of the disk a. $B=X-\frac{a}{2}$ and $F=X+\frac{a}{2}$. If R_1 and R_2 are the external radial stresses at the inner and outer radii respectively, then BR_1 gives the tangential stress at the inner radius which is caused by the radial stress R_1, and FR_2 gives the tangential stress at the outer radius which is produced by the radial stress R_2. B and F are independent of speed, weight of material and dimension units. Used in fomula (5a) and (5b)



C—Disk-Wheel Stress: Any straight line, as the dashed lines shown, connects the corresponding values of y, the ratio of radii K, and the shape constant of the disk section a. $C = y + \frac{a}{2}$. If R_2 is the external radial stress at the outer radius of the disk then CR_2 gives the tangential stress at the inner radius which is caused by the radial stress R_2. C is a function independent of the speed of the disk-wheel, of the disk material and of the dimension units. Used in formula (5a).



D—Disk-Wheel Stress: Any straight line, as the dashed lines shown, connect the corresponding values of the function *D* with the ratio of radii *K* and the shape constant of the disk *a*. Dr_2^2 gives the tangential stress at the outer radius r_2 due to the weight of the disk material alone. *D* is for 1000 r.p.m. and material of 0.2815 lbs. per cu. in. and varies with the square of the speed and with the specific weight of the disk material. Preferable to use value of *D* for 1000 r.p.m. and correct final results for the proper wheel speed. r_2 must be in inches then the stress is in pounds per square inch. Used in formula (5b).



E—Disk-Wheel Stress: Any straight line, as the dashed lines shown, connects the corressponding values of Z the ratio of radii K and the shape constant of the disk section a. $E = Z - \frac{a}{2}$. If R_1 is the external radial stress at the inner radius of the disk then ER_1 gives the tangential stress at the outer radius which is produced by the radial stress R_1. E is a function independent of the speed of the disk-wheel and of the disk material and of the dimension units. Used in formula (5b).

Of the different radial stresses at least two must be known. The radial stress at the bore may be taken as zero, for the shrink fit with which the wheel is placed on the shaft may be supposed to be almost neutralized at normal speed by the centrifugal expansion at the bore, and at some overspeed the radial stress is zero. The outer radial stress of the bucket load equals the centrifugal force of the buckets, covers, etc., at 1000 r.p.m. (14.2× weight in lb.×diameter in inches) divided by the outer cylindrical area of the rim. In the example, this radial pull per sq. in. of surface at $r=18\frac{3}{4}$ in. is 156.1 lb. per sq. in. at 1000 r.p.m.

Let the unknown radial stress at the lines dividing the imaginary rings be e between rings *1* and *2*, f between rings *2* and *3*, g between rings *3* and *4*, and h between rings *4* and *5*. Collect the data as shown in Table I. For the constants A to F calculate for accurate work from equations (4) and (7): for approximate results calculate from equations (6) and (7), or read from alignment charts values of equation (6) when placed in chart form.

From construction, there is only one thickness at any given radius, therefore only one set of stress values at any particular radius. Thus, at the line dividing the imaginary rings *1* and *2* there can be only one radial stress e and one tangential stress, so that one can write the outer tangential stress of ring *1* by equation (5*b*) equal to the inner tangential stress of ring *2* by equation (5*a*). In the same way, at the line separating rings *2* and *3*, the outer tangential stress of ring *2* equals the inner tangential stress of ring *3*. Write an equality of the tangential stress for each division line between imaginary rings and then solve for the unknown radial stresses (e, f, g, and h).

The equalities of the tangential stresses are:

at $r=6.25$,

$$3.18\times(6.25)^2-7.4\times0+1.74e=5.99\times(10)^2-4.17e+1.49f;$$

at $r=10$,

$$3.33\times(10)^2-2.31e+1.27f=6.58\times(16.25)^2-2.99f+2.25g;$$

at $r=16.25$,

$$3.59\times(16.25)^2-1.62f+1.69g=8.09\times(18)^2-4.03g+21.33h;$$

at $r=18$,

$$7.09+(18)^2-3.75g+19.03h=7.89\times(18.75)^2-24.51h+25.51\times156.1$$

TABLE I

Data for Stresses at Lines Dividing the Imaginary Rings in Fig. 2

Ring No.	1	2	3	4	5
r_1	3.25	6.25	10.00	16.25	18.00
r_2	6.25	10.00	16.25	18.00	18.75
t_1	5.00	5.00	1.28	0.68	3.14
t_2	5.00	1.28	0.68	3.14	3.14
$K=r_1/r_2$	0.52	0.625	0.615	0.903	0.96
a	0.00	−2.9	−1.3	15.00	0.00
R_1	0.00	e	f	g	h
R_2	e	f	g	h	156.1
A	6.98	5.99	6.58	8.09	7.89
B	1.74	4.17	2.99	4.03	24.51
C	2.74	1.49	2.25	21.33	25.51
D	3.18	3.33	3.59	7.09	7.48
E	0.74	2.31	1.62	3.75	23.51
$F=B+a$	1.74	1.27	1.69	19.03	24.51

The solution of these equations gives

$e=433$, $f=1398$, $g=1578$, and $h=238$.

Substituting in either the right or left side of the above equations gives the tangential stress at the respective radii. The tangential stress at the bore is $6.98\times(6.25)^2-1.74\times0+2.74\times433=1458$; at the outer rim $=7.48\times(18.75)^2-23.51\times238+238+24.51\times156.1=853$. The stresses at 1000 r.p.m. are

for $r=$	3.25	6.25	10	16.25	18	18.75
$R=$	0	433	1398	1578	238	156
$T=$	1458	877	1109	1345	915	853

The stress at intermediate points in any ring can be computed from the known values by the use of both equations (5*a*) and (5*b*).

For 3600 r.p.m. all the stresses should be multiplied by $(3600/1000)^2=12.96$, giving

for $r=$	3.25	6.25	10	16.25	18	18.75
$R=$	0	5608	18115	20450	3189	2020
$T=$	18900	11386	14368	17430	11858	11052

The radial elongation at any radius r is $\epsilon=(T-0.3R)r/29{,}000{,}000$, where 29,000,000 is the modulus of elasticity of the disk material. The radial elongation at 3600 r.p.m. is then for

$r=$	3.25	6.25	10	16.25	18	18.75
$\epsilon=$	0.00212	0.00208	0.00308	0.00633	0.00677	0.00676

The time required for an accurate solution, using the original Stodola formula, is about forty-five hours; the use of the approximate formula in alignment-chart form reduces the time to about five hours. As to the error in the approximation, a comparison has been made on seven disks in which one wheel had the maximum stress one per cent low; the remaining disks had too high a value of stress, the greatest error being three per cent.

THE LARGE TURBO-GENERATOR

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In the fourteen years since the installation of the first 5000-kw. machine, in 1903, the size of the turbo-generator has steadily increased, until today units of 45,000 kw. are being built. This is a ninefold increase. Coincident with this phenomenal increase in size, efficiency has been increased 100 per cent. In other words, for the same amount of power at the switchboard, the latest units will require half the amount of coal. These developments have been made possible largely through improvement in constructional materials, higher speeds, and higher steam pressures, superheat and vacuum. In the comparison that the author makes between prime movers for steel mill service, it is shown that the turbine plant has the lowest first cost and also the lowest operating cost. This is contrary to the usual case, for ordinarily the apparatus of higher first cost has the lower running charges. This article is abstracted from a paper read before the American Iron and Steel Institute, New York City, May 25, 1917. Portions of the discussion and the specifications of the plants between which comparison is made will be given in our November issue.—Editor.

The commercial utilization of steam turbines in power stations began with the installation of the 5000-kw. vertical machines in the station of the Commonwealth Edison Company at Chicago, in the year 1903. (See Fig. 8.) While various builders had been developing turbines before this date, this was the first installation of a unit of considerable size, and it gave a tremendous impetus to the turbine situation, as it turned the minds of those engaged in the development of power stations toward this form of prime mover.

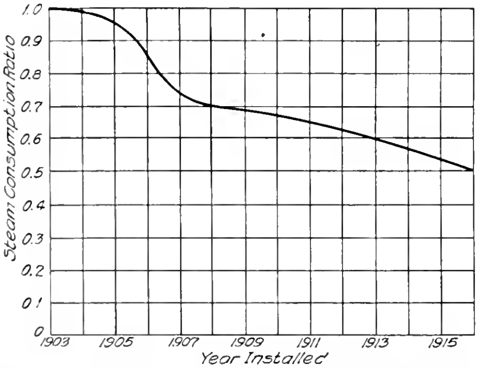

Fig. 1. Ratio of Steam Consumption in Successive Years to that in 1903, for largest size steam turbines

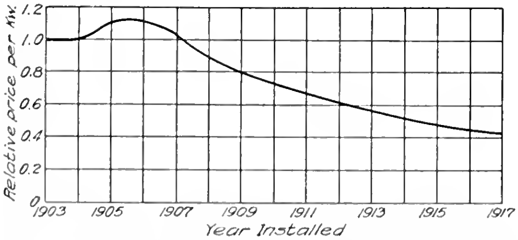

Fig. 2. Average Price per Kw. of Large Steam Turbines, for Successive Years, in terms of price of first 5000-kw. unit

This installation is typical of the boldness with which central station owners have risked their capital and their business to promote the development of apparatus of the highest efficiency. During the entire period of the turbine development, the central stations have always been receptive to new ideas and willing to purchase apparatus embodying these ideas and without regard to whether such ideas had been crystallized into actual apparatus in operation. Without such far-sighted treatment the development of the steam turbine, with the rapidity which has characterized it, would not have been possible. The whole engineering profession owes a great debt of gratitude to these liberal-minded and courageous men.

The first large turbines were made of the vertical type for the reason that this type lent itself to the particular speeds and dimensions adopted, better than any other type. The original large turbines were made of comparatively low speed in order that the ordinary materials of commerce could be utilized with moderate strains and good conditions of operation, and to match up with existing knowledge in regard to generator design. This vertical type of turbine was of such reasonable cost, as compared with existing apparatus for developing power, and of such good efficiency, that it rapidly displaced all other types of prime mover in power stations to a very considerable extent, because it reduced the cost of constructing stations and also of putting the current on the lines. This made possible a great expansion of central station business.

The vertical turbine was manufactured in immense quantities during the ten years from 1903 to 1913. During this time much was done to improve the efficiency of the turbine. It is some indication of this improvement that the 12,000-kw. units which replaced the original 5000-kw. Chicago machines had an efficiency exceeding that of the original units by 40 per cent. At the same time improvements in generator construction, advances in quality of materials obtainable, and continued research led to the use of higher speeds, and in 1913 this progress had gone so far as to lead to production of machines whose efficiency exceeded that of the original Chicago machines by about 65 per cent. The use of higher speeds of rotation forced the abandonment of the vertical type of machine in favor of the horizontal type, which is better adapted for the smaller diameters of turbine wheels and generator rotors, which such speeds necessitate. Therefore, from 1913 the development has been confined to the horizontal type. Since that time methods have been found by which the efficiency of turbines has been still further increased by reduction of the fixed losses. In order to exhibit in a practical way the progress which has been made the curves shown in Figs. 1, 2 and 3 are presented. These are based on the performance of the original 5000-kw. Chicago machines, first mentioned, and show very clearly the improvements which have been made in the reduction of steam consumption, in the price per kw., and in the weight in pounds per kw.

Referring to the steam consumption curve, Fig. 1, it will be seen that, regarding the steam consumption of the 5000-kw. Chicago machines as unity, the largest machine built in 1916 has a water rate which is exactly one-half of that of the Chicago machine. It is believed that this development in efficiency has not been paralleled by that of any other type of heat engine when it is considered that the original machines were competitive with existing apparatus. Coupled with the development above stated has been a very notable development in the capacity of single units, and this is not one of the least of the advantages of the steam turbine. The growth is illustrated in Fig. 4. The original machine, as stated, was of 5000-kw. capacity, and this was very close to the maximum capacity of steam engine generating units available at that time. In 1906 the maximum capacity had risen to 8000 kw., in 1908 to 14,000 kw., in 1911 to 20,000 kw., in 1915 to 35,000 kw., and in 1917 there are two units under construction of 45,000 kw. each. These figures refer to units in a single shell with a single generator. The largest engine-driven units ever constructed for central power station use were rated at 7500 kw.

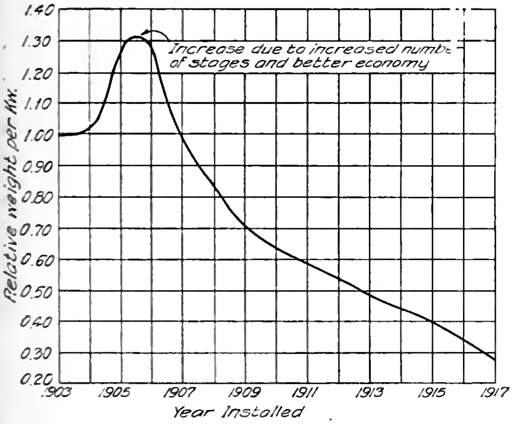

Fig. 3. Weight per Kw. of Large Steam Turbines, for successive Years, in terms of weight per kw. of first 5000-kw. unit

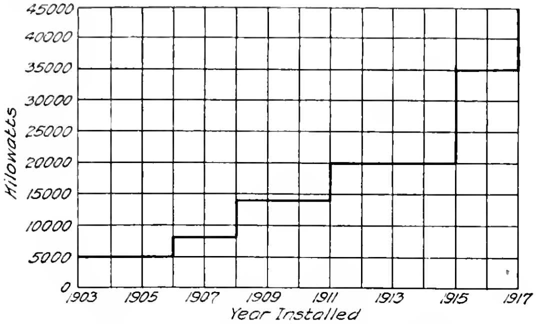

Fig. 4. Capacity of Largest Steam Turbine Units Installed in Various Years

It cannot be said with certainty that the ultimate capacity of single turbo-generator units is limited to the sizes now being built, although for the moment this is undoubtedly true. The limitation in the size of the unit is a limitation arising from the materials available for buckets and for bucket wheels, and from certain other constructional difficulties which may, or may not, be smoothed away by future improvements. Furthermore, an important limitation is the question of dimensions of pieces which can be transported by rail. Remembering, however, that in 1908 we could not foresee the possibility of making 20,000-kw. units, and in 1911 we could not see the possibility of making 35,000-kw. units, I have faith to believe that in a few years we will be building units of greater ratings.

The development of steam turbines has proceeded along various lines. One of these is the determination of the best methods of using the energy in the steam with moderate ranges of steam pressure and steam temperature. This has led, as much as anything, to the use of a constantly increasing number of stages. Another line of progress has been in the direction of extending the pressure range at its lower end. It was found early in the progress of the development that the use of a very high vacuum was attended with improved results. At the time when the steam turbine began to be used, it was the accepted opinion, arising from limitation of steam engine design, that 27 inches was as good a vacuum as it was desirable to obtain. The discovery that high vacuum was beneficial for steam turbines led to the early installation of condensing apparatus capable of giving 28 inches vacuum, and progress in this direction led to 29 inches as an ordinary, usual figure, and many stations in the country now operate throughout the colder months of the year with vacuum ranging between 29 inches and 29.4 inches.

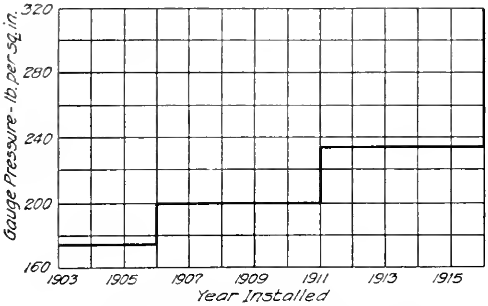

Fig. 5. Highest Initial Steam Pressures Used in Large Steam Turbines

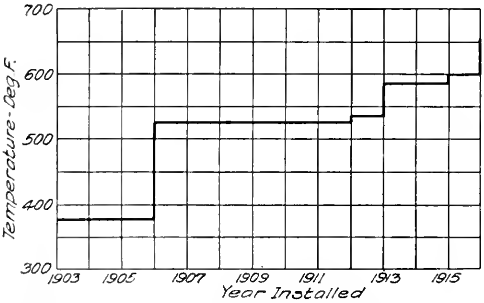

Fig. 6. Initial Temperatures Used in Large Steam Turbines

Still another line of progress, Figs. 5 and 6, is found at the upper end of the scale. The steam turbine lends itself well to the use of high initial pressures of steam and also to the use of high temperatures (that is, high superheat). The original turbines were intended to operate with 175 pounds steam pressure, without superheat, and owing to imperfect knowledge of the laws involved in the proper utilization of high superheat, it was for some time believed that high superheat was not attended with a corresponding increase in efficiency. At this time, the laws involved in the proper utilization of high superheat are known, and its economy has been demonstrated. Increased boiler pressure is also known to give increased efficiency, and therefore turbines are now in use and under construction which will utilize the highest steam pressures and temperatures which the present state of boiler and steam pipe construction are capable of safely generating and handling. The situation may be summed up as follows: The highest steam pressure now in use is 300 lb. per sq. in., while units are under construction intended for 350 lb. pressure. The superheat is chosen so as to make the initial steam temperature fall between 600 deg. and 700 deg. F.

Further progress in this direction depends upon the practicability of building boilers and piping to continuously withstand greater pressures and upon the desirability of the investment from a commercial standpoint, considering the necessarily higher cost of such apparatus. It is safe to predict that higher temperature and higher pressure will be used following closely the development of better materials, of improved design, and increased experience on the part of the boiler builders.

The last great line of progress to be considered here has been the improvement in boiler-house efficiency. The average boiler efficiency in steel mill and blast furnace installations was, in 1903, and in many cases still is about 60 per cent. In power stations at that time it ranged around 65 per cent to 70 per cent. Recent boilers in central stations, including economizers, show efficiencies of 82 per cent to 84.2 per cent. This increase in efficiency is chiefly due to improvements in stoking apparatus, to improvements in furnace construction, to the use of large boilers, and to the use of economizers. The economizer is a means of abstracting heat from the gases in their passage from boiler to chimney and imparting it to the feed-water. By abstracting this heat it lowers the temperature of the gases to a point just above the temperature at which moisture from the gases would be deposited on the economizer tubes, and it adds 4 per cent to 6 per cent to the thermal efficiency of the station. It is also possible practical and commercially profitable to obtain a further addition to the thermal efficiency of about the same amount by inserting a feed-water heater in the flues after the economizer, of construction suitable to work with the deposition of moisture above referred to without excessive deterioration, and by such means to reduce the temperature of the outgoing gases to even as low as 125 deg.

With blast furnace gas, using the most modern equipment of superheaters, boilers, furnaces and premixing burners, and using gas which has passed through primary washers, and with the same attention to the operation which is met with in our best central stations, it is confidently believed that a boiler-house efficiency of 81 per cent can be obtained in actual service.

Progress in increasing the energy output at the switchboard, per pound of coal fired into the boilers, has been dependent not only on improvements in the turbines, but also in condensing apparatus and in the boiler house, and the combined results is, of course, what interests the user. Fig. 7 has been drawn from the best data available, to show the progress that has been made. It will be seen that, starting in 1903, one pound of coal of 13,500 B.t.u. was capable of delivering 0.41 kw-hr. at the switchboard. Progress has been fairly uniform throughout the years to 1916, when we find that a pound of coal will deliver 0.82 kw-hr., or an increase in 13 years of 100 per cent.

One of the great difficulties met with in considering data concerning the operation of turbo-electric plants arises from the rapidity of turbine development. No sooner has a plant been installed and operated long enough to enable accurate tests to be made, than better apparatus has been designed and made available, so that the results of actual tests of power stations in operation never represent the state of the art. Machines which can be sold at time of test are always better than those which are being tested. No other prime mover has experienced such rapid development in efficiency, and no other prime mover is, therefore, subject to this difficulty. It is possible, given results from existing stations, to predict with certainty the results which will be obtained with turbines of the latest construction. The curve here shown in Fig. 7 is based on actual station test results and therefore does not represent the possibilities at this time, but rather gives results substantially inferior to such possibilities.

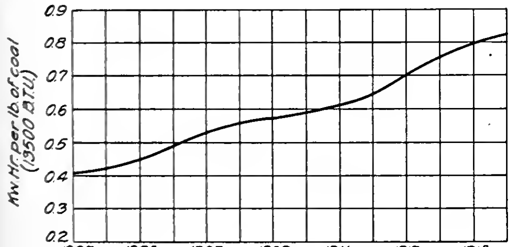

Fig. 7. Kilowatt-hours per Pound of 13,500 B.t.u. Coal, for Complete Electric Stations using largest steam turbines on steady load

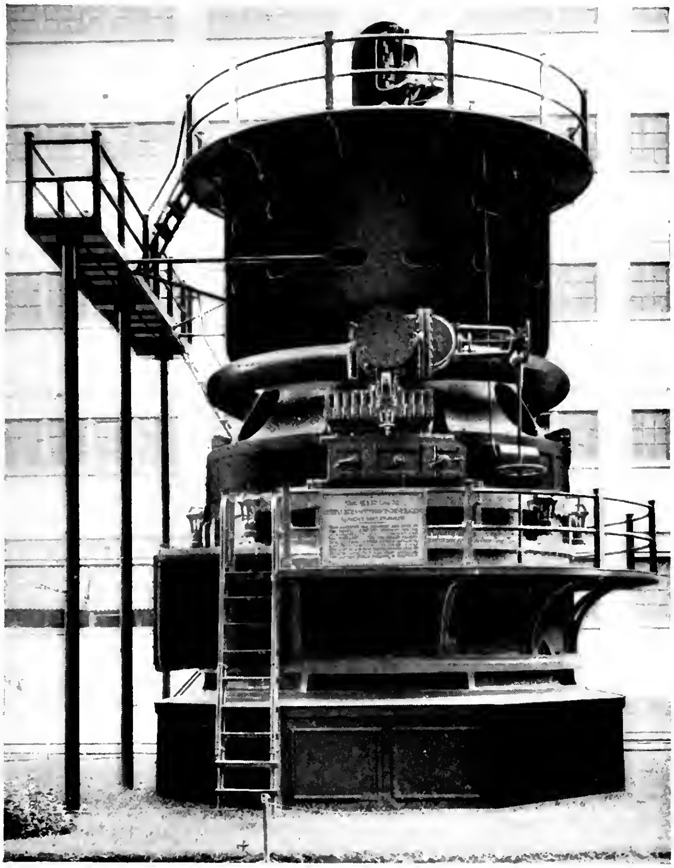

Fig. 8. First Large Steam Turbine, 5000 kw., Commonwealth Edison Co., Chicago, Ill.

The extensive gas-engine installations which have been made in the steel mills of this country were decided upon at a period in the

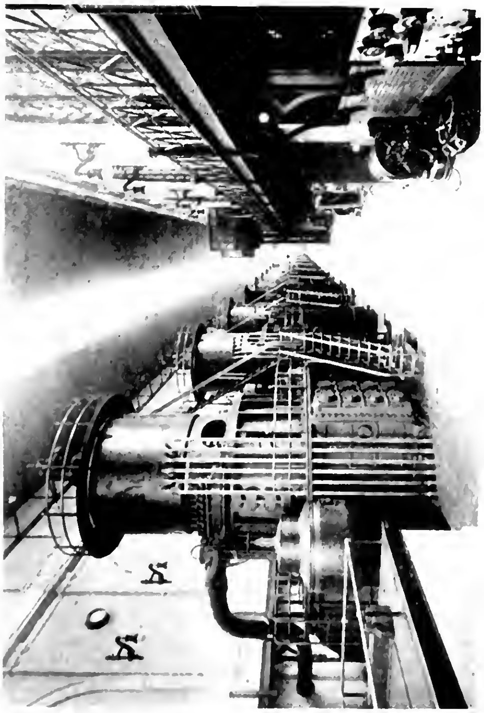

Fig. 9. 12,000-kw. Steam Turbines, Commonwealth Edison Co., Chicago, Ill.

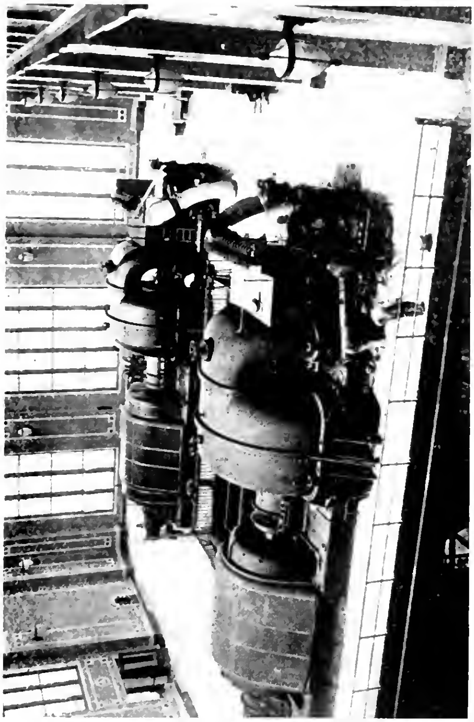

Fig. 10. Two 25,000-kw. Steam Turbines, Essex Station, Public Service Electric Co. of New Jersey

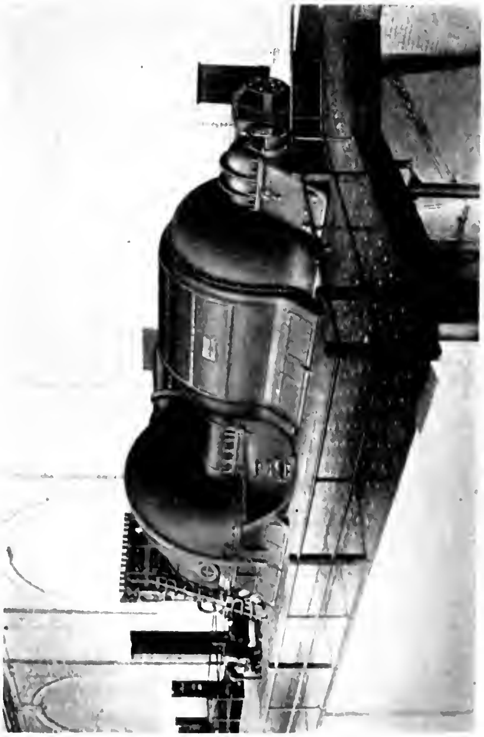

Fig. 11. Modern 20,000-kw. Steam Turbine, Commonwealth Edison Co., Chicago, Ill.

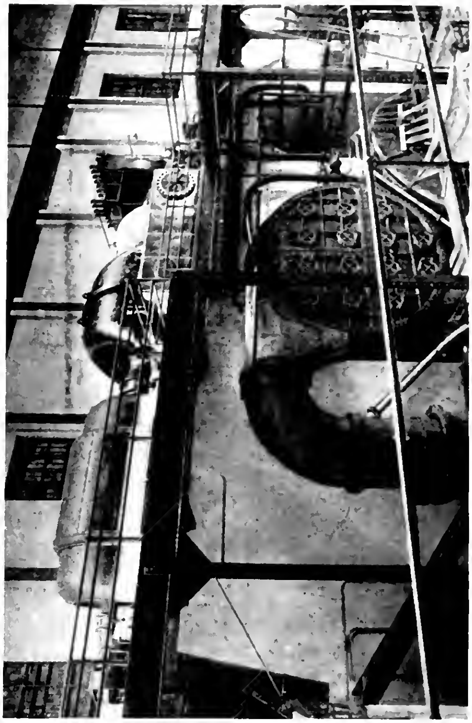

Fig. 12. Modern 30,000-kw. Steam Turbine, Commonwealth Edison Co., Chicago, Ill.

development of the steam turbine when, as shown above, the showings which could be made were much inferior to the results of today. Therefore, the comparison between gas engine and steam turbine is on an entirely different basis at this time, and the problem ought to be now considered in the light of these latest results.

In order to exhibit the relative characteristics as regards first cost, operating cost, and efficiency of plants containing gas engines as contrasted with plants containing steam turbines, layouts and data have been prepared covering a considerable number of plants, of which three plants have been selected as typical of the general situation. One of these plants is entirely driven by gas engines as prime movers. Another is entirely driven by steam turbines; while the third, hereafter referred to as "the combined plant" is a gas engine plant with such steam apparatus as is needed to give such a degree of operation-factor as to permit the operation of the plant with reasonable continuity, but, nevertheless, not equally as able to operate under unfavorable conditions as the steam turbine plant.

As regards continuity of operation, these three plants would rank as follows:

First, the steam turbine plant.
Second, the gas engine plant with steam reserve (combined plant).
Third, the all-gas-engine plant.

In preparing this information, a considerable choice presented itself as to the amount of emergency operating resources which would be provided to take care of the periods when gas supply is low in heat units and in quantity.

In a four-furnace gas engine plant, supplied solely with blast furnace gas as a fuel, there would be considerable periods occurring frequently when steel mill apparatus would have to be shut down for lack of power. In the gas engine plant which has been chosen, gas producers are installed for the purpose of supplying fuel to the gas engines during these periods. These gas producers, of course, have no heat storage. They are not capable of giving out, during such periods, heat stored up during periods when the gas supply is abundant. Therefore, the reserve capacity which can be provided in this way is not equal to plant No. 2, which contains steam turbines supplied by steam boilers which have heat storage capacity in the water thereof. The boiler capacity in this plant, in turn, is not nearly as great as in the steam turbine plant which, therefore, has considerably more reserve capacity due to the heat storage capacity of these additional boilers. Furthermore, in the case of the combined plant, and in the steam turbine plant to a greater degree, power can be produced for operation of steel mills when the gas supply is deficient, by the use of fuel, either oil, tar or coal, to supplement the low gas supply. This is possible in the gas engine plant, but not to anything like as great a degree, as the gas producer capacity provided is not sufficient.

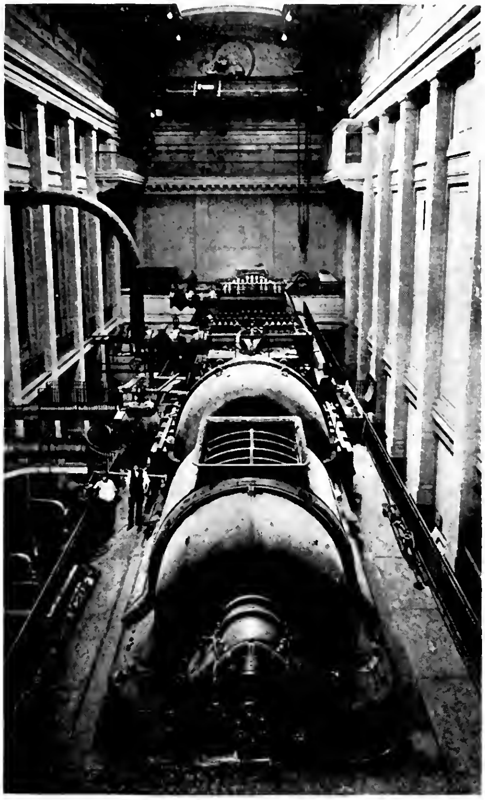

Fig. 13. 30,000 and 35,000-kw. Steam Turbines, Philadelphia Electric Co.

In making these comparisons, the size of plant which has been chosen is one which contains four blast furnaces, each capable of producing 550 tons of pig per 24 hours, with a coke consumption of 1800 pounds per ton of iron. The proper amount of electric generating apparatus for a steel mill has been provided of such capacity as to utilize the blast furnace gas of the full average quantity and quality; and all the other items necessary to constitute a complete, practical and modern blast furnace and steel mill of this capacity have been included.

The gas plant and the combined plant differ materially from the plant described in a paper on "Blast Furnace and Steel Mill Power Plants,"* since they provide less capacity for operation during periods of lean gas and low gas volume, less capacity for heat storage, and since because of the elimination of electric storage batteries and direct current generating apparatus, and in other particulars, they go to the extreme in the utilization of the latest experience in gas engine manufacture and operation.

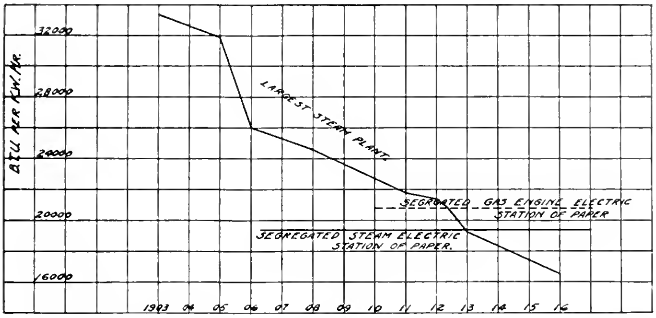

Fig. 14. Heat Consumption, in B.t.u. per Kw-hr., for Complete Electric Stations on Steady Load. The figures in all cases include all power-plant apparatus, including auxiliaries and emergency reserves

As the result of these differences, the first costs and operating costs of the gas and the combined plants are considerably lower than the figures above referred to.

In the paper referred to there was an allowance of an additional 25 per cent to normal costs to bring the cost up to those ruling at the time of the preparation of that paper. On account of the rapid change of cost of all sorts of apparatus, all costs have been restored to those ruling in the latter part of 1915 and the early part of 1916, which are considered as normal.

The steam turbine-driven plant which has been used for these comparisons is supplied with apparatus, buildings, etc., of suitable character for installation in a steel mill. While designed to be comparable in results obtained with the gas engine plant and the combined plant as regards continuity of service and protection by spares against shut-down of the mills, it will, by its inherent characteristics, give greater continuity of service, and this fact must be taken into account in considering the merits of the various plants. This turbine plant utilizes the latest improvements in steam turbine manufacture now actually on the market. Comparing this plant with the plant of the Engineers' Society of Western Pennsylvania paper, some increases have been made in economizers and switchboards.

In making up figures for the all-gas engine plant, an over-all efficiency of 20 per cent of the main units has been taken. This figure has been taken in order to conform to the views of engineers who have been consulted and who are familiar with the practical operation of gas engine stations, but, in the judgment of the writer, it is too high a figure to use for gas engines operating under variable load in steel mill service. The curve of efficiency of a gas engine is a steep one, and efficiency rapidly falls off with reduction of load, due first to the fixed mechanical losses; and second, to the variations in the gas which unfavorably affect the efficiency of operation much more seriously at light

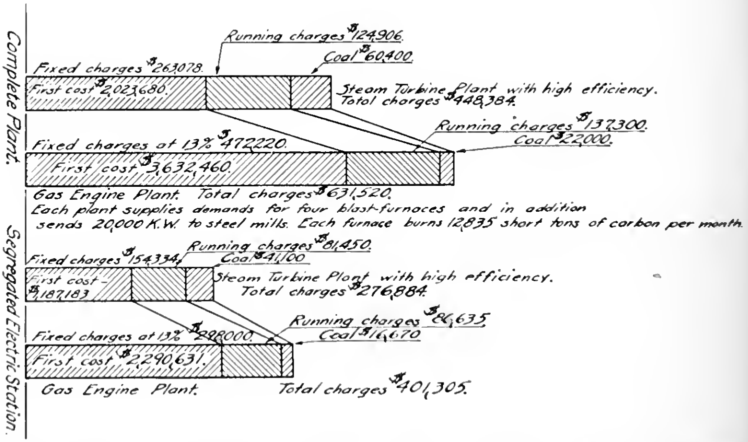

Fig. 15. Chart of Comparative Charges for Four-furnace Plants. The total lengths for each case give total costs of every kind, including fixed charges, repairs, maintenance and operation, and make-up coal. All figures are dollars per year

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* ("Blast Furnace and Steel Mill Power Plants," by R. H. Rice and S. A. Moss, Proc. Engr. Soc. of Western Pennsylvania, Vol. 33, No. 2, March, 1917.)

loads. If this figure is taken at 17 per cent, which, in the opinion of the writer is as high a value as should be used for variable load, the efficiency of the all-gas engine plant would be reduced to 15.9 per cent. This matter is one which will, no doubt, receive the careful attention and analysis of engineers who are seriously discussing the installation of a large plant of this character.

The units have been chosen with due reference to economy, flexibility and reliability, and in the gas engine installations include the largest units known to be available, with the usual spares. In the turbo-blower house one unit per furnace, as contemplated, has become standard practice, with spares. In the turbo-generator station, the three 12,000-kw. units chosen provide

TABLE I

COMPARATIVE COSTS OF FOUR-FURNACE PLANTS

First Costs	All-Gas	Gas Engines with Steam Reserve	Steam Turbine
Secondary washers and pipes	$ 120,660	$ 120,660	
Electric station	2,094,450	2,164,450	$ 709,640
Blowing station	1,001,350	1,085,350	536,304
Pumping plant	246,000	246,000	121,496
Boiler plant	30,000	104,500	656,240
Gas producers	100,000		
Gas producer auxiliaries	40,000		
Total first cost	$3,632,460	$3,720,960	$2,023,680
Running Charges, per Year			
Secondary washers	$ 11,300	$ 11,300	
Electric station	72,000	72,000	$ 46,396
Blowing station	34,000	34,000	21,920
Pumping plant	5,000	5,000	2,400
Boiler plant	5,000	6,000	54,190
Gas producers	10,000		
Running charges, total	$ 137,300	$ 128,300	$ 124,906
Coal at $2.00 ton, $0.50 firing	22,000	48,600	60,400
Fixed charges at 13 per cent	472,220	483,725	263,078
Total charges, per year	$ 631,520	$ 660,625	$ 448,384

TABLE II

SEGREGATED ELECTRIC STATION

Fraction of Plant, Supplying 20,000 kw. to Steel Mills

First Costs	All-Gas	Gas Engine with Steam Reserve	Steam Turbine
Secondary washers and pipes	$ 91,400	$ 89,300	
Electric station	1,979,000	2,014,000	$ 681,254
Pumping plant	113,100	91,000	59,689
Boiler plant	1,131	62,700	446,240
Gas producers	75,700		
Gas producers auxiliaries	30,300		
Total first cost	$2,290,631	$2,257,000	$1,187,183
Running Charges, per Year			
Secondary washers	$ 8,570	$ 8,370	
Electric station	68,000	67,000	$ 44,500
Pumping plant	2,300	1,850	150
Boiler plant	195	3,600	36,800
Gas producers	7,570		
Running charges, total	$ 86,635	$ 80,820	$ 81,450
Coal at $2.00 per ton, $0.50 firing	16,670	29,200	41,100
Fixed charges at 13 per cent	298,000	293,300	154,334
Total charges, per year	$ 401,305	$ 403,320	$ 276,884

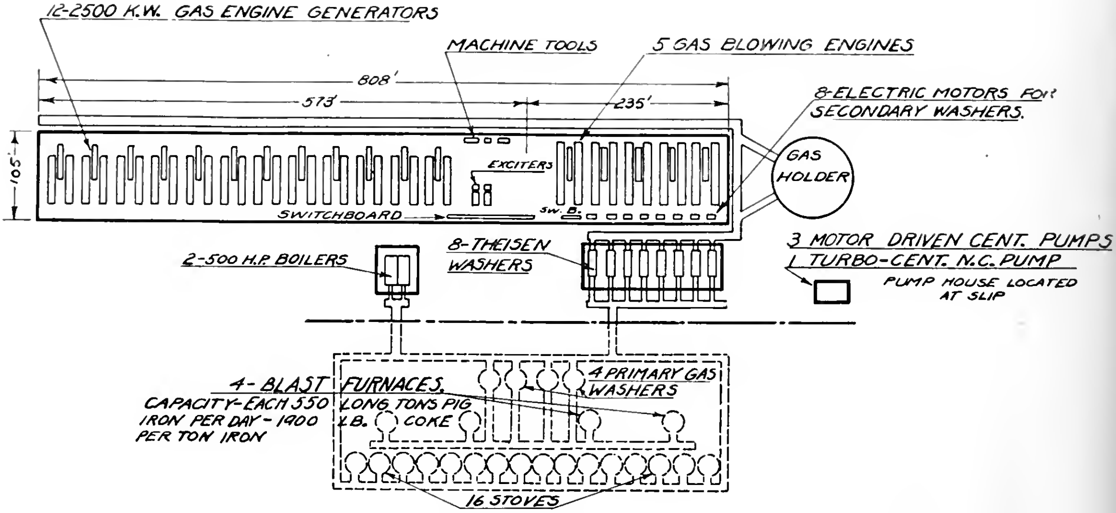

Fig. 16. Layout of Four-furnace Gas-engine Plant. The plant supplies all demands of four blast furnaces and in addition sends 20,000 kw. of electricity and 17,700 g.p.m. of water to steel mills

one spare and follow central station practice and experience in the use of the largest units which will give the flexibility desired.

In the various comparisons the gas engine plants come out with first cost one and a half to three times that of the steam turbine plants. The total charges, including fixed and running charges of the gas engine plants, are one and a half to two times those of the steam turbine plants.

In considering the effect of first costs on charges, I have included fixed charges, which consist of taxes, interest and obsolescence or amortization. (Depreciation is included under running charges as repairs and maintenance, and under fixed charges as obsolescence.) Fixed charges are taken for both gas and steam plants as 13 per cent. This is a customary figure for gas-engine plants, while steam turbo-electric stations often use a lower figure in the neighborhood of 11 per cent. Therefore, the use of 13 per cent for both is relatively favorable to the gas engine. Fixed charges may be itemized as follows:

Interest (on bonds or capital invested)	5%
Taxes	1%
Insurance	1%
Obsolescence (amount laid by as a sinking fund to replace or amortize the plant)	6%
Total	13%

Running charges include actual cost of operating the plant, and also maintenance and repairs, sufficient to keep the plant in first-class condition up to the time it is fully amortized. The only charges are therefore

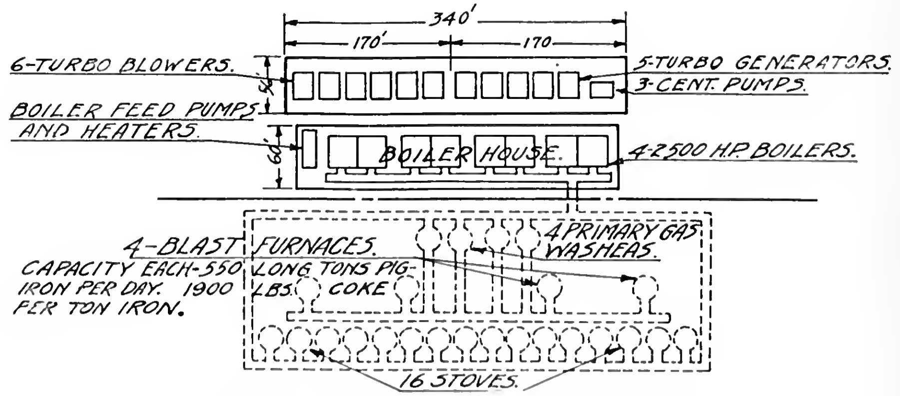

Fig. 17. Layout of Four-furnace Steam-turbine Plant

the fixed charges, the running charges and the cost of coal, for emergencies.

Attention should be called to the fact that the apparatus which has the lowest first cost has also the lowest total charges. In other words, by refraining from spending several million dollars, a saving in total charges of a quarter to a half million dollars will be realized. It is usually the case that the apparatus of higher first cost has lower running charges which provide income necessary to take care of the fixed charges. In this case, the lower operating costs are partly produced by the lower fixed charges from the smaller investment and partly by the fact that the running charges of the lower cost apparatus are themselves lower.

Fig. 14 shows the heat consumption of steam turbines of the largest sizes built from 1903 to 1916. There is also given a line showing the steam electric station above mentioned, and two lines, the lower of which gives the heat consumption of the largest gas-engine installation in the country, and the upper that which is considered the most economical and on which the gas-engine electric station is based. The turbine curve and the gas-engine line represent over-all performances on the same basis.

The thermal efficiencies of the segregated electric station comparing the two types of prime mover, including auxiliaries and emergency spares, on the basis of steady load condition, are as follows:

Thermal Efficiencies of a Complete Station

All gas engine plant of this paper	18.5%
Gas engine plant with steam reserve	16.4%
Turbo-generator plant of paper	17.6%
Largest turbo-generator plant	20.8%

With variable loads the thermal efficiency of the turbine plant will hold up closely to these figures, while the gas engine plant is known to fall off considerably under such operating conditions.

It should be pointed out that one of the difficulties connected with maximum utilization of the heat units available in the gas from blast furnaces, arises from the fact that utilization of these heat units is only one of the incidents necessarily attendant upon the operation of blast furnaces and the operation of steel mills. The attention of the management is largely fixed upon the question of production of pig iron and steel. The question of production of electricity and of blast are secondary. However, the savings which can be made over existing practice are so large, that they warrant giving this question the utmost attention. I, therefore, suggest the creation of a separate department of the works to handle this question of power generation, at the head of which should be an engineer of the necessary attainments and experience, whose sole duty should be to see that this power plant operates with the utmost economy and continuity. In this way, I believe that results equal to those obtained every day by our central power stations can be realized with equal facility in blast furnace and steel mill installations.

The utilization of waste heat from open-hearth and heating furnaces (and perhaps even from Bessemer convertors), to the limit, and of by-product gas resulting from the manufacture of coke, the installation of modern steam turbine plants at all furnaces, capable of utilizing blast furnace gas to the maximum extent possible, and the tying together of all plants in a closely developed section like Pittsburgh by a suitable network of electric cables, will probably render it unnecessary to develop any power in such a district by the use of raw fuel. In fact, it is confidently believed that such complete utilization of the heat available in any of our large steel producing centers will render it possible to supply considerable electric energy for external purposes at a very attractive rate.

MEASUREMENT OF ANGULAR DEVIATION

By R. E. Doherty

Alternating Current Engineering Department, General Electric Company

It is not unusual that the more baffling the problem, the more simple the final solution. The measurement of angular deviation was such a problem. Though its solution by the application of the principle of stroboscopic effect may not be original, the following article will particularly interest those of our readers who are concerned with angular deviation. A complete description is given of a simple measuring apparatus and instructions are included as to the method of using it.—Editor.

In the early days when the problem of parallel operation of steam engine driven alternators was being investigated there was great need for a method of measuring angular deviation, and considerable study was put on the problem of perfecting a measuring device. Although satisfactory operation of steam engine driven alternators was finally obtained without the aid of such a device, there have appeared since then new, and in some respects more difficult, problems of synchronous operation in the application of gas and oil engines to alternator drive; also in the application of synchronous motors to air compressor drive, in which cases there may again be occasion to measure angular deviation.

The method described herein, by means of which angular deviation can be measured with practical accuracy, was devised during the investigation of a complaint that involved, as was supposed, the angular deviation of a steam engine unit. Actual measurement, however, revealed that there was not excessive variation.

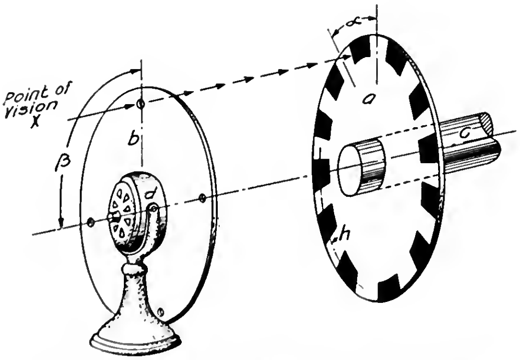

Fig. 1. Drawing of the Arrangement used in Measuring Angular Deviation

The method consists in making stroboscopic observations through holes in a disc which rotates at uniform speed. The apparatus used in the case just mentioned is shown in Fig. 4 and was made up as follows:

Referring to Fig. 1, a 30 in. dia. disk a accurately spaced into 24 sectors, alternately black and white, was bolted rigidly to the generator shaft (which of course was also the engine shaft). A circle h, of known diameter, was drawn through the sectors. Another disk b about 18 in. diameter, having 4 holes of ¼ in. diameter accurately spaced at 90 deg., was driven by a direct-current fan motor d the speed of which was adjusted approximately by a field rheostat, and then accurately by a leather strap over its shaft acting as a brake.

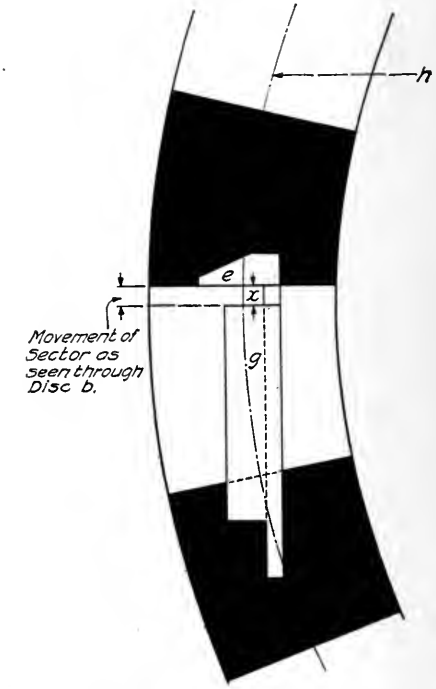

Fig. 2. Detailed Drawing showing how Angular Deviation is measured on Disk a

The speed of disk b was such that the number of holes which passed the eye per second was equal to the number of white sectors which passed a given point per second. That is, if both disks were rotating at uniform speed, then every time the observer got a glimpse of the disk *a* it appeared to be in the same position, i.e., stationary; because between glimpses, the disk *a* had moved through exactly the angle between the centers of white sectors. In other words, since there were 12 white sectors on disk *a*, and only 4 holes in disk *b*, disk *b* had to rotate at three times the speed of disk *a*; that is, *b* rotated through the angle β while *a* rotated through the angle α.

If the velocity of the disk *a* is not uniform, that disk will not move exactly the width of two sectors between glimpses, but will move instead first more and then less than that width; the result being an apparent forward and backward movement of disk *a*, as seen through disk *b*.

This movement is, of course, the angular deviation, and can be measured very accurately by means of the instrument shown in Fig. 2. This instrument is held as close to disk *a* as possible, and the upper jaw *e* is held so that it is in line with the bottom edge of a black sector when the latter is at its highest position. Then the sliding strip *g* is adjusted until its top edge is in line with the lowest position of the black sector. The movement is, of course, the distance *x*. The measurement should be made along the circle *h*, which is drawn on the disk *a* and which is of known diameter.

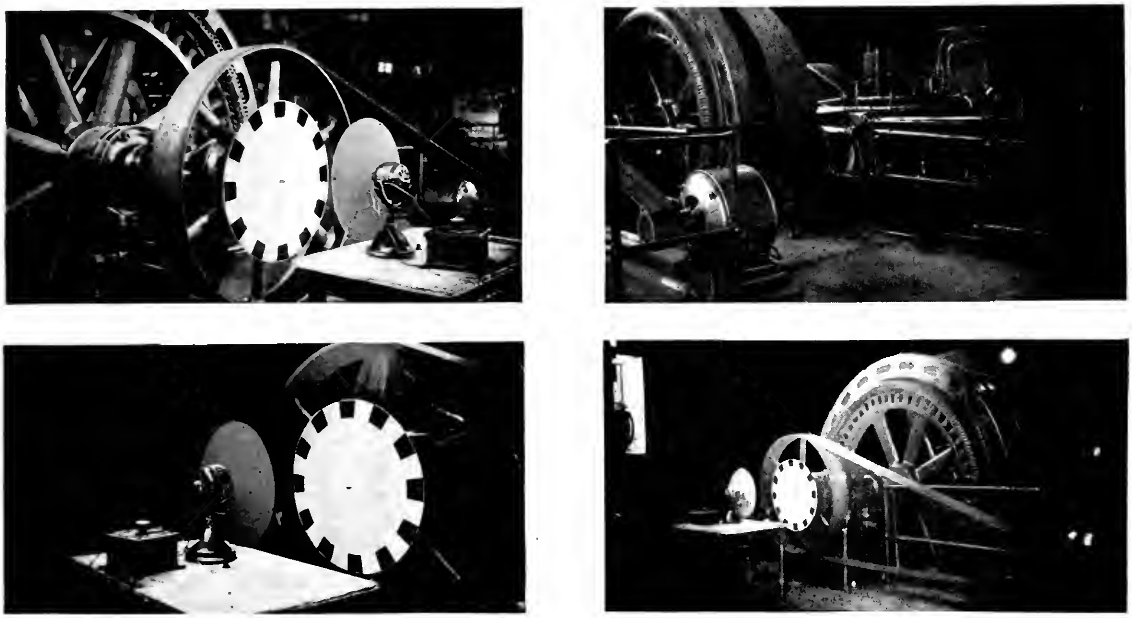

Fig. 3. Photographs Showing Arrangement of Apparatus for Measuring Angular Deviation

The observer's eye should be as near as possible to the disk *b*, and there should be a shroud of some sort over his head to reduce the light reflected from the disk *b* to his eye.

It was found convenient for the observer to have some one else hold the measuring instrument and make adjustments as advised by the observer.

An incandescent lamp should be held near disk *a* so that the portion of *a* near the instrument will be well illuminated, but also placed where the observer can not see it.

When the instrument has been adjusted to measure the movement, the distance *x* between upper and lower jaws can be measured by a scale.

Let d = diameter of circle (*h*) in inches
x = movement along (*h*) in inches
q = number of poles on generator

Then the plus and minus angular variation in electrical degrees from the mean position will be

$$\theta = \tfrac{1}{2} \times \frac{x}{\pi d} \times 2\pi \times 57.3 \times \frac{q}{2}$$

$$= 28.6\,\frac{qx}{d}$$

In the actual case of measurement, described above, three independent observers obtained results which checked within $\frac{1}{64}$ in. With a nicely constructed device this error could be still further reduced. Two disks *a* were made up. On the first the sectors were not accurately spaced, there being an error of about $\frac{3}{32}$ in. in the entire circumference, which error produced a corresponding apparent deviation. That is, in dividing disk *a* into sectors, the error of about 0.007 in. in the width of each sector (i.e., in setting dividers) caused an accumulated error of about $\frac{3}{32}$ in. when the sectors were stepped off with the dividers. The second disk was spaced accurately, and the apparent deviation was eliminated. But in all observations, including some in which the disk *a* was placed on the shaft with a slight eccentricity in order to produce additional apparent deviation, the results taken by three observers checked within $\frac{1}{64}$ in.

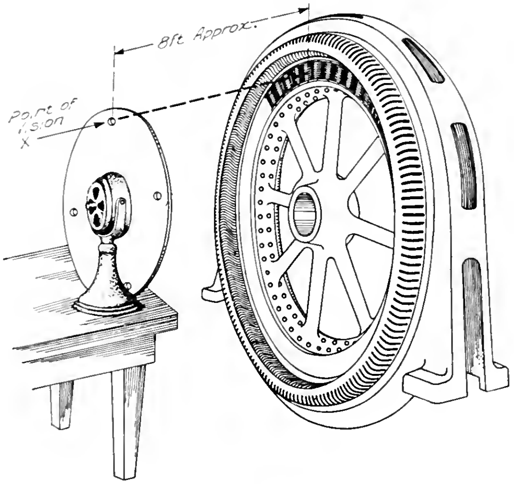

Fig. 4. Arrangement of Apparatus for Observing Hunting

There is another observation possible with this device which adds to its practicality, namely that the speed of disk *b* can be adjusted so that observations can be made of the poles of a synchronous machine, to see whether there is excessive movement.

If a generator, which is driven by a reciprocating engine, is giving trouble because of hunting or will not operate satisfactorily in parallel with other generators, it is desirable to know, first, if there is any angular deviation, and, second, what the amount of this deviation is. To construct the shaft disk *a* with the segments accurately marked off entails a considerable amount of rather painstaking effort, and when completed may be of no use, as there may be no deviation to measure. For this reason a preliminary observation that can be made with very little preparation, to see if there is any angular deviation, is most useful.

To make such an observation, the disk *b* (which can be made in a short time) is mounted on the little motor as before. The apparatus is then set up at a distance of about eight feet from the generator and at a height such that the observer, looking through the holes, sees the pole pieces of the alternator as shown in Fig. 4. It will be found that these pole pieces stand out in clean and clear cut outline when the speed of the disk is adjusted to conform to that of the generator. By observing the edge of the pole or the center line as the case may be, the amount of angular deviation can be determined. The standard limit beyond which trouble from hunting or unsuccessful parallel operation will be likely to be experienced is plus or minus 3 electrical degrees from the mean. Since one pole pitch (the span between centers of adjacent holes) represents 180 electrical degrees, a movement of the poles of 1/30 of a pole pitch represents the limit for satisfactory operation. The observer can estimate very easily whether the movement is of this magnitude and if so disk *a* can be prepared and the deviation measured accurately. The preliminary observation should be made at full load as well as at no load.

In the design of a device for general use the holes in disk *b* should be small. The smaller they are, the sharper and more definite will be the division line between sectors. It would probably be better to have narrow radial slits, say $\frac{1}{8}$ in. wide.

There is probably no better method of obtaining the finer adjustment of speed of disk *b* than the use of a brake on the shaft.

The disk *b* should be as large in diameter as is feasible.

A SMALL HYDRO-ELECTRIC DEVELOPMENT ON TOP OF THE ANDES

By J. H. Stokes

An element of general interest attaches to almost all hydro-electric developments. The principal distinguishing feature of the small system described in this article is its location at a great altitude and the fact that its transmission line crosses the continental divide of the Andes at 16,000 ft. It is probably the highets transmission line in the world. The power is developed on one side of the divide and transmitted across the summit to the opposite side, and is used mainly for the operation of copper smelters.—Editor.

Probably the highest transmission line in the world is located on top of the Andes Mountains, in Peru. Starting at Bella-Vista (elevation 12,500 ft.), it passes through Casapalca (elevation 14,000 ft.), crosses the "continental divide" at an elevation of 16,000 ft. near Ticlio, the highest railroad station in the world, and then drops down to Morococha (elevation 15,000 ft.).

On the west coast of Peru there are several rapid streams, among them the Rio Rimac, which has its source near the top of the continental divide, about 100 miles inland from Callao, where it empties into the Pacific. On its way to the ocean the Rio Rimac passes through Casapalca, where the Backus & Johnston Company have a large copper smelter. Some years ago this company constructed a small hydro-electric plant of 300 kw. at a point a short distance above Casapalca; and when four years later they decided to double the capacity of the smelter and install copper converters (which of course meant more power), it was decided

Fig. 1. Mine at Morococha, Peru. Lake Elevation, 15,000 ft. Glacier Elevation 18,500 ft.

Fig. 2. Dam and Intake. Canal passes under house and through mountain

Fig. 3. Power House, Bella Vista, Peru. Elevation 12,500 ft.

Fig. 4. Substation at Morococha, Peru, Elevation 15,000 ft., Mud Building

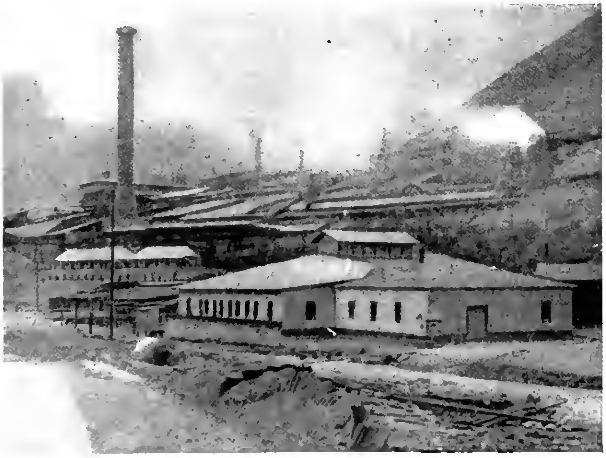

Fig. 5. Smelter at Casapalca, Peru. Elevation 14,000 ft.

Fig. 6. Electric Locomotive Handling Slag, Casapalca, Peru

to develop water power at Bella-Vista, five miles below Casapalca. In the wet season, or for nine months of the year, sufficient water is available to develop 2250 kw., but during the dry season (June to September) there is only one-third of this amount.

The dam was built of concrete and the intake made of two compartments so arranged that one of them at a time can be shut off and cleaned without interfering with the operation of the system. This feature is very important, because of the fact that between 400 and 500 tons of slag is dumped into the river from the blast furnaces at Casapalca every 24 hours. This slag pulverizes when it strikes the water and resembles sand to a certain extent.

The canal, which is about one mile in length, is cut in solid rock and is entirely open except for one tunnel 500 feet long at the intake end. The canal is provided with three sluice gates, as well as a waste-way above the power house. In front of these gates, in the bottom of the canal, there is a small compartment to catch any slag or sand, and by lifting the gates an inch or two these are washed out, thereby preventing the debris from reaching the buckets on the waterwheels.

The power house is located at Bella-Vista (meaning beautiful view), on the Central Railroad of Peru. Its dimensions are 100 ft. by 35 ft., and the equipment consists of three three-phase 60-cycle horizontal alternators, each rated 750 kw., 80 per cent power-factor, 2000 volts, 300 r.p.m. The generators are direct-connected to impulse waterwheels working under a head of 250 feet, and are fitted with direct connected exciters. The switchboard consists of two generator and two transformer panels. The transformers are of the three-phase, water-cooled type, and are of the same capacity as the generators. They are operated in multiple and transform the voltage from 2000 to 10,000. The lightning arresters are of the horn gap type, connected from line to ground through a resistance. A second set of horn gaps are connected between phases to take care of surges on the line; or what is the same thing, three gaps are connected delta and three Y, or star. The line, which is No. 3 B.&S. copper wire, is supported by 25,000-volt porcelain insulators mounted on iron pipe poles spaced 150 ft. apart. The telephone line is run on a separate pole line about 250 ft. from the transmission line and has a grounded return. Most of the material for these lines, as well as that for the dam and canal, was carried by llama and mules.

The equipment of the substation at Casapalca consists of two 450 kw., 10,000 to 440 volt, air-cooled transformers and two 500 kw., 10,000 to 2000 volt water-cooled transformers, all three-phase units. The switchboard consists of four transformer panels, with an oil-switch for each side of the transformers, and three feeder panels. Adjoining the substation is the old power house referred to above, the equipment of which consists of two 150 kw., 440 volt, 60 cycle, 600 r.p.m. three-phase alternators belted to Pelton waterwheels working under a head of 150 ft. and arranged for parallel operation with the Bella-Vista plant. The 440-volt transformers are used for driving air-compressors, hoists, various motors around the smelter, and a 100 kw. motor-generator set, the direct current obtained from the motor-generator being used for electric locomotives, elevators, and for turning the converters.

The 2000-volt transformers furnish current to the 725 h.p., 90 r.p.m. synchronous motors that drive the blowing engines which supply the converter with air.

After this development was completed the company's properties at Morococha showed a decided improvement in operation, and it was therefore decided to extend the line in order to furnish power for the air compressors, hoists, pumps, etc. As there had been no provisions made for this extension in the Casapalca substation, it was necessary to build another substation, in which two 500 kw., 10,000 to 20,000-volt water-cooled, three-phase transformers were installed. The lightning arrester arrangement at this substation is the same as that at Bella-Vista, and the line is also of the same construction, except for the use of 50,000 volt insulators. The use of insulators of this rating was deemed necessary owing to the fact that lightning disturbances occur almost

Fig. 7. Lightning Arrester Station at Antacona. Elevation 16,000 ft.

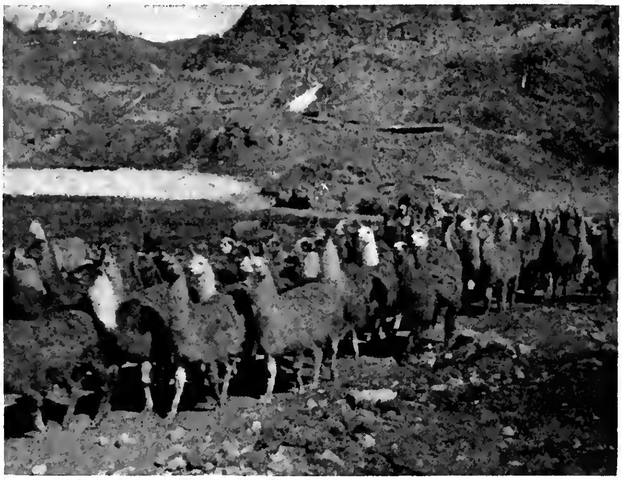

Fig. 8. Herd of Llama. These animals are employed as beasts of burden in many mountainous sections of the world

Fig. 9. Pole Line Passing the Highest Railroad Point in the World, Antacona, Peru. Elevation 15,885 ft.

every day in the year at the continental divide. This extension of the line, starting at Casapalca, crosses the Andes at an elevation of 16,000 ft., and drops down to Morococha on the other side.

It was also deemed necessary to install a lightning arrester station at Antacona, the highest point on the line and at about the middle of the line.

The equipment of the Morococha substation consists of one 500 kw. water-cooled, 20,000 to 2000-volt transformer, lightning arresters, and a four-panel switchboard with feeders for the various mines. All the material for this extension had to be carried by cholos (native labor) and mules, and 90 per cent of the post holes had to be blasted.

FLOOD LIGHTING IN THE OIL FIELDS FOR POLICE PROTECTION

By A. W. McBride
Electric Supply Company, Tulsa, Oklahoma
and
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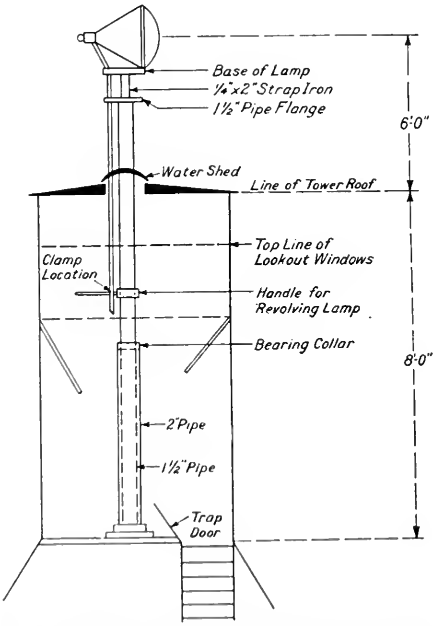
Southwest General Electric Company

The economical and efficient police protection of one thousand oil tanks, scattered over an area of fifty square miles, has been solved by the installation of flood lights as described below.—Editor.

On account of the present unsettled conditions a number of oil companies in Oklahoma have deemed it necessary, because of the enormous capital invested in refineries, tank farms, pipe lines and gasolene plants, to operate some form of guard protection against the destruction of any of the machinery, material or buildings. At first armed guards on foot were used to patrol the various farms and plants, and in one instance as large a number as three hundred and fifty were used in guarding a single tank farm on which were located about one thousand 55,000 barrel tanks, most of which were full of oil representing an investment of approximately $100,000.00 each. This system did not prove entirely satisfactory on account of the difficulty of guarding the property at night due to a lack of proper illumination. The problem then became one of supplying light where needed and it was found that the General Electric Form L-1 flood lighting projectors equipped with 400-watt Mazda C flood lighting lamps would fill the requirements. To give an idea of the area covered, this farm is approximately fourteen miles in length by three to four miles in width.



Lookout House and Method of Mounting Projector

In adapting the Form L-1 flood lighting projector to this class of service it was necessary to surmount a number of difficulties, as the service required the control of the beam from some point remote from the lamp. It was also necessary to mount the lamp on some form of derrick, the elevation of which would be above the elevation of the tanks so that the beam might be thrown unobstructed over an area limited only by the intensity of the light. To accomplish this a standard oil field derrick approximately forty-two feet in height was built, and on top of this extending up about eight feet was constructed a look-out house resembling very closely the look-out tower of a light house. The flood lighting projector was mounted six feet above the roof of the look-out house, and arrangement was made for the complete control of the beam from the house. This control was accomplished by mounting the flood lighting projector on a pipe support which extends six feet above the roof of the look-out house, and down to the floor level. The lower end is telescoped by a larger pipe which rises about four feet above the floor to which it is firmly fastened by means of a pipe flange. The larger pipe acts as a guide and at the same time supports the weight of the pipe support and projector through a bearing collar. An additional guide bearing was installed on the roof of the look-out house and a water shed installed over it. The control of the beam is accomplished by means of one lever arm which transmits vertical motion to the beam through a rod extending up and connected to the rear portion of the projector which is normally connected to the adjustment arm. The horizontal motion is transmitted through the pipe support.

These derricks were located approximately a mile apart, but, the spacing varied somewhat under topographical conditions. Small direct-current generators were installed to furnish current for the lamps, these serving from one to four derricks, depending on the layout. An armed guard was stationed at each derrick to operate the projector, and this guard had under him several other guards patrolling a given area. A definite set of flash signals was used between the guard operating the projector and the patrol guards, these signals being flashed by means of small pocket flash lights. This system proved entirely satisfactory and greatly reduced the number of guards required.

This system, as originally installed by one of the largest operating companies in Oklahoma, so satisfactorily filled the requirements that other companies made similar installations, until at this writing there are from three to four hundred flood light projectors in use for this class of service in the oil fields of Oklahoma.

AN APPARATUS FOR SEPARATING VISIBLE FROM INVISIBLE LIGHT

By W. S. Andrews
Consulting Engineering Department, General Electric Company

Below is described an ingenious apparatus which has been constructed by the author to separate visible from invisible light. With it a flux of pure invisible light can be readily obtained for the examination of the true fluorescent colors of fluorescent compounds or for other purposes.—Editor.

Prof. R. W. Wood delivered a lecture before the Royal Institute of Great Britain in 1911 on "Invisible Light," and described a method for separating the invisible ultra-violet rays from visible light of a mixed spectrum.

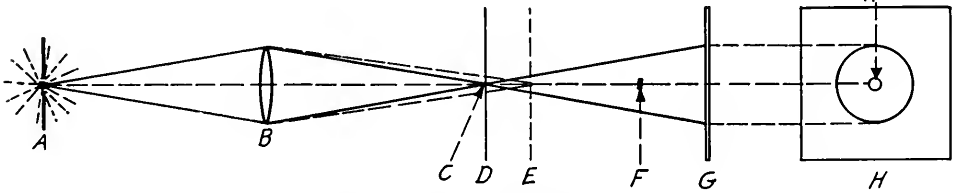


Fig. 1. Diagram of Apparatus

A simple and inexpensive apparatus based on Prof. Wood's idea has been made and its operation is so satisfactory that a description of it may be found acceptable.

Fig. 1 illustrates the principles of this apparatus in diagrammatic form, the letters referring to the different parts, as explained in the following:

A. Source of visible light mixed with a large percentage of ultra-violet radiation, such as may be produced by a high-tension disruptive spark between iron terminals.

B. A quartz lens.

D. A diaphragm of thin sheet metal pierced with a fine pinhole at *C*, the diaphragm being so placed that the pinhole is in the exact mean focus of the ultra-violet rays.

E. An imaginary line indicating in an exaggerated degree the mean focus of visible light from source A.

F. A small metal disk the function of which will be described later.

G. A screen of cardboard or other suitable material.

H. A front view of the screen *G.*

The operation of this instrument, which naturally must be in a darkened room, is based on the fact that the mean focus of visible light is located at a measurable distance beyond the mean focus of invisible ultra-violet light owing to the greater refrangibility of the latter over that of the former.

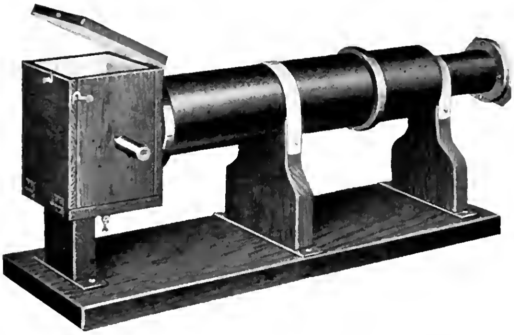


Fig. 2. Showing Appearance of Apparatus

If, therefore, the diaphragm *D* is carefully adjusted so as to bring the pinhole *C* into the exact mean focus of ultra-violet light, the rays of the latter will pass through the pinhole and spread out again on the other side of the diaphragm. The mean focus of visible light being some distance *beyond* the pinhole, its rays will be largely intercepted by the diaphragm, through the pinhole in which only a few of the nearly parallel rays of visible light will pass.

In operation, if the screen *H* is made of non-fluorescent material, there will appear on it only the small illuminated spot *K*, but if it is coated with a fluorescent substance, such as powdered willemite, this small luminous spot will be surrounded by a disk of bright green light produced by the fluorescence of the willemite excited by the circular field of invisible ultra-violet rays. Should it be found desirable to cut out the spot of visible light, the small metal disk *F* can be set up in such a position as to cast its shadow over the spot *K* and so transform it from a bright spot to a dark one, leaving the disk of green fluorescent light otherwise unimpaired.

Figs. 2 and 3 show the external appearance of this apparatus, which includes the spark gap *A*, the quartz lens *B* and the diaphragm *D*.

The screen *G-H* and small stop *F*, being external movable adjuncts, can be located so as to meet desired conditions of work. The size of the luminous disk that is formed on the fluorescent screen by the conical beam of ultra-violet light is naturally regulated by the distance of this screen from *D*, and the movable stop *F* may be adjusted to a proper position, or not used at all at the option of the observer.

This apparatus is valuable for determining the exact fluorescent colors of various compounds. When such compounds are exposed to the direct rays of an open iron spark, their true fluorescent color is masked to a greater or lesser degree by the visible light component of the spark, this being especially the case with compounds that show only a weak intrinsic fluorescence. When a compound is placed within the invisible field of the ultra-violet rays of this *separator*, it shows its true fluorescent color, and the passing it thus into a visually dark field and its becoming thereby illuminated produces a surprising and interesting effect.

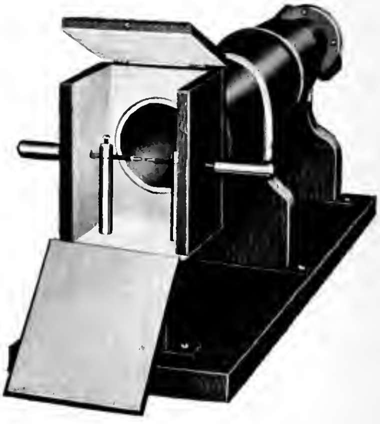


Fig. 3. End View of Apparatus Showing Iron Spark Gap

Fig. 3 shows an end view of the apparatus with the iron spark gap open to view.

A TEMPERATURE SCALE ADOPTED BY THE GENERAL ELECTRIC COMPANY AND THE RADIATING PROPERTIES OF TUNGSTEN WITH REFERENCE TO THIS SCALE

By Edward P. Hyde

Director of Nela Research Laboratory, National Lamp Works of General Electric Company

The following article deals with a very important problem which has been faced by both the theoretical physicist and the practical illuminating engineer: viz., what is the *real* temperature of the tungsten filament of a lamp under any given conditions of incandescence.—Editor.

In the measurement of high temperatures, such as that of incandescent tungsten, two sources of difficulty have been encountered which have occasioned uncertainties in making accurate comparisons of results obtained in different laboratories. One of these difficulties has arisen from a lack of agreement in regard to the temperature scale for high temperatures as established through the radiation from the interior of a uniformly heated enclosure, representing a theoretical black body, and the other from a lack of agreement in regard to the emissive power of the radiating metal.

The first of these difficulties, viz., the lack of agreement in regard to the true temperature scale, has recently been the subject of much investigation, but there still exist inconsistencies which require further study. Some years ago, Day and Sossman[1] in their work with the gas thermometer determined the temperature of gold at its melting point to be 1336 degrees K (1063 degrees C+273 degrees) and the melting point of palladium to be 1823 degrees K, the corresponding temperatures of various other metals at their melting points also being determined. These melting-point temperatures are generally used as bases of establishing the optical scale for the radiation from a black body, other points of the scale being determined through the use of Wien's equation:

$$E_\lambda = C_1 \lambda^{-5} \frac{1}{\epsilon^{\frac{C_2}{\lambda T}}}$$

In the region of short wave-lengths and for ordinary temperatures this is equivalent to the more rigorous form of the equation given by Planck which has a theoretical foundation. In applying Wien's equation in optical pyrometry, it is necessary to employ monochromatic light (or at least to know the effective wave-length of any spectral band used) and also to know the value of the constant C_2. Assuming the temperatures of melting gold and melting palladium as known, and making use of monochromatic light of known wave-length, it is obvious, of course, that C_2 is determined; but only recently have there been effected the refinements in optical pyrometry, such as the precise evaluation of the effective wave-length of transmission of commonly used so-called monochromatic filters such as Jena red glass *F-4512*.

Recently, under greatly refined conditions, determinations of C_2, on the assumption of Day and Sossman's[2] melting-point temperatures for gold and palladium, have been carried out; and at the same time various independent determinations of the constant C_2 by other methods not involving the melting point of palladium have been made. The observed results are inconsistent. The value of C_2 which seems most probable is about 14350 μ degrees, whereas the value of C_2 required to harmonize the melting point of palladium found by Day and Sossman (1823 degrees K) with that of gold (1336 degrees K) is more nearly 14460 μ degrees.

In order that there may be agreement among the laboratories of the General Electric Company and a degree of definiteness in the temperature scale employed, consistent with the best experimental data at present available, representatives of the Research Laboratory at Schenectady and of Nela Research Laboratory at Cleveland agreed to adopt a temperature scale founded upon the melting point of gold taken as 1336 degrees K, the acceptance of Wien's equation for the visible spectrum, and the value 14350 μ degrees for the constant C_2. On these terms all the best experimental data become reasonably consistent except that the melting point of palladium is raised 5 degrees to a value 1828 degrees K.

With respect to the other source of difficulty, viz., the uncertainty regarding the emissive power of tungsten, only recently have entirely satisfactory experiments leading to its evaluation been made, and the results of these experiments, just completed in Nela Research Laboratory, have not yet been generally adopted. The reflecting power of tungsten at room temperature has been determined by various experimenters,[3] and the emissive power is readily deducible from this determination. But the conclusion, based on the experiments of Hagen and Rubens,[4] that the emissive power of metals in the visible region is not a function of temperature is not verified for tungsten. The author[5] in 1912 showed that the emissive power of tungsten in the visible spectrum varied with the temperature in relation to the emissive powers of carbon and tantalum, and in the recent work of Worthing[6] this change in the emissive power of tungsten with temperature is completely isolated and accurately determined over a wide range of temperature and for two wave-lengths near the ends of the visible spectrum.

TABLE I

TEMPERATURE SCALE

Based on the following constants: Melting Point of Gold 1336° K. Melting Point of Palladium 1828° K. These result in $C_2 = 14350\mu \times$deg.

Brightness Temperature	True Temperature	Color Temperature	Lumens per Watt	Color Temperature	Lumens per Watt	Relative Watts
		Corrected for end effects and bulb absorptions		Uncorrected. These values apply to commercial vacuum lamps of the type given in Schedule T-1		
1600° K	1701° K	1714° K	0.78	1696° K	0.67	19.05
1650	1758	1775	1.04	1758	0.90	22.82
1700	1816	1837	1.40	1821	1.22	27.18
1750	1874	1898	1.81	1882	1.59	31.78
1800	1932	1960	2.31	1944	2.04	37.20
1850	1990	2021	2.90	2005	2.57	43.09
1900	2049	2082	3.56	2066	3.17	49.69
1950	2108	2144	4.35	2129	3.89	57.35
2000	2167	2205	5.26	2190	4.72	65.48
2050	2227	2266	6.30	2250	5.67	74.47
2100	2287	2327	7.45	2311	6.72	84.53
2150	2347	2389	8.69	2372	7.86	95.54

(*Melting point of tungsten = 3675° K*)

It was necessary, therefore, to rely upon direct determinations of the emissive power of tungsten, the measurement of which involved extreme difficulty. Determinations of this quantity were undertaken by Mendenhall and Forsythe,[7] Langmuir,[8] and others, culminating in the experiments of Worthing[6] in which a hollow tungsten filament with small holes punctured through the shell was employed. The radiation from the interior has the characteristics of black-body radiation, and consequently the true temperature of the interior may be determined with the use of a calibrated optical pyrometer. Correcting for the difference in temperature between the interior and the exterior of the hollow shell, the characteristic radiation from tungsten at a known temperature may be observed. Measurement of the brightness of the exterior in comparison with that of the interior, observed through the small hole, gives the emissive power of tungsten at the given temperature and for the wave-length of light used.

With this knowledge of the emissive power of tungsten it is possible to reverse the process, and from a measurement of the *brightness temperature*[*] of a tungsten filament to compute from the known emissive power the true temperature. The relation between the brightness temperature for $\lambda = 0.665\mu$ and the true temperature of tungsten is given in Table I.

Within the past few years the idea of "color temperature"[9] has come to be employed more and more, as it is frequently more convenient to determine the quality of the radiation from such a substance as tungsten than to measure the "brightness temperature." The color temperature is given by the temperature of a black body when its radiation matches in color the radiation from the incandescent metal at some definite operating voltage. The relation between brightness temperature and color temperature for tungsten has recently been

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[*] See Phys. Rev. Vol. 10, Oct. 1917, for a discussion of the substitution of the term "brightness temperature" for the term "black-body temperature" more commonly used in the past. The reason for the change is to be found in the growing use of a second kind of black-body temperature, viz., "black-body color temperature." To distinguish the two it is proposed to call the former "black-body brightness temperature," or, more briefly, "brightness temperature," and the latter, briefly, "color temperature."

determined by Cady and Forsythe in collaboration with the author;[10] and since the relation between brightness temperature and true temperature is now known it is possible to go directly from color temperature to true temperature.

The values of color temperature corresponding to given values of brightness temperature are included in Table I. Inasmuch as color temperature finds an important use in commercial lamps, the relationships between color temperature and lumens per watt, and between color temperature and relative watts have been determined[10] and are included in the Table. The first of these relations is given for the two cases: (1) when the cooling effect at the ends of the filament, and the absorption of the lamp bulb have been corrected; and (2) when no corrections whatever have been made, the lamps employed, however, being reasonably free from deposits on the bulbs. The relation between color temperature and watts is given only for the latter case. Of course, the observed relations, when no corrections are made, will vary with the type of lamp, but the values given in the Table are fairly accurate for all commercial vacuum lamps of the type given in the Lamp-makers' Schedule T-1.

The various relations given in the Table, based on the temperature scale described in earlier paragraphs, have been adopted for use in the laboratories and factories of the General Electric Company.

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[1] Amer. Jour. of Sci. *29*, p. 93; 1910.
[2] Loc. cit.
[3] Verh. d. Deutsch. Phys. Gesell. *12*, p. 112; 1910.
Bul. Bur. of Standards, *7*, p. 197; 1910.
Phys. Rev. *35*, p. 306; 1912.
[4] Phys. Zeit. *11*, p. 139; 1910.
[5] Astrophys. Jour. *36*, p. 89; 1912.
[6] Phys. Rev., *10*, Oct.; 1917.
[7] Astrophys. Jour., *37*, p. 380; 1913.
[8] Phys. Rev., ser. II, *6*, p. 149; 1915.
[9] Trans. Ill. Eng. Soc. (U.S.) *4*, p. 334; 1909.
Am. Inst. of Elec. Eng. *32*, p. 1945; 1913.
[10] Phys. Rev. *10*, Oct. 1917.

IMPROVISING A CURRENT LIMITING REACTOR BY D-C. EXCITATION OF A PAIR OF TRANSFORMERS

By F. Parkman Coffin

Research Laboratory, General Electric Company

Probably there is less excuse for not accomplishing a desired end when employing electricity than when using any other agent. This statement is based upon the fact that electrical apparatus is unusually flexible. The following article describes an instance in which unusual requirements were fulfilled by the application of direct current to alternating-current apparatus.—Editor.

In carrying on some experimental work in the factory requiring about 250 kilowatts of single-phase power at any frequency available, some difficulty was experienced in getting continuous power from the testing department's alternators without frequent interruption by the regular production testing.

The main source of power for testing purposes in the building was a feeder from the 10,000-volt, 40-cycle system, delivering power to a 1,000 kw. synchronous motor-generator. As occasional short circuits were expected to occur in the experimental apparatus it was deemed inadvisable to take power from this feeder without a protective reactance which would limit the current on short circuit sufficiently to prevent the automatic oil switch on the line from tripping and shutting down the synchronous motor. A heavy short circuit would be very likely to shut down the entire 40 cycle system supplying power to the General Electric Works as well as to the city of Schenectady. This had happened in the past when trouble had developed in other apparatus connected to this feeder, for instance, an insulation breakdown on an older synchronous motor formerly connected.

A transformer was installed to step down the voltage from 10,000 to 570. Then two old auto-transformers, of a type formally used on single-phase interurban railway cars for reducing the voltage from 3,000 to 453, were installed as an improvised current-limiting reactor in the 570-volt line, one side of this circuit being grounded to the iron floor. The two secondaries were connected in multiple with each other and in series with the grounded side of the circuit, as in Fig. 4, while the primaries were so connected as to allow of circulating a direct current of 50 amperes or less through the two coils in series, but connected in mutual opposition as far as the induced alternating voltage was concerned.

In this way the iron cores were initially saturated with a unidirectional magnetic flux of opposite polarity in each with respect to

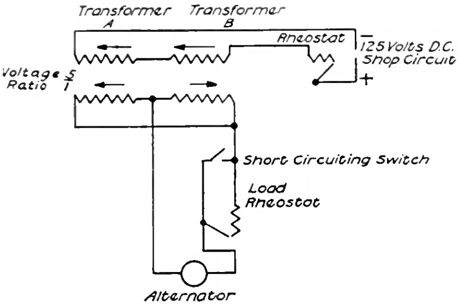

Fig. 1. Preliminary test of two transformers used as current-limiting reactors. Primaries excited with direct current. Transformers: core type, 10 kv-a., 1100/2200–110/220 volts, 5 to 1 ratio, used 1100/220 volts. Alternator, 8 kw., 250 volts, 125 cycles

the alternating e.m.f. in the secondary coils. This has been termed a "magnetically biased" condition of the core.*

Before setting up the large compensators a preliminary test was made with a pair of 10-kw. lighting transformers connected as in Fig. 1. The most convenient source of power at the time was a small 8-kw. alternator giving 250 volts at 125 cycles, although one test was made at 40 cycles.

The curves in Fig. 3 were taken with the load short-circuited so that the secondary coils of the two transformers were in multiple to act as a reactance connected directly across the alternator while the voltage was held constant. The d-c. excitation on the primary coils was varied to change the reactance, and the resultant alternating current plotted as ordinates.

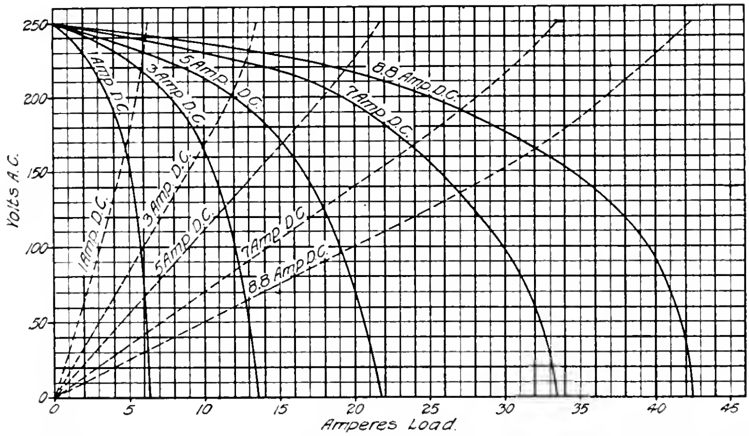

Fig. 2. Test curves made with the set-up in Fig. 1 to show the relation between the voltage across a varying load and the load (full curves), also between the voltage across the reactance and a varying load (dotted curves). Alternator supply held at 250 volts and 125 cycles. Direct-current excitation held constant for each curve

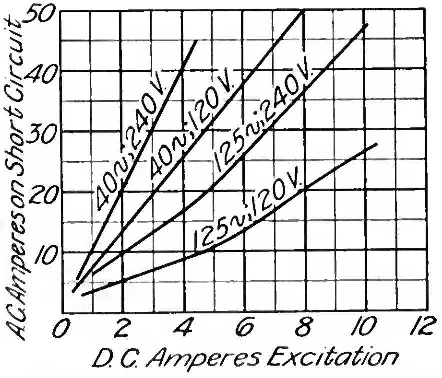

Fig. 3. Test curves made with the set-up in Fig. 1 to show the relation between direct-current excitation and short-circuit alternating current

For the curves in Fig. 2 the alternator voltage was held constant at 250 volts and 125 cycles. The d-c. excitation was held at a constant value for each curve while the load was varied. Curves were plotted for the voltage across the load and for the voltage across the reactance. These curves are probably not very representative of what might be shown by tests at a lower frequency. The dotted set of curves show an upward curvature which would give a better voltage regulation to the circuit under normal

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* This method of connecting transformers for use as a current-limiting reactor has been described by Mr. John B Taylor in a paper entitled "Even Harmonics in Alternating Current Circuits". Transactions of the A.I.E.E., Vol. XXVIII, Part I, page 729, 1909.

operation, for a given current limit on short circuit, than a coil of uniform reactance at all loads, such as an air-core reactor. When tests were made on 25-cycle transformers at 125 cycles the leakage reactance between primary and secondary was likely to be considerable. This would alter the current ratio between the a-c. and d-c. windings and might account for a large portion of the difference between the current ratios at 125 cycles and at 40 cycles, in Fig. 2.

On the results of this test the railway compensators were set up and connected as in Fig. 4. The winding on compensator *B* was opened at *S* between the primary and secondary coils in order that the d-c. excitation might be introduced across the gap. Necessary changes were made in the ground connections to allow of grounding the winding and casings as shown.

The outfit was then tested with current from the load side before being connected to the power lines, the tests being similar to those made with the small transformers on short circuit. In Fig. 5 the applied voltage was held at 570 with frequencies of 25 and 54 cycles, as 40-cycle power was not available. The d-c. excitation was varied by means of the exciter field rheostat and the resulting current flowing through the reactive coils plotted as ordinates. A third curve was taken with an impressed voltage of 190 at 54 cycles.

For Fig. 6 the d-c. excitation was set at 20 and 40 amperes, respectively, for the two curves, while the applied voltage was varied from 100 to 570 volts.

As these tests were made some time ago, and without any idea of publication, the data are not as complete as the writer would wish to have them. The two curves in Fig. 6 show a tendency to follow the magnetization curve of iron, and have just reversed their curvature in order to follow the knee of the curve with increasing saturation. It would have been instructive to have extended the curve to higher degrees of saturation and to have taken a parallel curve without d-c. excitation. This would have shown the normal magnetizing current of the transformer at different impressed voltages.

In Fig. 7 are shown a series of unsymmetrical hysteresis loops, starting at different flux densities along the magnetic saturation curve of silicon steel and dropping through an amplitude of 4,000 lines per sq. cm. in each case; then returning to the starting point. In each the steel is more and more magnetically biased as the centers of the

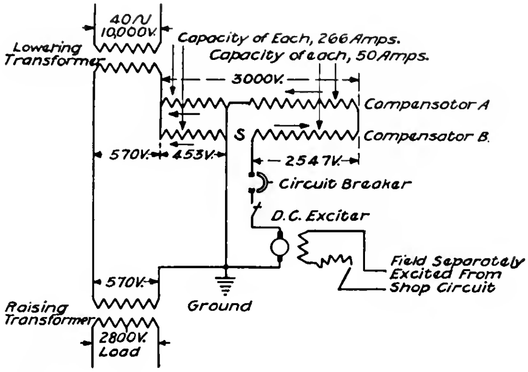


Fig. 4. A current-limiting reactor set-up employing two single-phase compensators with primaries excited by direct current

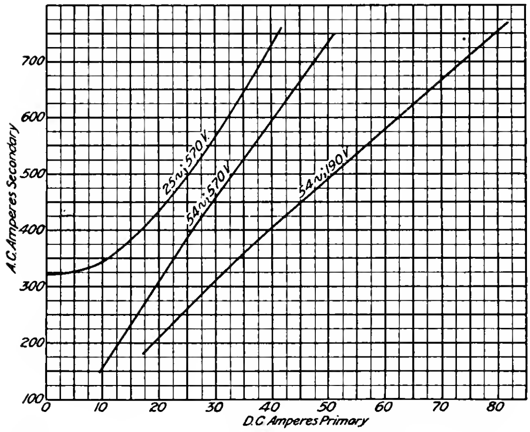


Fig. 5. Test curves made with the set-up in Fig. 4 to show the relation between direct-current excitation and short-circuit alternating current

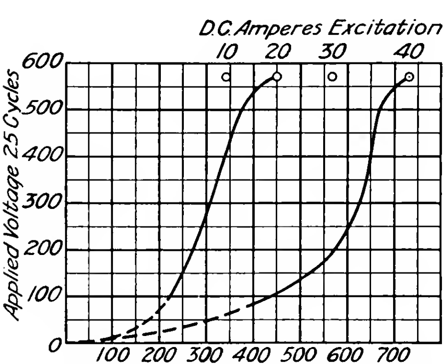


Fig. 6. Test curves made with the set-up in Fig. 4 to show the variation in short-circuit current for various applied alternating-current voltages with constant direct-current excitation for each curve

successive loops shift further away from the intersection of the neutral axes. In the reactor with a d-c. component of ampere-turns giving a magnetically biased core, if we impress a constant alternating voltage across the winding (B), and vary the d-c. excitation (H), the alternating magnetizing current will vary over the range of H at a rapidly increasing rate in the case of each of the successive loops. In other words, as we increase the direct-current ampere-turns we reduce the reactance because more alternating current must flow to overpower the d-c. magnetization before it can induce the same counter-electromotive force.

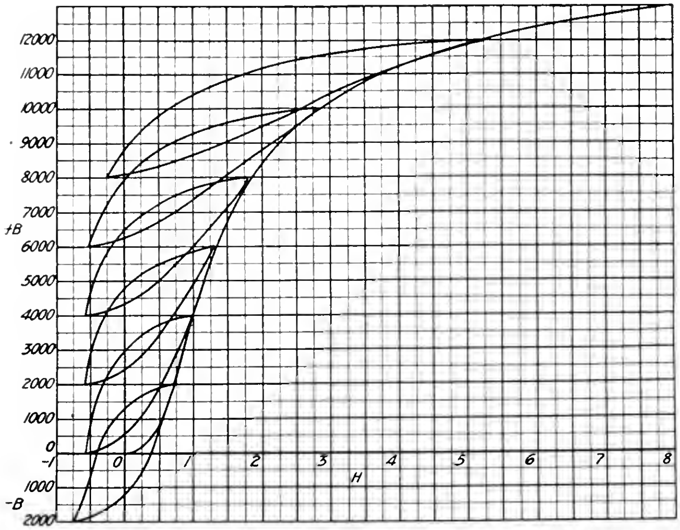


Fig. 7. Group of unsymmetrical hysteresis curves of amplitude $B = \pm 2000$, starting at various flux densities along the magnetic saturation curve of silicon steel and then returning to the starting point

The resulting magnetizing current will be unsymmetrical in wave form above and below the axis, as in Figs. 8 and 9.[*] As two reactors must be used with their coils either in series or parallel, this distortion will be opposite in each, and will be partially neutralized.

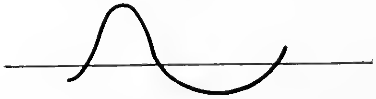


Fig. 8. Unsymmetrical Curve of Magnetizing Current on Saturated Iron

The raising and lowering transformers were each of 500-kw. capacity, 25 cycles, air blast, so that the impedance they offered to limit short circuit currents was small.

Several different transformer connections were available to obtain different voltages, but on each connection the voltage was controlled by varying the reactance with the exciter field rheostat, exactly as if taking power from an individual alternator. Power was frequently interrupted by opening the exciter field switch before opening the line switch, as the field switch was conveniently located on the testing table. Constant voltage was maintained with varying load by the exciter field rheostat, as the transformer ratios were such that a small margin of excess voltage was available for regulation over the rated voltage of the lowering transformer; viz., 2760 volts on the load side, which was held with a 250-kw. load and about 53 amperes d-c. excitation, while with excitation raised to 62 amperes nearly 3,000 volts could be obtained with a 200-kw. load.

This reactor was used with entire success for several months and all short circuits were limited to values which did not trip the oil switch on the feeder. The power drawn from the system varied from small amounts up to 250 or 300 kw. single phase.

Fig. 9. Oscillogram: Upper curve, applied voltage; lower curve, magnetizing current on saturated iron

[*] Reproduced from Mr. J. B. Taylor's A.I.E.E. paper.

REPRESENTING YOUR EMPLOYER

By A. B. Lawrence

Switchboard Department, General Electric Company

Into the minds of all members of the department should be instilled the fact that every one is in some degree responsible for the position attained by his company, and that the greatest possible service to the purchaser must be the steadfast aim of the entire organization.—Editor.

Remember that you individually represent the company that employs you. By the performance of your work you represent its status in the customer's mind. Your ideas, your workmanship, your service should be of the best. Never forget that, whatever part of the business you are responsible for handling, you represent the company. If you are a commercial man, the manner in which your proposal is written, the thoroughness with which you do your work and the care with which you answer all questions creates an impression good or bad. If you are a designer, the care and thought expressed in your designs to meet the customer's requirements will convey an impression to that customer, good or bad. If you are a production man, the manner in which you follow an order, the manner in which you tell the customer how the factory is getting along with it, will create an impression, good or bad. If you are a requisition engineer, the manner in which you carry on your correspondence asking for information, suggesting changes or executing them, creates an impression, good or bad. If you are a factory foreman, the appearance of your shop, the alertness with which your workmen are performing their work, and the efficiency of your organization establishes to a large extent the company's position in the customer's mind.

Confidence must be inspired; it cannot be bought. You must inspire confidence by your dealings, by your correspondence, by the statements you make, by the products you turn out. The impression the customer gains, the confidence he has in you and in your products, determines the possibility of your doing business.

You must represent your product honestly. This applies not only to the commercial man but to the designer and the production clerk, and all others who tell about your products. It is unwise to undertake to claim more than your goods will perform. It is unwise to neglect to tell the whole truth or to issue an erroneous statement. If you misrepresent your apparatus, its performance, its design, or any feature of it, you will lose a customer's confidence.

Be very thorough and follow instructions. These instructions are issued because conditions have warranted them. If the instructions should be changed, then those responsible for issuing them should know about it; but follow instructions first of all.

In your correspondence, be sure that you have answered all questions. There is nothing so annoying to a customer and so disastrous to your business interests as to give a partial reply or an evasive answer to a customer's letter. Be definite and thorough.

Act in keeping with the dignity of the company which you represent and with the quality of the apparatus you undertake to sell. If you appear to be slipshod, careless, and lacking in interest, naturally the customer will expect an inferior product.

Be courteous. Never offend, whatever the provocation may be. Make the customer feel that you are anxious to do what he wishes done and in the best possible manner.

Be responsive, not indifferent. There is all the difference in the world between a responsive attitude and an indifferent attitude. Be enthusiastic about your products. Be just full of good talking points. Perfect your knowledge, learn all you can about what your company is manufacturing, and why they are manufacturing it as they do.

Bring out the good points of the apparatus, but never, never belittle a competitor.

If you cannot sell your product by telling its good points let your competitor have the order. Under no circumstances and under no pressure are you to try to establish your product by belittling the output of those who are in competition with you.

If in any case you find that some one else has to offer some apparatus that appears to be superior to that which your company makes, do not attempt to prevent its sale, but let your company know the conditions and its engineers should do their best to enable you to meet the situation the next time it occurs.

There is nothing so helpful in doing business as to take a prospective customer to a man who has purchased some of your apparatus and have that customer say he has bought the best article that can be obtained.

The company's success is directly dependent upon the individual success of its employees. If you fail in performing your duty, the company will fail. If you succeed, if you do your duty well, you will add your little effort to the total product of success. The company will succeed and you will succeed. The two go hand in hand.

The success of the company is measured in dollars. Are you making the most of this opportunity? Are you seriously and conscientiously doing your part? Are you aiming to make the product so good that the customer will feel that he has the best there is, that he is going to buy of you again? Is he going to tell his friends that they should buy the same kind and that no matter what it costs, it is the best? To establish this fact in the minds of your customers and to create that impression which will give your company a continued increase in business, is your opportunity.

Loyalty is one of the prime factors of success, loyalty and co-operation. Never by word or deed fail to recognize that the company you work for is the best company you could work for. Help your fellows to see the things that are helping them; to stand by the company, to stand by its products, to be enthusiastic exponents of its efforts. Stand by your management, stand by those who are immediately placed in positions of responsibility above you. If you do this, you can be sure that you are paving the way to your advancement.

DEVELOPMENTS IN SWITCHBOARD APPARATUS

The devices described under this heading in this issue are a modified form of high voltage series relay and an improved safety-first enclosed lever switch. The high voltage relay is employed for tripping oil circuit breakers in cases where current transformers are not required for meter circuits and where their cost would not justify their use for the excitation of tripping coils. The enclosed safety-first lever switches are designed for the purpose of preventing the closing of the switch while its circuit is out of order or is being worked on. The switch is opened, and the cover is then closed and secured by a padlock against meddling.—EDITOR.

High Voltage Series Relay

The usual and most accurate method of tripping oil circuit breakers is by means of relays, or trip coils connected to the secondaries of current transformers. These transformers may also supply current to meters and instruments or they may be of special design for tripping purposes only. But when the cost of such current transformers is prohibitive due to the high potential of the circuit, some other arrangement is frequently introduced. One of these is the high-voltage series relay.

The solenoid is mounted on a high-voltage insulator which isolates the relay from ground.

The solenoid coil is connected in series with the circuit and in addition one end of the coil is connected to the solenoid frame to avoid objectionable static stresses.

The calibration parts, adjustments for load settings, and time-limit arrangements and contacts are connected to the series solenoid plunger by means of a wood rod. All these parts, with the exception of the contacts, are at ground potential. Thus adjustments can be made with safety at all times—even when the line is at operating potential.

When the relay operates it closes a set of contacts in series with the oil circuit breaker tripping circuit.

The normal ampere capacity of the relay coils should be equal to the normal current carrying capacity of the circuit to be protected. In this connection it might be of interest to say that although the relays are calibrated for current from normal to three times normal, they, of course, should not be subjected to continuous duty above their rated normal capacity.

High-voltage series relays are either instantaneous or time limit. Time limit, when used, is obtained by means of an oil dashpot arrangement.

The high-tension series relay shown in Fig. 1 contains various improvements over previous types, and is available for use at 15,000 volts and upward.

The features are:

1. The relay solenoid is above the relay contacts and adjusting parts. This keeps the high-tension leads away from adjacent apparatus.
2. The operating rod is in tension. This avoids bending and breaking.
3. The solenoid, which is mounted on a post insulator, does not require change in adjustment after installation.
4. The inverse time element is an oil dashpot mounted on the frame which holds the tripping contacts. Thus the calibration can be adjusted while the relay is in service.

5. A counter weight is used to balance the weight of the contacts and rod. This allows accurate calibration with a switch rod of any length.

6. A sliding weight with holding clamp is used to vary the restraining force on the solenoid plunger and consequently to furnish a means for calibrating the relay.

7. The contacts are strong and have a large double break. They are protected from dust and mechanical injury by a sheet iron cover.

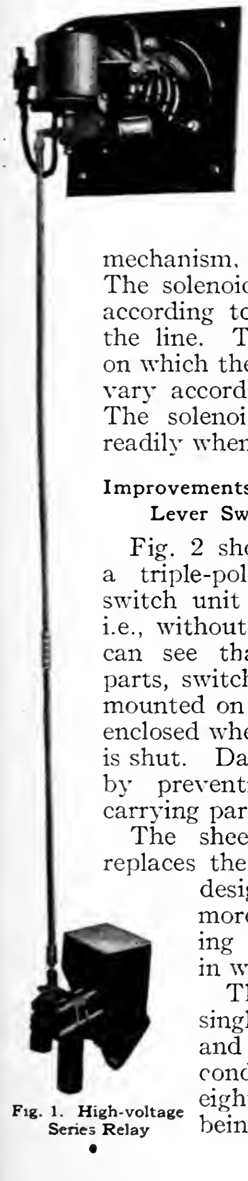


Fig. 1. High-voltage Series Relay

8. With each relay there is furnished a wood rod which gives ample insulation and allows the tripping switch, the time limit details, etc., to be mounted where they can be adjusted easily without danger to the operator.

9. For all voltages the same contacts, mechanism, and solenoid are used. The solenoid coil varies in capacity according to the normal current of the line. The size of the insulator on which the solenoid is mounted will vary according to the line voltage. The solenoid coil can be changed readily when the line is dead.

Improvements in Safety-first Enclosed Lever Switches

Fig. 2 shows a phantom view of a triple-pole, safety-first, enclosed switch unit with plain lever switch, i.e., without quick break parts. One can see that all current carrying parts, switch, terminals, and fuses—mounted on a slate base—are totally enclosed when the fuse chamber door is shut. Danger of shock is obviated by preventing access to current-carrying parts when they are alive.

The sheet metal enclosing box replaces the cast iron box of earlier design, making the device more substantial, yet affording an appreciable reduction in weight.

This box is adapted to single or group mounting, and can be used for open or conduit wiring. It has in all eight entrance holes and when being installed the cover and mechanism are removed, thus converting the switch into a convenient pull-in box.

The operating mechanism consists of an external handle, attached to a "U" shaped shaft which in turn engages hook shaped castings (one for double-pole, two for triple-pole) mounted upon the cross bar of the lever switch. The switch handle is so arranged in conjunction with the cover that the fuse compartment is accessible only when the switch is in the open position. By the same arrangement it is also impossible to close the switch while the fuse cover is open. Raised letters on the cover indicate, according to the position of the handle, the open and closed positions of the switch.

Fig. 2. Safety-first Enclosed Lever Switch

Provision is made for locking the switch in the open position so that only authorized persons holding the key will be enabled to close the circuit controlled. In the latest design, Fig. 3, which will be available in the near future, three locks, each controlled by a different individual, may be used. This means, for instance, that no person will be able to close this switch while another person is working on the line. This feature is of distinct advantage. The fuse compartment may also be locked, thus preventing tampering with the line fuses.

Two improvements which have met with great favor have been added to the switch, but these for the present will be furnished only as accessories upon specific order. A safety catch, Fig. 3, may be furnished for fastening to the switch cover immediately under the operating handle. When this catch is used, it is impossible to close the switch by accident or otherwise, without first disengaging the catch. Thus when the switch is open the operator is required to use both hands to close it, one to move the handle, the other to hold the catch in the released position. This positively removes the possibility of accidental closure.

The second improvement consists of the use of porcelain bushings for the top and bottom entrances where open wiring is being used. This tends to produce greater safety, as it provides not only increased insulation but also prevents mechanical injury to the insulating covering of the wires.

These safety-first lever switches are low in cost, afford the maximum protection to controlled apparatus and to operators, and should be specified for every installation where front connected knife switches are required. They are especially adapted to the control of individual motors on machine tools in all industrial applications, and to all lighting and power circuits coming within the range of the switch rating.

Fig. 3. Safety-First Enclosed Lever Switch showing Safety Catch for Operating Handle—Provision for Three Padlocks

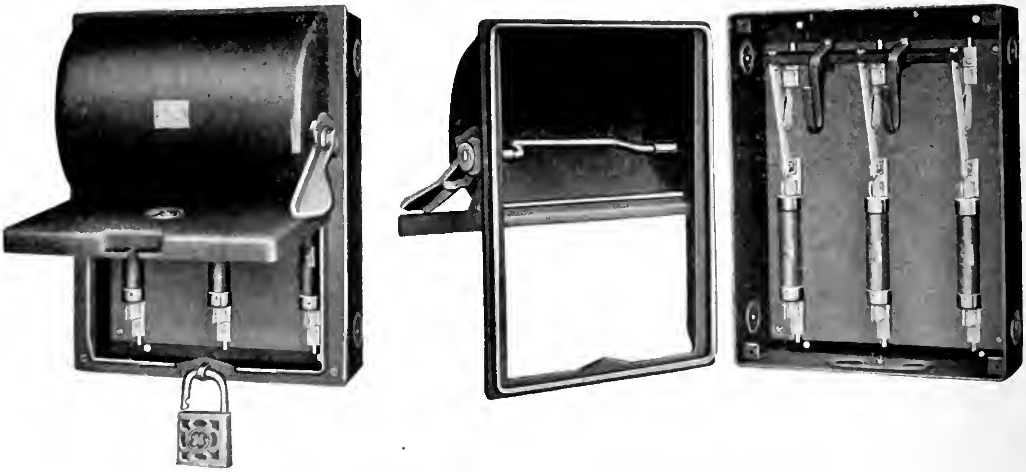


Fig. 4. Safety First Enclosed Lever Switch, showing Quick Break Parts

LIFE IN A LARGE MANUFACTURING PLANT

PART III. FIRE PROTECTION

The question of fire prevention is of vital importance to every one of us. The liability of personal injury or loss of property from this cause is one of our daily concerns. There is nothing that will create panic in an assembly so quickly as an alarm of fire. In large manufacturing plants, where a large number of men and women are often employed in one building, it is a moral obligation of the management to institute special precautions against this hazard, and to provide adequate means to extinguish fires when they do break out. In this installment of the series we describe the fire-fighting system and the fire organization of the Schenectady Works of the General Electric Company.—EDITOR.

The cost of a man's life insurance is a measure of his security from early death; the cost of a manufacturing plant's fire insurance is a measure of the plant's security from fire.

It is a very rare occurrence for the cost of a man's life insurance to grow less; for even though he improves his health (his resistance to disease) he nevertheless grows older; but the manufacturing plant can grow older and at the same time reduce its fire insurance rate by improving its resistance to fire.

This has been proved to be true to a surprising degree by the experience of the General Electric Company in its various plants. At the Schenectady Works, for example, the cost of each $100 fire insurance in 1893 was 75 cents as compared with an average of less than 10 cents for the last ten years. In this chapter we will describe the provisions that were made which have brought about this remarkable reduction in insurance cost, and the corresponding decrease in the fire hazard.

These improved conditions have benefited the Company, the employees, and the public in the following respects:

The Company:
  Maximum safety from loss of property.
  Maximum safety from loss of profits.

The Employees:
  Maximum safety from loss of life.
  Maximum safety from loss of wages.

The Public:
  Maximum assurance of prompt deliveries, due to minimum interruptions.
  Maximum safety from fire as the result of using electrical devices.

The actual fire losses year by year for the past ten years in the Schenectady Works are given in the table.

Year	No. of Fires	Fire Loss	Average Loss per Fire
1907	43	$1049	$24.00
1908	36	462	12.00
1909	19	284	14.00
1910	17	76	4.00
1911	53	1836	34.00
1912	73	3435	47.00
1913	57	3366	59.00
1914	62	827	13.00
1915	62	817	13.00
1916	66	7021	106.00
Total for 10 years	488	$19,173	$39.00

In the first eight months of 1917 there were fifty fires in the Schenectady Works with a total property loss of $588. Since this represents an average loss of approximately $11 per fire, it can readily be seen that: first, the fire department is operated efficiently; and second, the employee's loss in wages is trifling.

Mutual Insurance Contract

For over twenty years the General Electric Company has placed its insurance with a mutual fire insurance company. The business is handled by this company at cost, i.e., no profits and no agents. The cost includes expenses of management, service, inspections, and losses.

This insurance contract requires that all the member manufacturing companies have their properties built according to certain specified standards of fire-proof or slow-burning mill construction, and equipped with standard sprinkler systems, individual water supply plants, etc. In all the plants of the General Electric Company there are installed about 250,000 automatic sprinkler heads which adequately cover approximately 15,500,000 square feet of floor space.

Mr. M. F. Westover, Secretary of the General Electric Company, in charge of matters relating to fire insurance, stated recently that the architectural and engineering advice received from the insurance company in connection with new building construction was alone worth the money paid out in premiums.

Building Construction

Wherever possible the factory buildings are subdivided into sections by fire-proof walls, designed to prevent the spreading of a fire. The openings in these fire walls are provided with self-closing fire doors which are held open by a fusible link of alloy of such a character that when the temperature rises to a predetermined point the alloy melts and the door automatically shuts. These doors are hung on wheels which run on an inclined track, and when released by the melting of the alloy the force of gravity propels the door down the track until it is firmly shut. These doors are constructed of metal and other fire-proof material, and at regular intervals the operating mechanism is inspected and tested.

Giving Fire Alarm from Master Box

In all modern buildings throughout the various factories special stair towers are erected. These are also provided with fire-proof doors and windows, and serve a double purpose, viz., to prevent a possible fire from sweeping up the stairway and spreading to additional floors, and to serve as fire-proof and smoke-proof exits for employees. The location of these stairs has been carefully worked out by the various experts of the insurance companies and the State Factory Inspection Department. As a general rule they are provided at both ends of the building and in the middle of the building. By this arrangement a large number of exits is provided; if a fire were to break out at one end of the building the employees could use the stairways at the other end and in the middle, or if a fire were to break out in the middle of the building the stairs at both ends would be available.

The same arrangement is used in the large office buildings; for instance, in the main office building at Schenectady each wing is isolated by fire-proof walls and doors and is served by an enclosed stairs at the end, which is shut off from the halls by fire-proof doors. In addition there is a main staircase at the middle of the building.

Exits are clearly marked by red signs, and at night by red lights. All fire alarm boxes are marked by blue lights, and all fire hose lines inside the building are indicated by green lights.

Fire Fighting Equipment in Buildings

Each building is provided with an elaborate equipment for preventing, detecting, and extinguishing fires, night and day. A standard fire alarm system is used, to which are connected 82 fire alarm boxes on four separate circuits. The number of the box corresponds to the number of the building in which it is installed. Fire gongs operated from the central station announce the existence of a fire to all buildings in the vicinity. For a first alarm only certain designated companies respond; but on a second alarm all companies respond.

Giving Alarm from Auxiliary Box

Each floor of the buildings is supplied with $1\frac{1}{2}$-in. hose lines permanently connected to the water system. There are over ten miles of these shop lines in the Schenectady Works alone. 3326 water pails are distributed throughout the works, as well as numerous other pails containing sand, sawdust, and wet bags for extinguishing oil and electrical fires.

Automatic sprinklers, numbering almost 75,000 in the Schenectady Works, are the standard means employed for automatically extinguishing fires at their inception. These are placed eight feet apart at the ceiling. Here again the skill of the metallurgist is employed, as in the case of the fire doors, for when the temperature rises to a dangerous degree at any point it melts the alloy of the sprinkler, and the surrounding walls, partitions, floors and contents of the building are drenched. The fact that only those sprinklers close to the fire are put in operation results in a great saving of property, as much unnecessary flooding is thus avoided. The auto-sprinkler both discovers and extinguishes a fire, as it is first on the scene.

Each building is further supplied with fire ladders, thus making it unnecessary for the ladder companies to carry extra long ladders for the high factory buildings.

It has been found that two of the main sources of fire are spontaneous combustion and careless smokers, and special precautions are taken to obviate these hazards. Oily waste must be thrown in metal cans specially provided and emptied at regular intervals. Smoking is prohibited in the factory buildings at all times, and in the yards and streets except during the noon hour. Certain men are made responsible for preventing accumulations of rubbish, dust, greasy overalls, etc.

Handling Inflammable Materials

In manufacturing electrical apparatus there is more opportunity for fires than in some other lines of work. Certain departments require special care on the part of the employees against this danger. They include the painting and japanning departments, where benzine or other solvents are used that are very inflammable, and under certain conditions explosive; the insulating departments, where linseed oil, varnish, benzine, alcohol, and other highly inflammable materials are used; departments in which cotton, numerous soldering irons, lead melting pots, etc., are required; and testing departments and all other places where electric wiring, much of it carrying current at high voltage, is to be found.

A great quantity of transil oil is used in the installation of transformers, regulators, switches, and other apparatus, and in treating wood; and while this oil is not specially liable to become ignited, when once burning it makes a bad fire and one that is hard to put out.

In departments that use japan, varnish, and oil tanks, and in baking ovens where special risk is involved, special equipment for putting out fires has been provided. Some of the ovens are connected with steam pipes to smother fires; some of the testing departments have a supply of carbon dioxide for putting out oil fires in closed tanks. In some places sawdust boxes for smothering japan, varnish, or benzine fires have been installed.

Permanent Fire Ladder Installation

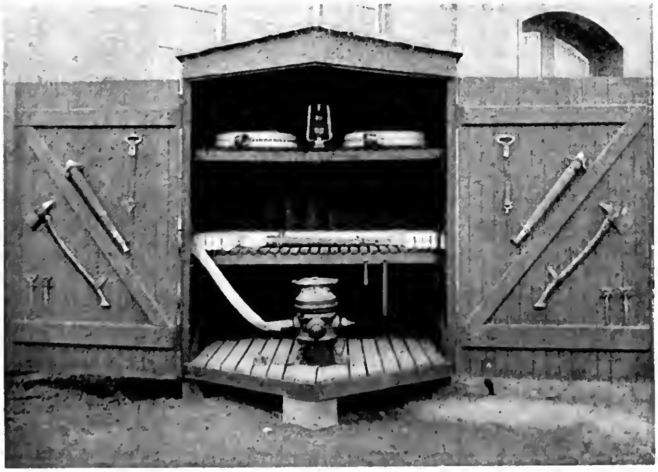
The idea of the fusible plug used in the sprinkler system can be carried still further and used to advantage in automatically smothering fires that start in dripping tanks. Iron doors, hinged and swung beyond the center of gravity, are held in place by fusible links which melt in case of fire and close the lids.

Central Fire Station Equipment and Water System

The fire headquarters building is shown in Fig. 1, page 834. Hose companies 3 and 7 (the latter the night company) and the ladder company are quartered in this building. The fire chief also has his office here. The emergency hospital occupies the rear. Its work was described and illustrated in the installment on Medical Service and Hospitals, appearing in the GENERAL ELECTRIC REVIEW of August, 1917.

This station contains the following apparatus: one automobile hose wagon carrying 1500 ft. of $2\frac{5}{8}$-in. hose, play pipes, extinguishers, two deluge sets, 1 rubber covers, axes, rakes, forks, shovels, door opener, hose lines and life line; seven two-wheeled hose reels, each carrying 500 ft. of $2\frac{5}{8}$-in. hose, play pipes, axe, and pipe holder; two ladder trucks, carrying ladders, axes, forks, shovels, extinguishers, and rubber covers; and three spare hose reels to replace regular equipment when repairs are to be made, one of the spare reels being fully equipped so that it can be pressed into service at any time.

Typical Hose House



Interior of Hose House, Showing Four-way Hydrant, Hose, and Other Equipment

There are 125 hydrants in service in the Works, 41 of these having hose houses over them, in each of which is installed 200 feet of $2\frac{5}{8}$-in. hose (100 ft. connected to the hydrant and 100 ft. in reserve), two play pipes, one pipe holder, one axe, two spanners, and hydrant wrenches. There are almost 14 miles of fire hose in service, disposed of as follows: 5000 ft. of $2\frac{5}{8}$-in. hose carried on fire apparatus; 8200 ft. of $2\frac{5}{8}$-in. hose in hydrant hose houses; and 57,950 ft. on fire plugs in the buildings.

The pressure on the water system is maintained by both gravity and pumps. In the main pumping station (Buildings 13 and 13A) are installed one Snow pump of 6,000,000 gallons capacity daily, one Drane pump of 3,000,000 gallons, and two Worthington fire pumps of 2,160,000 gallons. In Building 61 there are two Worthington fire pumps of 4,320,000 gallons capacity, and in Building 118 one Alberger pump of 7,000,000 gallons capacity, making a total daily pumping capacity of 22,480,000 gallons. The tank on the hill in Bellevue at the back of the works contains 1,036,000 gallons of water. The water for the system is taken from the Mohawk River and the old Erie Canal and is distributed through $14\frac{1}{2}$ miles of yard mains. The mains are interconnected and arranged in such a way that a rupture at any point in the system can be quickly isolated by valves and will affect only a very small part of the system. Additional protection is afforded by connection to the city water system, which will enable city water to be utilized in the event of a breakdown of the whole of the Company's pumping plant. The average daily consumption for factory purposes is 8,650,857 gallons. This does not include water for drinking purposes, which is obtained from the city mains.

The Organization

The fire organization was formed during the summer of 1889, and consisted of forty men. Its present strength (in 1917) is 176 men, formed into eight hose companies and one ladder company, each with its own quarters and apparatus.

It is significant of the efficiency of the present fire-fighting system and organization that during this period of 29 years, in which the Schenectady Works has increased in size from 144,000 square feet of floor space to 5,333,000 square feet, the fire department has been enlarged only 4.4 times and is protecting a space 38½ times as large.

Hose House Containing Reel Cart

The permanent professional fire fighters of the Schenectady department consist of a fire chief, who is a member of the International Association of Fire Engineers and the New York State Fire Chiefs' Association, assistant chief, two inspectors, and the captain of the night fire company. The night fire company consists of two officers and ten men located at the central fire station. These men sleep in the station and the Company furnishes them with lodging, supper and breakfast. Each member is on duty from 5:30 p.m. until 6:30 a.m., and with the exception of the captain, all are regularly employed in the shops during the day. They are allowed one night off in three and are the busiest fire company in the department. They responded to 59 fire alarms in 1916.

Fire Crew for Each Building

The other members of the department are termed "call men," who are selected from the shops on the recommendation of the foremen. Men are preferred who have had experience as professional fire fighters. These men receive one week of vacation in the summer and other perquisites.

Each building is served by a definite number of firemen, who are assigned to certain departments or floors. They are formed into companies and are put in charge of a hose house, where they report upon the first fire alarm. These companies average fifteen men each, and are organized with a captain, lieutenant, and senior hoseman. Each member of the company is responsible for the fire equipment in his department or section of the building under his care, and he makes daily inspections of the sprinkler system, fire hose, pails, fire alarm gongs, etc. The cleanliness and general good order within the buildings are also looked after by these men.

Hose House Containing Two-Hose Reel Cart

Each man is furnished with a helmet, coat, rubber boots, and other items that make up a fireman's equipment. This paraphernalia is kept in a metal locker close by his station in the shop. He is supplied with a fire department badge which admits him to the works at all times.

Fire Department Drills

Under the direction of the chief, the fire department is drilled twenty times a year.

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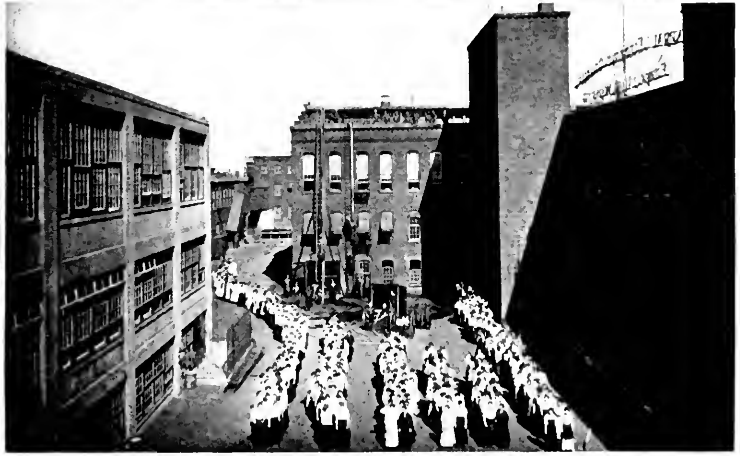

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1. Fire Station, Schenectady Works. 2. Interior of Fire Station. 3. Fire Drill with Hose Equipment. 4. Fire Drill for Employees. An entire department consisting of 400 employees is regularly emptied in 1½ minutes. Another complete floor with 500 workers requires an average of 2[illegible] minutes to vacate

each drill being entirely unannounced. When responding to this alarm no one but the chief is aware of the fact that it is a drill; and thus the surprise element keeps every member on the *qui vive*. At all fire drills a second alarm is sounded, which calls the entire department into action.

Hose races are held once a year to determine which company has the greatest speed. The night patrol men are drilled once a month on hose duty, sprinkler valve duty, and shop fire protection. In the winter instructions are given to the whole department by the fire chief. These lectures and discussions are held in the gymnasium of the central fire station.

Regular inspections are being made constantly. The buildings and grounds are inspected by the chief and assistant chief, and the sprinkler valves by the assistant chief and inspectors. The inspectors also inspect all of the indicator post valves on the sprinkler system, the hydrants, yard valves, hydrant hose houses, hose companies, and apparatus. These inspections are conducted weekly, and are in addition to the inspection of the buildings and departments by the other members of the fire department.

Exit Drills

Exit drills for employees are given once a month. A complete organization is formed in the shops at each drill, consisting of leaders, stairway guards, firemen, searchers, and power men. These exit drills are conducted by the foreman of each department, who has a regular corps of assistants. It is the duty of the leaders to form the line for the march to the various exits and to lead the way out. The stair guards are stationed on the landing at the top of the stairs and on intermediate landings to direct and assist the employees in leaving the building. The duty of the searchers is to search the building for anyone who may have been left behind, due to injury or faintness. The searchers are the last people to leave the building. In the meantime the power men shut off all power and stop all machinery in the building, and the firemen turn in the alarm and use the inside hose lines, extinguishers, buckets, etc., every possible means being employed to extinguish the fire while the fire department is responding. An alarm is provided on every floor, consisting of an air whistle of distinctive tone which can be heard distinctly over the entire floor.

Firemen's Club Facilities

On the second floor of the fire central station is a pool room, reading room, gymnasium, and shower bath room for the convenience and recreation of all members of the fire department. The dormitory for the night company is in the same building.

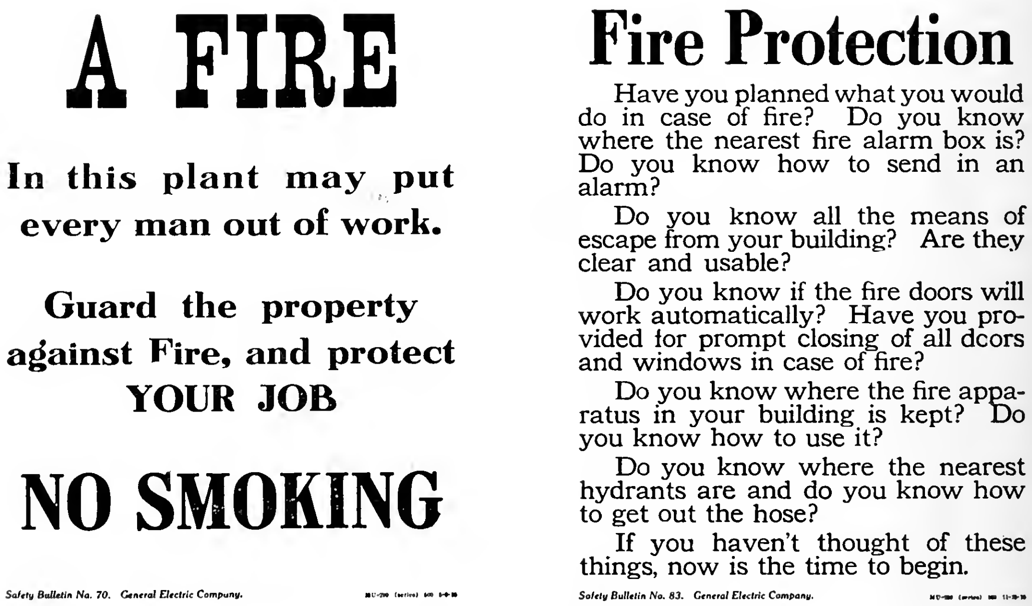
Firemen's Quarters in Fire Station

A relief association is formed among the members of the fire department, and an assessment of 10 cents a week is paid in by each member. A benefit of $9.00 per week for 13 weeks is paid members of the association on account of illness or disability. This organization is a flourishing one, has a good substantial surplus in the treasury, and since the association was organized in 1904 has paid a substantial dividend to the members.

A Typical Year's Work

During the year 1915 the fire department responded to 62 alarms of fire, 22 bell alarms, and 40 still alarms. The fire loss was $817.29, the largest individual loss being $300.00. Twenty-five fires were extinguished with 1½-in. shop lines, 15 with fire pails, 11 with extinguishers, 6 with 2⅝-in. house lines, 6 with sprinklers, 4 with sand, 1 with wet bags, and 1 with pyrene.

The longest fire with which the Schenectady Works fire department has fought lasted three months. A pile of soft coal 500 feet long, 40 feet wide, and 25 feet high caught fire from spontaneous combustion. From one to five streams of water were played night and day upon this coal fire for ninety days. But this was not sufficient, as it was found necessary to turn over the coal so that the water could penetrate all portions of this huge pile. The expense of doing this with skilled firemen and high-class mechanics soon became such an item that foreign laborers with shovels were employed to perform the work. Forty pairs of rubber boots were worn out in extinguishing this one fire.



A FIRE

In this plant may put every man out of work.

Guard the property against Fire, and protect YOUR JOB

NO SMOKING

Safety Bulletin No. 70. General Electric Company.

Fire Protection

Have you planned what you would do in case of fire? Do you know where the nearest fire alarm box is? Do you know how to send in an alarm?

Do you know all the means of escape from your building? Are they clear and usable?

Do you know if the fire doors will work automatically? Have you provided for prompt closing of all doors and windows in case of fire?

Do you know where the fire apparatus in your building is kept? Do you know how to use it?

Do you know where the nearest hydrants are and do you know how to get out the hose?

If you haven't thought of these things, now is the time to begin.

Safety Bulletin No. 83. General Electric Company.

Bulletins Reminding Employees of the Dangers of Fire

It is a peculiar fact in the life of members of the fire department that the more efficiently they do their work the less exciting the work becomes. The members do not feel, however, that their work is less interesting, as there is nothing that gives an ambitious man greater satisfaction than the feeling that he has done his work well; that by doing so he has benefited others. The record of the Schenectady Works Fire Department is one of which they can feel justly proud; there are few fire departments which can boast that the average loss per fire is only eleven dollars.

The activities of the General Electric Company in fire prevention are not limited to the protection of its manufacturing plants and its employees; its work in this direction has been extended to the benefit of the public by careful study of all its products with the view of minimizing the chance of fire through their use. Some of the devices that are more commonly used by the public that receive special attention in this respect include electric lamp sockets, flat irons, snap and push switches, small motors, and domestic heating devices. Frequent conferences are held between the company's engineers and representatives of the National Board of Underwriters with the purpose of adopting designs that insure the greatest security from electrical fires.

The foregoing description relates particularly to the fire department of the Schenectady Works, as this is the largest organization of the kind in the Company. The Company's other plants have each a well organized fire department that resembles in most respects, though on a smaller scale, the department at Schenectady.

GENERAL ELECTRIC REVIEW

A MONTHLY MAGAZINE FOR ENGINEERS

Manager, M. P. RICE
Editor, JOHN R. HEWETT
Associate Editor, B. M. EOFF
Assistant Editor, E. C. SANDERS

Subscription Rates: **United States and Mexico, $2.00 per year; Canada, $2.25 per year; Foreign, $2.50 per year; payable in advance. Remit by post-office or express money orders, bank checks, or drafts, made payable to the *General Electric Review*, Schenectady, N. Y.**

Entered as second-class matter, March 26, 1912, at the post office at Schenectady, N. Y., under the Act of March, 1879.

VOL. XX, No. 11

NOVEMBER, 1917

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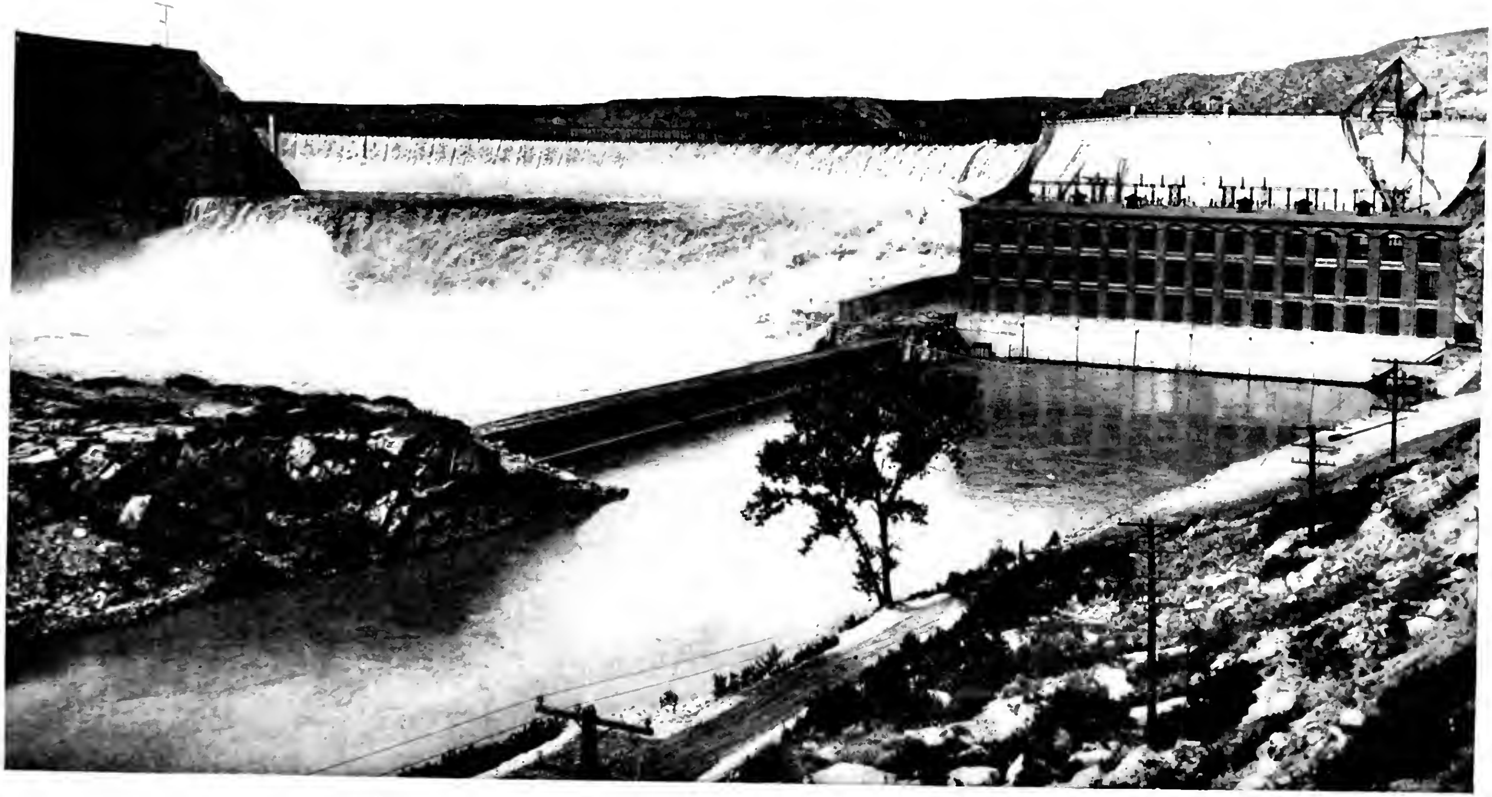

GREAT FALLS POWER HOUSE AND DAM AT GREAT FALLS ON THE MISSOURI RIVER
Power from this station is transmitted by the Montana Power Company to the Chicago, Milwaukee and St. Paul Electrification

GENERAL ELECTRIC
REVIEW

CONSERVING AND RECLAIMING RAW MATERIALS IN INDUSTRY

The metal, fuel, and lumber resources of the United States are so great that many of us had come to consider them, at least for the regular demands of peaceful times, as inexhaustible. This state of mind has been responsible for a waste of raw material in the conduct of American business that is appalling in the light of the enforced economy being practiced today by the warring countries of Europe.

But the heavy demands created by the war for raw material of all kinds and the steeply rising prices have brought many industries to a rude awakening of their wastefulness; and now that our country is involved in the strife and will require the full measure of its resources adequately to provide our soldiers, sailors, and allies with the necessary implements of war, it is a clearly defined patriotic duty of every American firm to institute means for conserving and reclaiming every particle of useful material.

War is a campaign of destruction against the enemy; its success is measured in terms of destruction. Heavy waste of material and loss by reprisal are unavoidable; but this waste can and should be offset in part in our factories by a strict economy of materials. This practice should be adopted without exception, for the increased demands caused by factory waste may entirely deplete our supply of some materials, or so reduce them as to interfere seriously with the prosecution of the war.

As outlining what results can be accomplished in reclaiming materials in manufacture, we publish in this issue an article by Mr. W. Rockwood Conover descriptive of the methods employed at the Schenectady Works of the General Electric Company for salvaging all material having intrinsic value. We may safely venture the statement that, aside from the service rendered to the country at this time by this practice, the proceeds for the year will show a handsome margin of profit over expense. This fact of itself, apart from any motive of patriotism, should induce every manufacturer, railroad and other consumer, large and small, to adopt some such system for making every pound of raw material serve a useful purpose.

An indispensable product in this war is coal, and little less important are petroleum and its products. One or the other of these fuels is necessary for the movement of troops, artillery, supplies, etc., the operation of our naval and air fleets, and the manufacture of a large part of our ammunition. The demand for coal is so urgent that a real shortage is reported, and many of our large power plants have had to operate on a hand-to-mouth basis for months owing to the inability to obtain a reserve supply of coal. This condition focuses attention on the enormous waste of coal that occurs under the boilers of many of the smaller power houses, a large part of which is preventable and, at a time like the present, inexcusable. Proper attention to stoking and the installation of a steam-flow meter and a few small devices to show how combustion is proceeding will do much to help matters in isolated plants. But when we read the statement by Mr. R. H. Rice in his article on The Large Turbo-Generator, that the larger turbine units being built today deliver twice the power at the switchboard for each pound of coal that the first large units did—a better performance by 300 to 400 per cent than that of the usual isolated steam plant—we perceive that the avoidable waste is greater than is apparent on first thought.

Another means of conserving our coal supply is afforded by the use of fuel in powdered from. Not only is combustion of the better grades of coal improved by this method, but the lower grades of fuel are thus made available. This subject is being very thoroughly covered by the series on "Methods for More Efficiently Utilizing our Fuel Resources" now appearing in the REVIEW. The installment in this issue by Mr. V. Z. Caracristi deals with the firing of railroad locomotives with powered coal, and the results that have been obtained are highly gratifying. Railway locomotives are one of the largest users of coal and they are notoriously wasteful of this valuable fuel.

The electrification of some sections of trunk line railways and the employment of water power for their operation is still another means of conserving our fuel supply. What may be accomplished in this way is outlined in a contribution by Mr. W. D. Bearce to the series mentioned above.

Public Utility Rates

By H. S. Cooper

Secretary, Southwestern Electrical and Gas Association

This article should be read by every central-station manager, public utility commission member, and municipal officer. The greater the spread of knowledge concerning the operating mechanism of public utilities and the factors which influence their rates, the less will be the unjust criticism of their rates. Not infrequently, a city thinking its public utility rates are high will compare them with those of similar cities with the ultimate intent of enforcing a decrease in its own rates. Mr. Cooper carefully and completely analyses this situation and conclusively shows that inspection of rate schedules by the comparison method is fallacious. He concludes the article with the earnest recommendation that public utilities educate their public to a better understanding of the conditions under which the utilities have to operate.—Editor.

To the untechnical outsider, "the ultimate consumer," the charges for the "product" of a public utility: the "rates" for water, gas, or electric current (especially the last) are mysteries, open to the suspicion of having been made and maintained as such for the express purpose of deluding the user of the product. This suspicion has been fostered by two opposite forces: the utilities themselves and those opposed to them. The utilities have strengthened it by having rates which could not be justified or could not be logically explained, or else by refusing or neglecting to explain their rates even when they were perfectly just and explainable. The opponents and enemies of public utilities, privately owned and operated, have not only seized on any and every case of negligence, carelessness, irregularity, inequity, or discrimination in the rates and made public capital of them, but in many cases have taken advantage of the ignorance of the general public on these matters to make positively untrue and entirely misleading statements with the evident intention of making capital with the public in favor of themselves. This latter condition has been made worse by the fact that a majority of the utilities have refused, or neglected, to enlighten the public fully and intelligently upon the subject of their rates or the reason for those rates, even after such biased or untruthful charges have been made.

Therefore, between these two parties, there is little wonder that the general public is not correctly conversant with either the general operating mechanism of its public utilities or the basing of their rates. If this miscomprehension went no further than a misunderstanding, even then the result would be unsatisfactory; but this ignorance, incited by misinformation, paves the way for suspicion of *all* the acts and motives of the utilities, and incites reprisal for so-called wrongs and inequities which have been either greatly exaggerated or have been entirely imaginary.

Added to this, as a factor of misunderstanding, is the great and, by the public, unrecognized difference between the public utility and any other class of business. As a rule the public understands, thinks it understands or takes on trust every other kind of business, manufacturing or distributive, or both. It believes that the principles which it sees underlying all these private businesses are of universal application, and it is rendered still more suspicious of the utilities and their methods when the fact is forced on it that, in certain things, the utility business operates in ways apparently opposite to the ordinary commercial businesses with which they are familiar.

Moreover, the public has so much more business to transact with the average private commercial establishments than it has with the utilities that it conceives that the methods of the private enterprises are the only correct ones, and that any business the methods of which vary greatly from these *must* be wrong in its principles. No full and concerted effort has ever been made to explain clearly and practically that the difference between the operating mechanism of a public utility and that of a private commercial enterprise is one of form only and that the eternal axioms of all commercial life, the basic principles of all permanently successful businesses, rule the public utility plant as well as the department store, the hardware shop, or the livery stable.

To further complicate the matter, the product of the more important utility, electricity, is an intangible substance; it is in all its uses merely a "form of service." The public has been familiar with dealing in commodities, in tangible goods, in an actual physical and personal service. However the electric "unit of rates," the kilowatt-hour, is fundamentally an entirely different unit from that of any other business with which the public deals and it is, consequently, suspicious of that unit and all its combinations in rate schedules. No full and concerted effort has ever been made to explain clearly to the public that the "product" is not a quantity or a bulk or a measure, but that it is actually a service expressed in terms of quantity and time as a "kilowatt-hour"—the supply of a certain amount of a certain kind of electrical service for a certain length of time. Thus explained and illustrated by the concrete example of a service of light, heat, or power, there is immediately laid a basis for explanation of the equity of varying rates for the same product—the great stumbling-block and trouble-breeder with the public.

The ordinary retail commercial organization, such as a department store, conducts its selling and prices on a system of averages by which the profitable customers pay for the unprofitable ones. The charge customers, no matter how slow in paying they may be, obtain their goods at the same price for the same quantity as do the customers who pay spot cash; the one who requires a spool of cotton delivered in a remote suburb pays no more for it than does the one who carries it away. The service which, to a greater or lesser extent, must necessarily accompany all retail merchandizing is averaged over *all* customers, as are all other costs or expenses (including bad debts and, often, poor buying of goods). The whole commercial teaching of the retail purchaser at private commercial establishments is on the one-price principle. It is the same as that impossible "single-rate" ideal of certain rate faddists. This method of average charging is, at the present time, perfectly legal in a private manufacturing or distributing business, but the instant any business is, or becomes, a public business (a "Public Service Corporation" or a "Public Utility") the manner of selling its goods or product or service to the public is legally changed.

The private enterprise has entire control of the price it may demand for its goods or services. If the cost of its operation, its material, or its labor increases, it is at perfect liberty to instantly increase its price or "rates" to its customers, and the only limit to such raise of price is what the customers will stand. This course is not open to the utility, its rates are generally contractually fixed at a maximum for a long term period, and it cannot raise those rates without the consent of the public no matter how much its loss or loss of profit may be under the existing rates. Also, the private concern may legally practice any discrimination it may desire among its patrons. It may charge one price to one customer and another price to another; it may, simply as a matter of like or dislike, give credit to one and refuse it to another; it may sell to one and refuse to sell to another, and there is no legal recourse against it or its practices. This the utility cannot do, its price for the same service must be identical to all; and it may refuse service to no customer or prospective customer who complies or agrees to comply with the reasonable rules and regulations approved by the public and put in force by the utility. It must serve friend and foe alike, no sentiment must enter into its business relations with its customers; its most bitter enemy and detractor must have the same service and courtesy as its best friend.

The profit of the private concern is legally unlimited. Without regard to the cost to it of any article or service it sells, it may set any price it may desire on that article or service and the public must pay that price, go elsewhere to get it, or failing to do the latter must go without it or use a substitute.

This is not the case with the utility. Its product or service must be sold to each consumer at as near the particular cost of the product or service demanded by such consumer as is commercially possible, *plus* a certain legally fixed, agreed, permitted, or passively allowed profit.

As very few customers of any one utility (except in the case of the largest utilities) require the utility service or product under identical conditions, it would seem that it would be commercially impossible to have a different rate for each customer. This is true and brings up another matter in which the public utility method of charging is necessarily different from that of the private concern. While it would be *possible* to obtain the exact cost of service or product to every individual customer, such an operation would entail so great a cost of labor and accounting as to make the rates prohibitive to all but the well-to-do; a condition to be avoided in public service as the very intention of such service is to be directed to the largest number in any community, to the whole public if this is possible.

It is therefore the custom among public utilities to form their customers into groups or classes whose demand for product or service is more or less similar in character. The members of such groups as residences, rooming-houses, hotels, stores, theaters, churches, etc., make as individuals very similar demands for their electrical service. Private residences will, on the average, burn only a certain percentage of the lights installed and will burn these only during certain hours of the day. Other groups, such as churches, theaters, or meeting-halls may burn their lights only one or two evenings a week or month. The residence may light up one or two lights at a time as daylight fails, the theater or church may suddenly turn on hundreds of lights and as suddenly turn them off. In fact, there are hundreds of variations of demand which may be made on the electrical service desired by the public.

The public actually makes a "demand" of the public utility in regard to its service; it orders the public utility to serve it in such and such a manner and to such and such a degree, and the public utility is legally compelled to fulfil each and every such demand if the public pays it cost plus profit to do so. It is this ability of the public to compel the fulfilling of a demand which is one of the principal factors in the difference of price-making between the public utility and the private commercial concern. If the public went to its grocer and said, "I want a pound of sugar, send it up at the most convenient time for you," the price of that sugar would be at its minimum per pound. But if the customer said, "Send me, at your very busiest time, ten pounds of sugar in one-pound packages, a package every ten minutes," that grocer would soon advance the price of sugar to that customer or find some method of avoiding filling any more such freak orders. But the utility is not only compelled to fill such freak orders as long as it is paid cost plus profit to do so, but it must stand prepared to fill, at any minute, night or day, Sundays or week-days, any and all of the freak orders or demands of every one of its connected customers. It cannot store or reservoir its product—electric current—so it must have a reserve of machinery and apparatus ready at any time to generate, translate, and distribute electric service in quantity and kind the very instant it is demanded; in other words, must have it "on tap" so fully and completely that any customer who, at any time, throws in a switch gets instantaneously the electric service he pays for.

If the grocer gets out of sugar the customer may be dissatisfied, may even transfer his patronage to another grocery, but there is no legal obligation on the part of the grocer to maintain, as far as is humanly in his power, a stock of sugar which will fill *any* sudden demand from his customer, nor is there any liability for damages against the grocer because he allows his regular customers to fail to receive their supply from him. But the public utility is legally compelled to do this or forfeit the right to do business in that community. Now, to be so able to fulfil any such demand at any time, to have a reserve of capacity to accomplish this, adds greatly to the costs and consequently to the rates, and it especially adds to the rates of those customers whose demands are responsible for this condition of affairs. The simple and correct commercial reason is "that he who dances must pay the fiddler;" in public utility rates "he who demands must pay for his demand." In other words the customers, or class or group of customers, whose ordinary demand for the most of their electric service is in the evening only but who, at the same time, demand that this service shall be on tap the whole twenty-four hours whether they use it or not, because they *may* want to use it, these and such as these must not only pay for the electric service which they use but, in equity, they must pay the expense of keeping it on tap ready for their use the whole twenty-four hours because, by their actions and by their installation, they demand that this shall be done.

As has been shown, the public utility does not merely sell its product—gas, water, or electric current. If it sold merely the product, the customer would be compelled to come or send to the gas works, water reservoir, or station switchboard and carry away its needs of gas, water, or electricity, if such a procedure were possible. But because such procedure is nearly impossible practically, and absolutely so commercially, the public utility *delivers* its product in every case and in that delivery lies the difference in rates, because that delivery is always in accordance with the demand of the customer, and, as stated, the demand of the customer may be exceedingly varied but in all cases it must be fulfilled by the utility as long as that customer pays the utility sufficient to reimburse it for the cost of its raw product, for the cost of the specific service demanded and, in addition, the profit legally due the utility on the transaction. It will be seen therefore that actually the basis of rates or the "prices" of the public utility are not only figured very similarly to those of the private commercial concern but that, as a matter of fact, they are more strictly and impartially equitable than are those of the private business. The private price method is simpler and easier to understand because it is a one-price method; the same price to every one for the same quantity and without regard to the cost of the varying demand made by the different customers. This, as can be easily seen, is so inequitable that it actually amounts to discrimination because discrimination is, in one of its phases, "the charging of an equal tariff for unequal service." The public has, however, in its modern retail dealings with its private suppliers become so accustomed to this average or one-price method of charging that it not only has not been able to recognize the inherent equity and reasonableness of the public utility price-methods, but it has actually viewed these methods with grave suspicion as being an endeavor on the part of the "wicked corporations" to "put one over on the public"!

Outside the fact that this matter has not been fully explained to the public lies the further fact that the utility has never explained to them that its price methods, or rate-bases and rate-schedules, are now and have been for a long time fixed on it by legal enactment, and that even if the utility desired to return to the slipshod and inequitable price-fixing methods of the private merchandizing concerns, neither the public nor its representatives would allow them to do so upon full consideration of the matter. While the public "kicks" at the amount or the comparative amount of its public utility bills, while it hoots at "kilowatt hours" and affects inability to comprehend "demand," there are among it and representing it in the council-chamber, commission-room, legislative-hall, or on the judicial-bench those whose understanding or training enables them to see the defects of the private commercial price-making methods, especially when applied to public or quasi-public supply by a virtual local monopoly. Left to the untechnical public, the price-fixing of public utility product or service would be "a thing fearfully and wonderfully done," and the utilities should be thankful that, in many cases, those outside of the utility business have been more industrious in forming true rates on a proper rate-basis than have many of the utilities themselves.

In order to comprehend and appreciate fully the equity of a proper public-utility rate schedule, it is necessary that the public should be preinformed as to what has been aptly termed "the operating mechanism" of a public utility, the peculiar conditions which differentiate its method of doing business from the methods of the private commercial business. Mention has been made of the fact that the utility may not select its customers: it cannot refuse its service or product to any person within its franchised territory who desires that service or product, providing that the one so desiring shall indubitably pay the cost plus profit. Mention has also been made of the fact that the profit, or the percentage of profit, made by the utility is a matter fixed in some public manner and that its prices, or rates, are not allowed to fluctuate with fluctuating costs but are generally fixed by the public, or their maximum is fixed by the public for greater or less periods in the future.

Almost always the utility is a "monopoly," that is to say, it has the monopoly of supply of its particular product or service within the community in which it operates or within which it has chartered and franchised rights. This privilege of sole sale of its product or service is not a positive right as no states, nor any community within them, have the right to give directly to any utility such a privilege. But it has come to be a recognized economical and commercial fact that competition in any one public-utility service almost invariably leads to price-cutting, loss of profit, and the final failure of one or the other of the competitors; and it has also been found that, in the end, the public pays the loss, directly or indirectly. In view of all these proved facts, the existing utility is often allowed to remain a monopoly by the community refusing to enfranchise a competing utility. The advantage of this negative method of creating a monopoly is that it leaves the way open for the community to permit of a competitor if it desires or has reason to do so, and the original utility is thus to a certain extent put on its good behavior.

The cost of having the utility product on tap is entirely a separate matter from the cost of manufacturing and distributing the product. It goes on, as one of the most authoritative state public-utility commissions declared "whether the consumers use much, little, or none of the product," and its actual cost to each customer should be paid by that customer in addition to what he pays for the actual product which he uses. In fact the "fixed-service charge," or as it is often miscalled "the minimum charge," is really something which is paid the utility by the consumer for his privilege of having the product or service continuously on tap.

These charges are greatly misunderstood by the average consumer and are especially resented by the small consumer. It is true that the exaction of such a charge does seem, at first glance, like an imposition on and an injustice to the consumer whose total monthly use of gas, water, or electric current at its regular rate to him may not amount to the sum of the fixed-service charge. His proportion of the charge is so large, compared to that of a larger consumer of the same class, that it would seem to be a palpable injustice to make the small consumer pay more for the fixed-service charge for *potential* service, than he does for the gas, water, or current which he has used for *actual* service.

But the one who takes this view forgets that there are matters, entirely outside of the quantity of product used, where the small consumer makes a demand that entails a cost to the utility that is as large (not proportionally as large nor in ratio to the product used, but actually as large) as the same character of demand made by the largest consumer. The small consumer costs very nearly as much to meter and serve as does the larger one, the small consumer costs just as much to read meter, to bookkeep, bill, and collect as does the large one and the small consumer demands, equally with the largest one, that the product be on tap for him similarly in every particular, except in quantity, as it is for the largest consumer, no matter whether he uses "much, little, or none of the product."

Equally with the larger consumer, the smaller consumer demands at all times a "100 per cent service;" and the ability on the part of the utility to satisfy this demand instantly and fully is not only a large portion of its everyday active operating expense but it constitutes also quite a portion of its fixed charges for bond interest, taxes, insurance, superintendence, deferred maintenance, and all the expenses that run on whether the product is used "much, little, or none at all."

Another matter peculiar to the utility business is the right of the utility to protect itself from bad or slow debts, by compelling customers or intending customers of doubtful or unknown solvency or credit to make a deposit or give a bond or guarantor for the possible amount of their use of the utility product or service. The utilities of gas, water, and electric current are compelled to sell to all meter consumers on at least thirty days time, and it is becoming more and more the rule to meter all utility product consumption, and to read the meter at intervals one month apart, and to bill the customer in the same manner. As the utility is compelled to supply everyone within its franchised territory who agrees to follow its reasonable rules and regulations, it would be entirely at the mercy of any unscrupulous person who used the product or service as long as he was allowed to do so without payment and then refused to pay for it. Such amounts would be small, the legal expense of collection comparatively large, and the actual collection uncertain. Therefore, the law generally allows the utility to protect itself from such losses by requiring the prerequisite of a cash deposit, a bond, or a guarantee from all customers whose credit is doubtful or unknown. Many customers of utilities and even some whole communities object to the enforcement of this precaution which is a double necessity in the case of a public utility as it is designed to protect both the utility and its prompt-paying customers, and is another instance of the superior equity of public utility rate-schedules over those of private commercial concerns.

In its competitive efforts to sell against its rivals in or out of the community, the private commercial concern often takes credit risks which result in a large amount of bad debts, and these it invariably adds into its costs. Thus the prompt or solvent customers pay the losses of the slow or insolvent ones. Such a method, being inequitable, could not be allowed in a public utility; each one of its consumers must pay only the costs which he, individually, causes. Therefore the utility must make no commercially preventable bad debts and, as it is compelled to take as customers anyone and everyone, no matter what their credit may be, it is only equitable to the prompt and solvent customers that those whose credit is doubtful, and who might cause bad debts, be put into such a position that they cannot do so.

The costs of generating, translating, distributing, and serviceing gas, water, or electric current and the profits of a utility are very dependent upon local conditions. This condition is absolutely true of the individual utility in any one community or small group of small communities. It is also true, to quite an extent, of those new large groups of interconnected communities now often served by high-potential transmission lines from central generating plants. Such being the case, it follows that the rates would be liable to vary greatly in different communities. This is found to be exactly so and is another matter in public utility business which the public does not comprehend, of which it is suspicious, and on which it has never been fully enlightened. Even with the advent of state Utility Commissions in a majority of the states, the fact that these commissions do not forthwith compel the higher rate utilities to come down to the rates of those lower or lowest is always an argument as to whether "the public service corporations are or are not running these commissions."

There is scarcely a town or city contemplating a revision of its public utility rates whose first thought is not to compare its own rates with those of some other town or city which has lower rates, and to seek forthwith to reduce its rates to or below those of the compared towns or cities. The public has not been made to comprehend clearly and to appreciate fully the easily proved fact that, in most cases, local conditions absolutely fix rates *independent of any action or intention of the local utility.*

The public reasons that as the price of its other staples are matters of comparison with adjacent and somewhat similar communities, the same ought to be true of its gas, water, or electric current. It notices that the products of the flour mills and grist mills and furniture factories and bakeries and breweries and other manufacturing and distributing concerns in adjacent towns sell locally at about the same price, and it cannot understand why this should not also be the case with the product of the utilities. It has never been informed by its home utilities as to the peculiarities of the "operating mechanism" of a public utility and especially of its utility or utilities. To it all electric central stations "grind out juice" somewhat as different grist-mills grind out meal. That the difference in capital invested, age of plant, kind of fuel, kind and quantity of water, station and pole-line investment per customer, use of current per capita, and a hundred other such local matters could make a very perceptible difference in the costs of operating—and consequently in the price of the current delivered—would hardly enter the heads of the general public. Naturally, therefore, a large difference between the rates of one city and some other similar one (especially if such similar one were closely adjacent) should indicate that one or the other of these two plants was charging too much—making too much money—and, if the rates in the one town were the higher, the first instinct would be to lower them compulsorily, the lower rates in the other town being a seemingly justifiable reason for such action.

It is hardly necessary to point out the inequity of such a proceeding but it may be necessary to show the utter uselessness of any formal attempt to compare the rates in any separate cities with the intent of using such comparison as a factor in the revision of rates in any one of the cities compared.

Suppose the comparison is made; what has been proved? Simply that the rates of one city are higher than those in another city; that is all. Suppose that even in the comparison of the rates of one city with those of a hundred or a thousand other cities, the one has the highest rates of all; what has been proved? Simply that they are the highest. Such comparisons do not in the slightest particular *prove* that these high rates should be lowered.

The citizens of the high-rate town might think so, but thinking so and proving that thought to be just and equitable are two different things. Merely as a mathematical fact some towns among the hundred or thousand will have higher rates than all the others; will that fact alone be justification for lowering the rates of those towns to the same level as the next lower, or should they be lowered until they equal the very lowest in the whole group, and this shuffling continued until they are all on one lowest level? "It is a poor rule which will not work both ways;" if, in such comparison, the adjacent town or towns are found to have higher rates than the one, ought not the rates in the latter be raised? Any point of view in this matter shows the fallacy of the idea of comparison of rates as a basis for fixing rates, but its first apparent equity appeals strongly to those who have no technical knowledge of rate-making and, strange to say, it has even had and still has in a few cases an appeal to those who should know better; some heads of public utilities and some members of city and state public utility commissions.

The fault of this condition as a whole is actually that of the public utilities themselves and the remedy lies with them also. In the "ancient days" of the utility business, ten or twelve years ago, very few of the public utility plants had a full schedule of rates which they could justify as a whole. Therefore when threatened by a comparison of rates they were in no condition to act on the defensive and most of them made a reduction here and there in their schedule or made a sliding cut—all as "a sop to Cerberus"–and Cerberus swallowed the sop and took a nap until hunger assailed him again and then the performance was repeated. The fault of the utility lay in the fact that, even if the city were right in its contention as to the rates being too high, the utility should not have permitted the city to compel it to lower, revise, or rearrange its rates on a viciously false basis: that of comparison with those of some other city or cities. The course of the utility should have been to protest to the utmost against such a basis of revision and to have immediately started a revision of its own upon the proper basis of cost plus profit and with variations to groups according to service rendered—the *only* correct and equitable method of rate-making. By allowing the public to bulldoze it into a "revision of rates by comparison," the utility not only virtually acknowledged the justice and equity of this method but it established it as an accepted and approved precedent to be used not only again and again against itself later on, but to be used against other utilities with the prestige of victory attached to it.

If the revision of the rates of a public utility were a matter of frequency, say every six months or a year, and if such revision were actually what its name indicates and not an attempt to arbitrarily lower the rates as a whole, the use of the comparison method would not be so vicious. However, not only is the so-called "revision" more often an arbitrary "reduction" than anything else, but it is nearly always the case that the results of such revision are made to stand for a term of years, and there is thus perpetuated an inequity and injustice to both utility and public, for it is an axiom that rates which are too low in whole or in part are not finally advantageous to the public. If the utility loses money on certain of its rates and makes up that loss on other rates, it is most certainly practicing discrimination; and if it loses on all its rates or even if it loses all or a portion of its legitimate profit on all its rates, the public will be finally compelled to make up that loss or a large portion of it—if only by receiving a less than 100 per cent local service.

Another fault of the utility has been that it has often endeavored to rebut the claims of the city in its comparisons, by introducing evidence tending to show that there were cities whose utility rates were *higher* than those in the home city. Such an attempt at rebuttal is probably more mischievous than no action whatever, as it virtually acknowledges the equity and justice of the comparison method and the occasion then becomes a Marathon race in which each side endeavors to bring in a majority of cases favorable to its contentions. There are two other objections to this method: one is the peculiarity that there never was a public utility with rates so low but what the municipality could find others with rates still lower; and the other is that no matter how few examples of lower rates the municipality may find the fact that it finds any at all is always used as a hammer to endeavor to pound down the rates.

For the utility to wait until the actual comparison is sprung upon it is a poor policy and a heavy handicap but, if such is the case, the first and only action of the utility in the matter should be to discourage, to the extent of strong opposition, the idea of "the comparison of rates" by the representatives of the public.

The first step in this "discouragement" should be to lay before the public representatives the facts, data, and reasons showing that such a method of fixing rates is not only unreasonable, inconclusive, and useless for the end desired, but also the further fact that any action taken by the city or its representatives based on such comparisons is liable to be *confiscatory* of the property or legal profits of the utility and *discriminatory* in its results among those of the public who are consumers of the product of the utility

It is always wise to fully educate the public to the incontrovertible fact that where one community pays more for its public utility product or service than does another community, that fact is not of itself prima facie evidence that the higher rates of the one community are too high and should be reduced. There is, in the first place, always the chance that the lower rates in effect in the other communities are too low for a reasonable profit on a 100 per cent local service and that the service is "low" as well as the rates. In the next place, public utility products or services produced or given by local plants are strictly home products and are subject to all the variations and increases in cost which local conditions will cause Therefore as a safety-first preliminary—long before the danger actually comes to a head—the utility should educate its community to the knowledge that any local conditions in any one community which are more unfavorable to low costs of utility operation than they are in another city will tend to give the first city higher utility rates *independent of any action or intention of the utility itself.*

Once a community is made to fully understand and appreciate this point, a large amount of the utility's rate troubles will have been brushed away.

Also if a community is made to fully understand and appreciate what these local conditions are and how they affect the cost of operation, a still further amount of the rate troubles will be eliminated.

This presupposes, however, that the rates of the utility have been made on some equitable basis and give only a reasonable return to the utility.

Conserving 80,000,000 Pounds of Industrial Wastes a Year*

By W. Rockwood Conover

General Electric Company

Saving and reclaiming waste products in industry may be a far greater factor in supporting our National Government than any one of us is able to understand or conceive today. To conserve everything possessing inherent value should be the policy of every American manufacturer. It is today a patriotic and economic duty.—Editor.

Within the last decade conservation has become a world-wide slogan. The word has become a popular one in both business and private life. In many industrial establishments throughout the country saving and utilizing the waste products of production are receiving a new prominence among other established practices of recognized value in engineering and manufacturing. Saving by-products is at all times a desirable and economic procedure. This is true in times of peace. In time of war it becomes not only a universal necessity but an imperative duty under which every citizen is bound to faithful pursuance and performance. In a period of conflict between nations certain kinds of by-products may rank in close importance with products, and the things which we have been accustomed to consider waste may become necessities in the general furnishing of the engines and equipment of war. The industrial manager in every field, the manufacturer large and small, the business man in every calling in life must, in this great crisis study the conservation of waste and the reclaiming of the by-products of production and every-day living as never before in the history of the country. Such conservation may constitute a far greater degree of helpful support to our National Government than we have yet been able to understand or conceive.

Metal By-products

In the larger industries engaged in the manufacture of a mechanical and electrical product such as the several plants of the General Electric Company, and similar companies, also in those industries the products of which are composed chiefly of metal parts such as machinery for mills and factories, agricultural and traction machinery, automobiles and their accessories, etc., metal scrap such as steel, iron, copper, brass and various alloys constitute the greater portion of the valuable by-products. In the Schenectady plant of the General Electric Company the aggregate of by-products reclaimed in 1916 amounted to more than 80,000,000 pounds—over 40,000 net tons. Of this large amount approximately 15,000,000 pounds of scrap were used for home consumption in the foundries in the making of steel, iron, brass, and composition castings.

Under the present system all shops are given credit for the scrap produced in each department. In the large boring mill and machine departments the metal borings and turnings are shoveled into steel boxes, capable of holding about two tons, which are placed in convenient localities near the machine tools. These boxes are provided with hinged ends to facilitate discharging, and with handles for lifting with the shop cranes and conveying to the cars. This obviates the operation of wheeling out chips to the sidings in barrows by the floor labor gangs, thereby effecting a good economy in cost of handling. This class of scrap is shipped in car lots in its original form.

The process of briquetting steel and iron borings and turnings which has been estab-

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* From *Industrial Management*

lished in several of the larger manufacturing centers of Europe as in the cities of Berlin, Vienna, Budapest, Stolberg, Chemnitz, Cassel, Milan, and in Switzerland at Winterthur, has in recent years come into use to a limited extent in this country. It is one of the new developments for which, in connection with certain prospective metallurgical reactions, there appears a somewhat attractive field about to be opened up, and one in which the big industries of the country will more generally take interest in the future. In giving consideration, however, to the increased market value of steel and iron borings and turnings which have been briquetted the cost of the installation and operation must not be lost sight of, as this has a very material bearing on the net gain to be credited to the operation. This is especially true where liberal market figures are already being obtained for these by-products shipped in their original form. In the present crowded condition of industrial plants it is obvious that the cost of installation in a very appreciable number of cases must include the erection of new buildings for the purpose, which will involve an important item of investment to be charged against the receipts. In general the larger industries throughout the country are still adhering to the practice of shipping their borings and turnings unbriquetted in car lots.

In the sheet steel punching department where the armature disk work is performed the scrap from an annual production of more than 27,000 tons of punchings is bundled on the shop floor and wheeled to cars on the sidings in close proximity to the shop. Approximately 100 machines are in constant daily operation and many of the presses are operated overtime during the year to keep pace with the demands on the department which results in increased output of scrap. The small scrap from this department is accumulated in steel cans or barrels at the presses and loaded by the floor truckers into a separate car from those containing the bundled product.

Main Building where By-products are Reclaimed

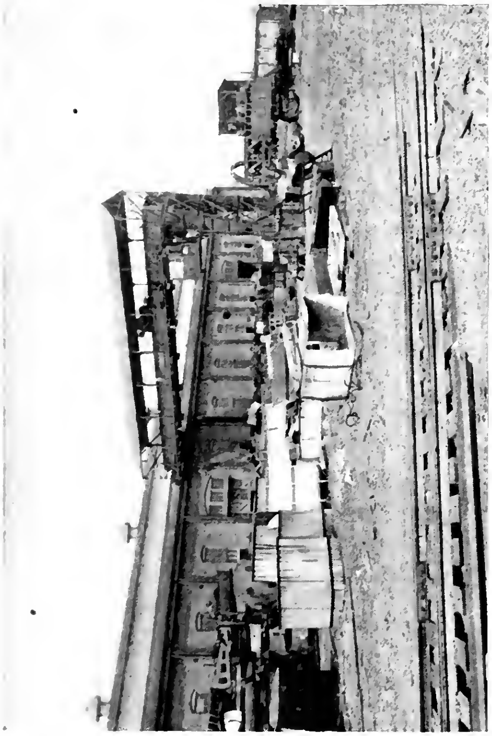
In the manufacturing departments having machine-tool sections devoted to the machining of small parts and in the automatic machine departments the chips and turnings, consisting of steel, iron, copper, brass, composition, babbitt, etc., are collected in steel barrows and containers, weighed, tagged, and sent to the scrap building on narrow gage cars. The tag attached to the container designates the department from which the chips come, class of material, and weight. As far as practicable the scrap from these departments is kept separate in the process of machining, the chips from one kind of metal being removed from the tool pans as soon as the job is finished and before another metal is started cutting. Chips removed from machines operating with cutting oils are run through oil separators before delivery to the scrap building.

Mixed chips and turnings from machines operated on short jobs, involving frequent changes of metal, and from those operated on parts assembled from two or more metals or materials are collected by the floor sweepers and forwarded to the scrap building for sorting and loading. Here a force of thirty-five men is engaged in the process of separating the various metals, compositions and alloys, and preparing for shipment. Several electromagnetic machines are employed in separating the various classes of mixed turnings, such as copper mixed with iron, steel, mica, etc., babbitt with brass or iron, and other mixed metals.

The by-products reclaiming and storage building is sixty-two feet wide by three hundred and twelve feet long, and is equipped within with narrow and broad gage tracks and overhead cranes for loading and unloading cars and the transfer and placement of obsolete machinery and materials to be stored. The contiguous outside yard area is provided with narrow and broad gage trackage, loading platforms, storage sheds, and with gantry crane service for the handling of heavy materials, a considerable quantity of which, such as heavy castings, must necessarily be stored without the building while awaiting disposition.

Apparatus and material designated by the mechanical inspection force of the shops to be scrapped has a blue tag attached and reaches the by-products building where it is taken apart and all materials of value saved. Benches are provided for the men who do the work of disassembling, and the various metals and materials are sorted into barrels, boxes, or bins in preparation for shipment or consumption in the home foundries.

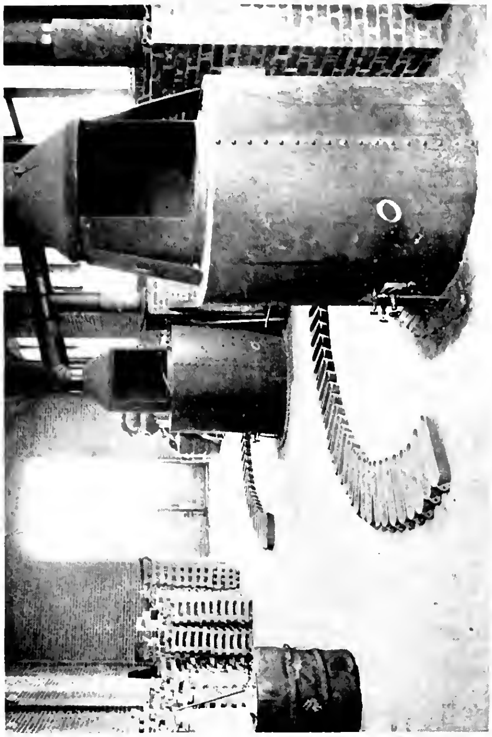
A great variety of materials thus reach the scrap building from the various shops in addition to the chips and turnings collected from the machine sections. Fiber, rubber, rope, rags, burlap sacks and wrappings, leather belting, asbestos board and paper,



By-Products Building, showing Gantry Crane and Loading Platforms

Interior of By-Products Building—Electro-magnetic Separator in Operation

Reclaiming Oil from Chips and Turnings



Interior of Foundry for Making Babbitt Castings
327,000 lbs. of this metal was reclaimed and cast into pigs during one year

cloth trimmings, armature and field insulation papers, insulated copper wire, and small lots of copper, brass, and composition in various forms and stages of shop processes which have been condemned by the inspectors, due to engineering changes or defects in workmanship or material, are forwarded to this building for sorting and disposal.

Destructor Plant, showing Overhead Conveyor from Carpenter Shop

Rope slings which have been cut in the process of lifting and moving castings or become worn by use are inspected by the chief rigger and wherever possible made into shorter lengths. In like manner steel crane and elevator cables are regularly inspected, defective sections cut out and slings made from the remaining portions which are intact and safe for the lifting of heavy loads. Steel slings are used to a large extent in many of the manufacturing departments of the Schenectady plant, and a certain percentage of these are made up from cables removed from elevators and cranes. Leather belting also receives careful inspection before it is discarded by the millwright department, only such portions as are of no value for repairs or for making short belts being sent to the scrap building. All insulated wire ends, clippings, and short lengths of cable and conductor are sent to the scrap building where the insulation is burned off. This leaves the pure copper for shipment at market prices for this class of scrap. Certain grades of clean copper wire are wound by machine into bundles of a suitable size to go into standard crucibles.

Special care and attention are given to the sorting and preparation of all the various classes of metals in order to meet the market rulings as to condition, size, and form in which the different grades of scrap must be shipped, and also to obtain the highest quotations which the market affords.

Babbitt Casting Department

Adjoining the main scrap building is an addition equipped with furnaces and molds for the melting and casting of babbitt chips and turnings received from the machine shops. The furnaces have a capacity of 3000 pounds per run, or 12,000 pounds total production per day. All of the clear babbitt scrap, also babbitt which has been separated from brass or other metal turnings in the separators, is sent to the department for casting. Approximately 327,000 pounds of this metal was reclaimed and cast into pigs during the year 1916, practically all of which was consumed at the home plant. Babbitt dross which in previous years was shipped to outside dealers is now rendered in the local plant.

Destructor Plant

The destructor plant, a building of steel construction having a floor area of 10,000 square feet, is equipped with two 300-h.p. Heine boilers. The steam from these boilers is delivered through the mains to the shops. The waste products and refuse of the manufacturing departments, except such as are scheduled to be sent direct to the scrap building, are collected in narrow gage dump cars placed near platforms located at the shop sidings and hauled from these points to the destructor plant. Two trains of five to six cars each are in constant operation daily collecting and hauling material from the yards and shops.

The waste products of the carpenter shop (shavings, sawdust, board ends, etc.), are conveyed to the destructor plant by an overhead conveyor, the board ends from the box lumber saws first passing through a cutting machine which reduces the material to chips. The larger sizes of scrap from this shop, refuse lumber from construction work, boxes in which incoming materials have been received, excelsior, refuse from the shop waste cans, and a variety, also, of by-products having little or no commercial value are collected and brought to this building by the refuse trains. All lumber fit for future use is sorted out and saved, as are also boxes, excelsior and other materials of value. The lumber serves a valuable purpose for temporary skids and blocking in the shops, and in frequent cases is suitable for permanent work. All the excelsior taken from incoming freight and express cases is baled and sent to the shipping department. Shavings and sawdust are also used in packing wherever practicable.

Two important reclaiming processes conducted in the destructor plant deserve mention. These are the repairing and saving of boxes, and the cutting and bailing of waste papers from the general offices and the shop offices. All incoming boxes of suitable size, from which materials have been removed in the receiving department, are sent to the stock department floors overhead to be used in delivering materials out to the shops. Incoming boxes which are unsuitable for stock deliveries, boxes opened in the shops, also tote boxes which have become broken and worn in service, are placed in the refuse cars at the shop sidings and delivered to the destructor plant with other materials. A workman equipped with hammer and saw and nails is assigned to the task of repairing. Boxes which are not too badly worn or broken to render the process of reclamation unprofitable are mended with the refuse lumber delivered at the building. Fifty to sixty boxes are reclaimed daily having an average value of twenty-five to thirty-five cents each. A constant supply of boxes for handling or storing materials is thus going back to the manufacturing and shipping departments and store rooms.

Waste papers are collected from the general offices, engineering offices, production, accounting, and shop offices in sacks and in this manner sent to the destructor plant on the refuse cars. These papers are run through a slitting machine for the purpose of effacing engineering or commercial data which might prove of value to the public, after which they are baled for shipment to the mills. In the process of baling paper and excelsior, board trimmings and scrap wire received at the building are utilized exclusively.

Careful attention is given by the foreman to inspection and sorting of the refuse, and all scrap metals, wire, and other materials of value, which by accident have been mixed with the normal waste products of the shops, are thus reclaimed.

The output from the two 300-h.p. boilers in 1916 amounted to more than 53,000,000 pounds of steam. Aside from its practical utility in the disposal of waste the plant shows a good profit in steam production.

Paper By-products from the Shops

The waste cuttings and trimmings of armature and field coil insulations, pressboard papers, and other papers used in production are accumulated in sacks in the various shops and sent to the main scrap building for storing and shipping. These papers are kept carefully separated in the manufacturing departments, thus avoiding the labor of sorting at the scrap building, and insuring the receipt of the highest market prices for the various grades. Wrapping papers received on incoming materials are accumulated and sent to the central stores building to be used in wrapping small packages of materials delivered out to the shops. In the end these papers reach the destructor plant and are baled and sold to the dealers. Magazines and periodicals are put into separate bundles for which a proper rate for this classification is obtained. Printed office forms which have served their original purpose, are cut and glued into pads and the backs of these sheets are used in the various shop offices and on the shop floors for scratch-pad purposes in a systematic effort to reduce as far as practicable the expense of clerical routine. As in the case of wrapping papers, they are eventually sold as scrap product. At the present time the total shipments of paper by-products from the Schenectady plant average approximately 550 tons per year.

Interior of Destructor Plant Producing 53,000,000 lbs. of Steam a Year

In nearly all manufacturing plants there are more or less scrap metals lying about the yards and open areas between shops unless some system of inspection and collection is established. In addition to the regular collections from the manufacturing departments, a man is assigned to the task of looking over the grounds and gathering up these metals, usually consisting of pieces of copper, brass, iron, or steel, such as bolts, nuts, scrap wire, pipe, etc. At the points of filling of low ground areas, the materials unloaded by the dump trains are also inspected and all metals reclaimed from the refuse which is discharged and burned at these places.

The process of reclamation in some cases is carried on within the departments, where the raw materials are used in production.

In the research laboratory every effort is made to conserve the valuable elements used in laboratory work. The by-product from the production of tungsten contacts is regenerated and reduced to its original form, effecting a large saving in the yearly expenditure for new stock. The by-product of molybdenum is also reclaimed and utilized in regular consumption.

In the foundries waste products are conserved as far as possible. Slag from the cupolas is carefully inspected and all metal of value picked out and again used in the process of charging. Sand from the gangways and molding floors is screened, and a considerable percentage saved for further use.

In the mica-insulation department, where more than 300 hands are employed in the production of mica insulations of various kinds, the waste product is treated in furnaces which burn out varnish, paste, etc., enabling it to be again used in the process of manufacture. All of this scrap is thus utilized in the production of insulation sheets to be cut into various forms of pasted mica.

Power house ashes are delivered to the dump cars by mechanical conveyors and used for filling depressions and low areas and for the underlying base of plant roadways and trackage. Ashes from the destructor plant are also used for filling. Because of the nature of the material burned under these boilers the potash content is not sufficiently high to render the process of reclaiming commercially desirable or practicable.

Improved Methods of Handling By-products

Under the period of reconstruction after the war the new condition of intensified activity in all industrial undertaking will render more scientific and improved methods of handling materials not only desirable but imperative. This will be true in the handling of factory by-products only in a relatively less degree than in the handling of materials used in production. New and more economic methods must be developed. Transveyors under floors along the line of machine tools, receiving chips through metal chutes direct from the machines, oil extractors and power loading facilities, all combined in a complete system of mechanical performance of previous manual operations, will be necessary to establish the work of handling the metal by-products of the big machine shops of the future on an economic and efficient basis. Those industries manufacturing a uniform, standardized line of product, such as the automobile industries, agricultural machinery plants and like industries, offer greater opportunity for the development of progressive methods of handling by-products than do those industries manufacturing a varied line of apparatus such as the larger of the electrical manufacturing companies. In the latter all methods of procedure are subject to interruption and modification coincident with the constantly changing conditions arising from the production of a largely diversified line of semi-standard and special product in addition to the regular standard lines.

Present Need for Greater Conservation

Nothing that is of value should be allowed to escape the process of reclamation even in normal times. In times of war it may be advisable to reclaim certain by-products which show a loss to the manufacturer in order to conserve the supply of those materials which, because of the increased consumption, might otherwise become abnormally depleted. Now, more than ever before, the manufacturer must give increasing attention to the conservation and reclaiming of the by-products of his factory.

It is the purpose of the management of the General Electric Company to conserve everything possessed of inherent value. The question of profit in the process of conservation is not always the chief or deciding factor. It is the desire of the company to render all the assistance possible both to the National Government and to the mills which manufacture raw materials or finished fabrics in conserving everything that may be of use in production, and in consistently following out this principle it is endeavoring to be of service to the public at large.

METHODS FOR MORE EFFICIENTLY UTILIZING OUR FUEL RESOURCES

PART V

THE USE OF PULVERIZED FUEL FOR LOCOMOTIVE OPERATION

By V. Z. Caracristi

Vice-President, Locomotive Pulverized Fuel Company

It has often been pointed out that electrification of the steam railways will not involve the relegation of serviceable steam locomotives to the scrap heap. They will be used on other lines until worn out. Electrification will proceed gradually, and we shall probably continue to use the steam locomotives on some of our railroad lines for many years to come. The conservation of our fuel resources demands that when improved methods of combustion can be economically installed on locomotives it should be done. The steam locomotive, at its best, is a wasteful type of prime mover, as compared with a large central station, and it is especially so when burning inferior grades of coal on the grate. The use of pulverized fuel offers an opportunity for utilizing low-grade coals with the same efficiency as the best grades, either on the locomotive or in the power station of an electrified railroad.—Editor.

The weight and power of modern locomotives have about reached the maximum in those of recent construction, and the factors that prevent further development in hauling capacity are the following limitations in design:

1. That of size, which is governed by the right-of-way conditions and clearances through bridges, tunnels, etc.
2. The track, bridge, and culvert conditions limiting the weight on wheels.
3. Tractive power which can be expressed in terms of frictional weight available for tractive effort.
4. The ability to construct the boiler of sufficient size to furnish steam, particularly when operating under severe overload conditions.

The magnitude of the boiler limitations can be more readily understood when the fact is taken into consideration that it is necessary to develop a boiler horse power from each two or less square feet of available heating surface, particularly when the available heating surface is largely represented by boiler tubes of approximately 2 in. internal diameter, having a length, in some cases, of as much as 23 ft., whereas the efficient work performed in the transmission of the heat to the water through such boiler tubes is all accomplished in the first eight or ten feet.

Much progress has been made and development work done in the direction of improved boiler design and efficiency by the use of:

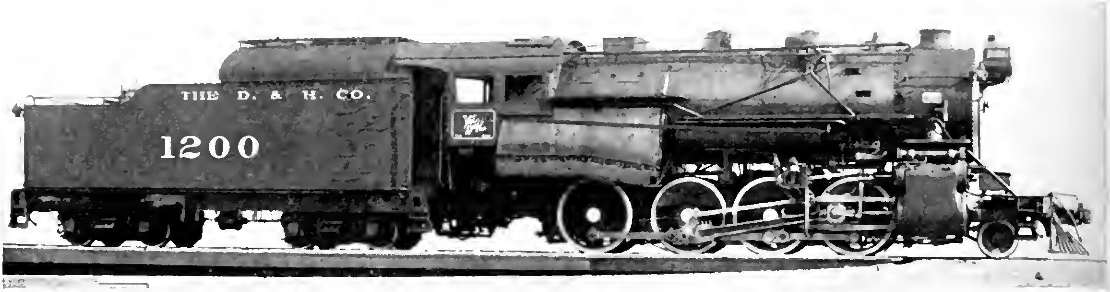
1. Brick arches, which, through the regenerative action of the heat stored therein, insure more complete combustion of the gases arising from the fuel bed.
2. More efficient utilization of the steam evaporated by the boiler by means of superheating, and evaporation of the water carried in suspension in the travel of the steam through the superheater tubes to the engine cylinders.
3. Feed water heating by utilization of the heat from the exhaust steam.

The overall thermal efficiency of a locomotive when operated under full tonnage and speed conditions is very low, particularly when deductions are made for the combustible in the fuel passing through the grates in the form of coal and coke and out of the stack in the form of unconsumed gases and in the form of cinders which are rich in carbon content.

The fact to take into consideration is that a locomotive passes through all stages of load conditions, being represented by no load during the times spent at stations and on sidings; a heavy load when overcoming the inertia of the train at starting or when accelerating; extreme load when operating on level tracks or grades at speeds; and no load when drifting down-grade.

Estimates have been made as to the amount of fuel lost by the boiler through these operating conditions, which run from 40 to 60 per cent of the coal as fired.

Because the locomotive is a self-contained unit, it is necessary for the boiler and the firebox to receive careful attention at each terminal. The necessity, on account of fire risk, for carrying the ash in an ash-pan between terminals limits the capacity for operation. This limitation, however, is not as great as that brought about by the necessity for cleaning the melted ash or clinkers from the top of the grates in order to prevent a blocking of the air necessary for the combustion of fuel, or the cleaning of the



Consolidation Type Locomotive in Service on Delaware & Hudson

Cylinders	27 inches x 32 inches
Driver wheels	63 inches
Weight on drivers	267,500 pounds
Boiler pressure	195 pounds
Tractive power	61,400 pounds

flue sheets, which cleaning is generally impracticable when on the road.

A locomotive, when starting out from a terminal, if considered as a 100 per cent unit, will drop off in efficiency so that at the end of a 125-mile run the efficiency is reduced to probably not more than 60 per cent. This condition is very much accentuated when the coal supply is of a poor grade, and it is becoming worse from year to year as the mining conditions and fuel supply for railroads grow less efficient.

The best seams and grades of coal are being depleted and the proper grade of coal for locomotive operation is becoming more difficult to obtain. Some coal, now being used on a number of roads, is of such quality as would not have been considered at all suitable for locomotives some few years ago.

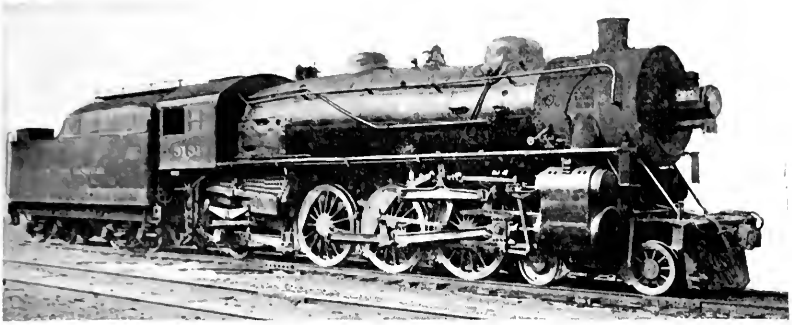
The extreme draft conditions under which it is necessary to operate a locomotive are such that, either hand or stoker fired, the fine coal is drawn through the firebox, flues, and out of the stack before it has been in the high temperature zone a sufficient length of time to be consumed.

The percentage of slate and other foreign non-combustible matter in the coal is becoming greater as the thinner seams of coal are being mined, and as the labor condition grows more difficult to control. The percentage of fine coal is also becoming great, due to the modern methods of mining through undercutting by mechanical means and the use of high explosives for the removal of the coal.

Efforts have been made to increase the boiler capacity of large locomotives through the use of mechanical stokers. The results, from the standpoint of steaming ability, have been good, but the fuel consumed under stoker conditions has been materially increased. The use of mechanical stokers on engines of high power has become an economic necessity, brought about by difficulty in securing labor to handle the coal from the tender to the locomotive firebox, and in general it may be

Mikado Type Locomotive in Service on Atchison, Topeka & Santa Fe

Cylinders	25 inches x 32 inches
Driving wheels	57 inches
Weight on drivers	220,200 pounds
Boiler pressure	200 pounds



Pacific Type Locomotive in Service on New York Central

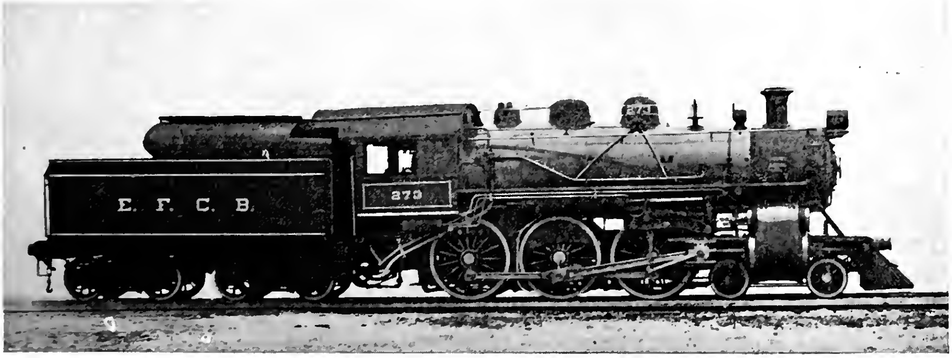
Cylinders	26 inches x 26 inches
Driver wheels	69 inches
Weight on drivers	174,500 pounds
Boiler pressure	180 pounds

said that the grade of men entering the railroad service has been considerably lowered on account of the unattractive conditions of firing, through which apprenticeship it is necessary to develop locomotive engineers.

Fuel oil, although largely used by the railroads in the Southwest, is not an ideal locomotive fuel for the reason that high rates of combustion are not possible without loss of efficiency, resulting in heavy fuel consumption when operating under overload conditions, dense smoke and waste of oil at the burner.

Although the supply of fuel oil is in no immediate danger of being depleted, the demand for hydrocarbon fuels for automobile and truck service and for marine and navy use is becoming greater each year, and it is quite possible that the use of fuel oil for steam generating purposes will be legislated against as a movement in the direction of conservation of this valuable product.

The use of pulverized fuel, burned in suspension, offers an opportunity to overcome a great many of the difficulties mentioned above in the operation of steam locomotives. In the first place, this method eliminates the necessity for manual labor for firing; and, owing to the fact that the combustion of the particles of fuel, when entering the combustion zone, takes place so rapidly when properly supplied with necessary air for combustion that high rates of firing and of steam generation can be maintained, irrespective of the ash or volatile content. The combustion takes place in suspension, and the air is admitted into the firebox through free openings from the atmosphere. The necessity for high firebox vacuum is eliminated, permitting the engine to be relieved of about 75 per cent of the cylinder back pressure, which, in turn, reduces the steam necessary per horse power of cylinder output,

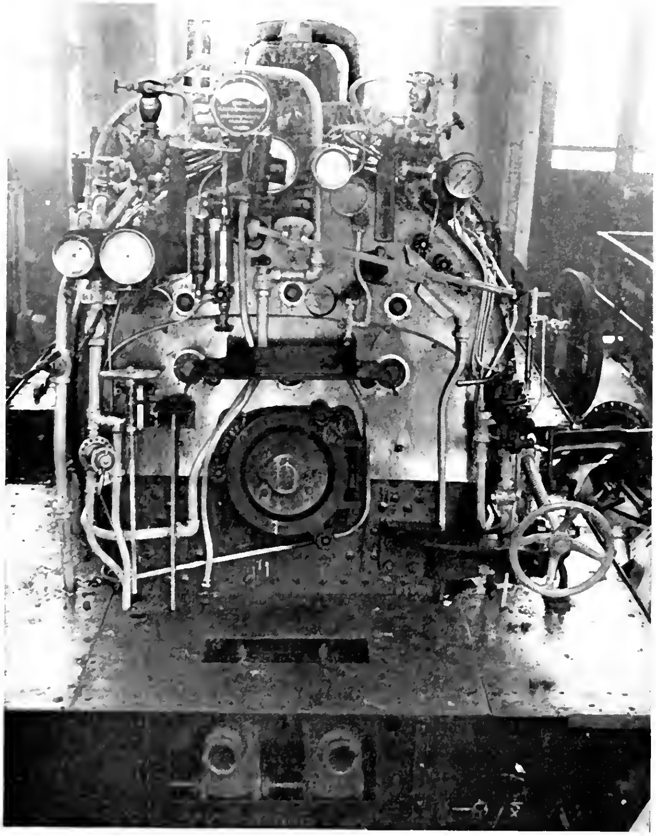


Ten-wheel Locomotive in Service on Central Railway of Brazil

Cylinders	21½ inches x 20 inches
Driver wheels	68 inches
Weight on drivers	124,200 pounds
Boiler pressure	175 pounds

thus enabling the engine to be operated at shorter cutoff and under more favorable conditions.

The waste of combustible through the stack in the form of unconsumed gases or cinders and through the grates to the ashpan is entirely eliminated.



Arrangement of Back Boiler-head showing Addition of Equipment Necessary for Operation of Pulverized Fuel Burning Apparatus

At the present time there are in successful road service a number of locomotives scattered throughout the United States and Brazil operating with pulverized fuel. The possibilities for the use of low-grade fuels, such as lignite, bituminous slack, anthracite dust or tailings have been demonstrated. Furthermore, the efficiency of the firebox, as compared with that by hand firing, has been increased from 20 to 25 per cent, and the ability to instantly stop combustion and the use of fuel when the engine is standing or drifting is resulting in a fuel saving of from 25 to 40 per cent.

Advantages of a Combustible Such as Pulverized Fuel

The advantages can be summarized as follows:

1st. Possibility of applying pulverized fuel to existing motive power without changes in the boiler or other heavy expense.

2nd. Possibility of increasing train load over ruling grades and on long, heavy pulls, due to the improved steaming capacity and reduced cylinder back pressure of the locomotive.

3rd. Reduced handling and delay to locomotives on engine house and ash-pit track through the elimination of cleaning, dumping, and rebuilding of fires.

4th. Reduced fuel consumption at terminals and on road through more effective combustion and the positive control over the fuel fired.

5th. Ability to utilize inferior grades of fuels that are not now suitable for burning on grates in locomotives or for the commercial trade.

6th. Conservation of the better grades of fuel for revenue tonnage.

7th. Greater average monthly mileage possible for the locomotive.

8th. Less liability for engine and train-crew overtime, particularly on relatively long runs and under the present eight-hour basis.

9th. Elimination of the necessity for more than one fireman or for labor or equipment to shovel or push the fuel ahead on the tenders.

10th. Reduced coaling station labor.

11th. Reduced ashes and cinders to be disposed of at terminals and on the line of road.

12th. Elimination of smoke, sparks, and fire hazards, resulting in reduced loss and damage claims.

13th. Less classification and switching of company used fuel at coaling stations.

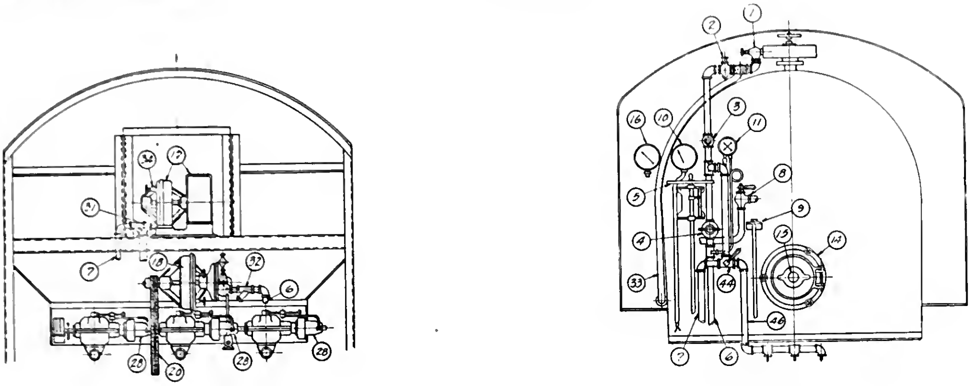
14th. No loss of fuel from tenders, fuel being carried in an enclosed tank.

15th. No special fuel or equipment for firing up locomotives.

16th. Elimination of liability for burning of wooden trestles and cross ties or snow sheds.

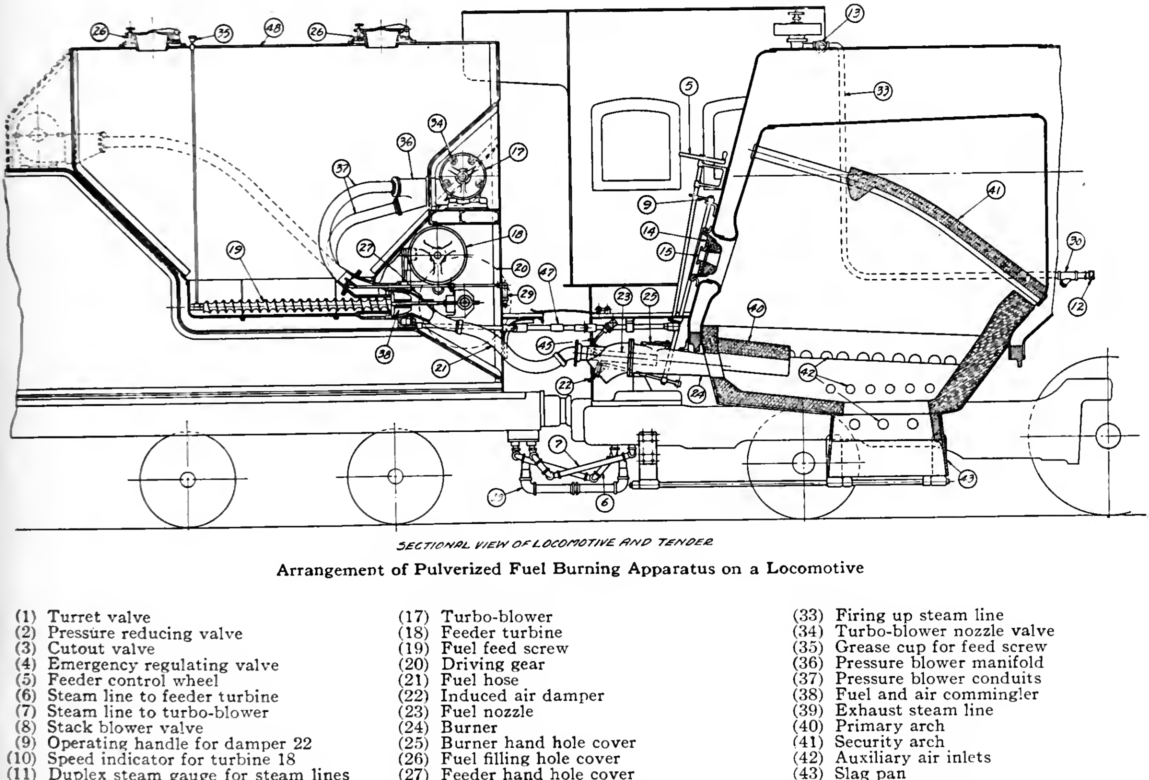
17th. Better drainage and reduced work on road bed, due to elimination of ashes and cinders from the right-of-way.

18th. Elimination of grates, ash-pans, smokebox draft appliances, inspection, adjustment, repairs, and renewals.



FRONT VIEW OF TENDER

VIEW SHOWING ARRG'T OF CAB EQUIPMENT



SECTIONAL VIEW OF LOCOMOTIVE AND TENDER

Arrangement of Pulverized Fuel Burning Apparatus on a Locomotive

(1) Turret valve
(2) Pressure reducing valve
(3) Cutout valve
(4) Emergency regulating valve
(5) Feeder control wheel
(6) Steam line to feeder turbine
(7) Steam line to turbo-blower
(8) Stack blower valve
(9) Operating handle for damper 22
(10) Speed indicator for turbine 18
(11) Duplex steam gauge for steam lines 6 and 7
(12) Firing up steam coupling
(13) Firing up steam valve
(14) Fire door
(15) Peep-hole
(16) Boiler steam gauge
(17) Turbo-blower
(18) Feeder turbine
(19) Fuel feed screw
(20) Driving gear
(21) Fuel hose
(22) Induced air damper
(23) Fuel nozzle
(24) Burner
(25) Burner hand hole cover
(26) Fuel filling hole cover
(27) Feeder hand hole cover
(28) Feeder clutches
(29) Feeder clutch operating handle
(30) Steam strainer for firing up line 33
(31) Steam strainer for turbo-blower line 7
(32) Steam strainer for feeder turbine line 6
(33) Firing up steam line
(34) Turbo-blower nozzle valve
(35) Grease cup for feed screw
(36) Pressure blower manifold
(37) Pressure blower conduits
(38) Fuel and air commingler
(39) Exhaust steam line
(40) Primary arch
(41) Security arch
(42) Auxiliary air inlets
(43) Slag pan
(44) Three-way valve
(45) Steam nozzle
(46) Steam nozzle pipe
(47) Flexible connection
(48) Pulverized fuel container

19th. Reduced firebox and boiler repairs and renewal through the maintenance of more uniform firebox temperatures.

20th. Elimination of firing tools and like loose equipment on the locomotive.

21st. Elimination of losses brought about by neglect in the proper method of firing coal on grates.

The above advantages are slightly offset by the cost of drying and pulverizing the fuel. The expense of this, however, is again balanced by the possibility of reducing the first cost of the fuel on a B.t.u. basis; and as such expense is directly chargeable to the cost of the fuel it is only indirectly an operating charge.

The capital account requirements for the installation of pulverized fuel have, in this country, somewhat retarded the universal application of pulverized fuel to existing power. The cost of suitable fuel for hand, stoker, or oil firing, however, is reaching a point where the installation of pulverized fuel burning equipment is becoming an economic necessity.

Foreign countries not as well favored as the United States with suitable coal deposits for hand and stoker firing are rapidly coming to a realization of the necessity for the utilization of the low-grade fuels which are in nearly all places available. Such countries as are now depending upon the importation of high-grade coal for locomotive use are, at the present time, operating under severe handicap, brought about by the inability to get English coal and the necessity for substituting American coal, which is more firable and is of a structure such as will not stand the handling incident to transportation without a large loss due to the formation of an extremely fine dust.

ANALYSIS OF FUELS WHICH HAVE BEEN USED ON LOCOMOTIVES IN PULVERIZED FORM

Kind	Moisture	Volatile	Fixed Carbon	Ash	Sulphur	B.t.u.	FINENESS THROUGH	
							100 Mesh	200 Mesh
Illinois unwashed screenings...	3.70	35.25	48.74	10.61	1.70	12,400	99.66	97.25
B. R. & P. bituminous........	0.88	25.67	63.05	10.40	1.64	13,912	.....	.....
Brazilian bituminous..........	1.73	14.02	60.04	25.94	8.25	10,904	99.8	96.6
Texas lignite................	21.52	33.08	29.28	16.12	1.97	7,801	97.2	88.0
Eagle Pass bituminous........	0.65	33.45	40.10	26.43	0.84	8,845	98.8	91.8
Bankhead graphitic anthracite.	0.48	13.68	70.83	15.49	0.94	.....	98.2	90.5
Calgary, B. C., lignite.........	8.84	33.97	54.63	11.40	....	......	98.7	90.5
Bituminous (1)...............	0.50	29.50	60.00	10.00	1.50	13,750	.....	86.0
Anthracite slush (2)..........	1.00	6.00	71.00	22.00	2.50	11,250	.....	86.0
Kentucky unwashed screenings.	2.46	36.00	54.00	7.94	0.79	13,964	.....	83.0

NOTE.—Locomotive using a mixture of 40 per cent of (1) and 60 per cent of (2).

It is interesting, perhaps, to note that such coals as are not suitable for use in hand or stocker fired installations on locomotives are particularly adapted for burning in pulverized form. In the first place such coal is usually high in volatile constituents and is easily pulverized and gives better thermal efficiencies in the evaporation of water than the so-called high-grade coal.

Some of the coals which have been successfully burned in pulverized form in locomotives are given in the table above.

It will be noticed that this table covers the entire range: Brazilian bituminous coal, for which no other method of combustion has been found practicable; graphitic anthracite coal, such as is found in the Canadian Northwest and in the New England States, which has heretofore been considered of no value for fuel; and lignites from other sections, which cannot be burned in locomotives in any other form, due to the formation of clinker on the grates and the impossibility of keeping unconsumed coal from passing out of the stack and causing right-of-way fires.

In the burning of fuel in pulverized form in locomotives the principal difficulties which had to be overcome were:

1. To maintain a combustion intensity suitable for developing high overload capacity of the locomotive boiler.

2. Formation of honeycomb on the flue sheets, due to the iron and sulphur in the ash in a molten condition freezing on the flue sheets, stopping the flues and preventing the passage of the gases to the stack. These difficulties have been successfully overcome but each fuel has to be treated as an independent problem and sufficient progress has not as yet been made to determine the proper relationship in the various elements of the combustion process from an analysis of the fuel and ash. Sufficient progress, however, has been made to reduce the variables to a known quantity and simplify the adjustment of these known elements. After the firebox has been properly arranged for a specific fuel, considerable latitude in the analysis of the fuel as received from the mine is permissible without the necessity for re-adjustment, so that each coal deposit can be treated as a unit and the variations brought about by the different mining operations and working of the seams developed can be disregarded.

It is perhaps interesting to recall that the first efforts to burn fuel oil under locomotive boilers were extremely discouraging, and it was only after considerable development work in methods of combustion, extending over many years, that it was found possible to maintain the rate of combustion necessary to give good steaming results with the use of this fuel. Even now, due to the use of steam jets, and the necessity for sanding flue sheets to remove unconsumed carbon, etc., it is a most wasteful practice as far as utilization of heat value in the fuel is concerned.

In stationary practice the introduction of natural gas under boilers required special regenerative features and, until the firebox had been properly arranged, practically no evaporation results were obtained.

PART VI

POSSIBILITIES OF CONSERVATION OF FUEL BY RAILWAY ELECTRIFICATION

By W. D. BEARCE

RAILWAY AND TRACTION ENGINEERING DEPARTMENT, GENERAL ELECTRIC COMPANY

The most potent factors in the conservation of fuel during the last twenty years have been: (1) the development of water power, (2) the concentration of the production of power from fuel in central stations where the most economical methods may be utilized, and (3) the distribution of power electrically. There is still much to be done in the way of replacing inefficient isolated power plants of various kinds and sizes with electric power From the point of view of fuel conservation the most important field remaining for the more extended use of electricity is on the railways. One-fourth of all the coal mined in the country, as well as a considerable quantity of oil, is consumed by steam locomotives. The locomotive is an isolated power plant of low efficiency, and the only excuse for its continued existence is the cost of electrification. Data are now available which show that in one case, cited by the author, an electrified railway has earned 20 per cent annually on the investment.—EDITOR.

According to the classification of the U. S. Geological Survey, the steam railroads are the next to the largest consumers of coal products in the United States, their requirements being exceeded only by the group of industries classed as "Industrial Steam Trade."* Out of a total production of more than half a billion tons of bituminous coal, the steam roads are charged with the consumption of 135,000,000 tons, or 27 per cent. The railroads also consume 6,735,000 tons of anthracite, or 7.7 per cent of the total production.

The report of the Interstate Commerce Commission gives figures for the fiscal year ending June 30, 1916, showing a total of 63,862 steam locomotives in service. These engines are operating over 259,211 miles of route, or a total of 394,944 miles on a single track basis The transportation systems represented by these figures operated every type of railway from light infrequent service roads to heavy transcontinental freight and passenger haulage. Locomotives vary in size from small switchers up to the heavy freight engines weighing 300 tons or more.

Figures on the consumption of fuel oil for steam locomotives indicate that oil burners consumed a total of more than 42,000,000 barrels for the year 1916. These locomotives were operated over nearly 32,000 miles of track in twenty-one states.

At the present prices of the crude product, it is probably somewhat more expensive to operate with oil than with coal, although in some cases the reduced damage from forest fire offsets the extra cost. Many of the western roads, however, on account of the proximity of government reserves are required to use oil over long distances. Large amounts of fuel oil are required by the United States navy, as well as by large numbers of merchant ships, and the supply of the principal product of the oil refineries in the shape of gasolene hardly equals the demand. It is, therefore, quite as important to save fuel oil as to conserve the supply of coal.

The number of electrically operated railways is small in comparison to those operating by steam, totalling only 47,000 miles, or 10½ per cent of the total trackage. The rolling stock includes 80,000 passenger motor cars, more than 1000 express motor cars, and about 540 electric locomotives. The coal consumption per mile is small, however, when compared with that required by steam locomotives. In fact, it may be conceded that the traction systems of our large cities, such as New York, Boston, Chicago, and others, are operated on a most efficient basis as far as coal consumption is concerned. Many cities, such as Buffalo, Baltimore, St. Louis, and San Francisco, are supplied to a large extent from hydroelectric plants, and thus require little if any coal for their operation. This is also the case with a large

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* This classification covers a wide range of consumers including the following: large mills, factories, central power stations, pumping plants, and brick and cement burners

Fig. 1. 100-ton, 600-volt Locomotive on the Detroit River Tunnel Electrification

Fig. 2. 130-ton, 600-volt Direct-current Gearless Locomotive Coupled to the Twentieth Century Limited on the Electrified Division of the New York Central Railroad

Fig. 3. 80-ton, 2400-volt Locomotive on the Butte, Anaconda and Pacific Railway

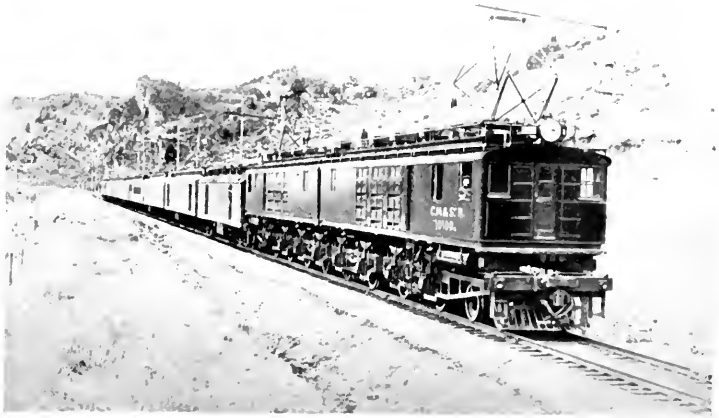

Fig. 4. 300-ton 3000-volt Direct-current Locomotive on the Chicago, Milwaukee and St. Paul Railway

number of small interurban roads throughout the country. Taking into account the large amounts of hydroelectric power utilized and the efficient use of coal in the power plants of the large electric railway systems, it is obvious that if our steam railroads were operated on the same efficient basis tremendous savings of coal would result.

It is evident, therefore, that the most significant economies should be secured by reducing the 27 per cent of the total output now required by steam engines used on our great railway systems. Some improvement in efficiency is being secured by modernizing large numbers of engines of the older types and by discarding obsolete engines for up-to-date equipment. Competent engineers, however, are satisfied that the greatest reduction in coal consumption could be obtained by the electrification of a great many of our railroads which are large consumers of coal. The results obtained on various roads in the United States during the past twenty years have amply demonstrated the feasibility and desirability of electrification.

It is a remarkable fact that ample water powers exist within easy transmission distance of practically all the great railways of the northwestern United States and Canada. Many of these powers are undeveloped owing to the absence of a market for power and in some cases because of their location on government lands. By the development of these water powers, electricity could be delivered to the right-of-way of all the trans-mountain railways of the northwest for a distance of 1000 miles from the Pacific Coast. The use of fuel for railroad trains would thus be entirely eliminated, saving thousands of tons of coal and many barrels of fuel oil.

In European countries, where the high price of coal and its scarcity have furnished added incentive, railway managements are vigorously pushing plans for electrification. In Italy and Switzerland the coal situation is acute, and plans are well matured for the utilization of the vast water powers in order to become independent of foreign coal supply in emergencies such as the present war. These plans contemplate not only the electrical operation of the railroads but the electrification of industrial plants as well.

In addition to the actual saving in coal resulting from electrification of the existing steam railroads, the experience of main line railroads now operating electrically demonstrates that an increased capacity of track is made available by the increased train loads and the greatly increased operating speeds. Furthermore, under steam operation, the fuel coal has to be transported over the road as non-revenue tonnage from the mines or from the point of delivery on the right-of-way to the various coaling stations, thus occupying the tracks and engines which might otherwise be used in the production of revenue. A non-revenue movement which is much more difficult to reduce to actual figures, however, is the hauling of this same coal in the engine tenders. This movement of company coal in cars and on tenders, together with water for steaming purposes, is estimated by Mr. A. H. Armstrong* in the case of mountain divisions of a trunk line railway (sections now

Figs. 5 and 6. Exhibition Test of Chicago, Milwaukee and St. Paul Locomotives on 1.66 per cent Grade near Janney Substation. Three steam locomotives operating at 9–10 m.p.h. with 2000 tons trailing; two electric locomotives operating at 15–16 m.p.h. with 3000 tons trailing

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* See General Electric Review, November, 1916, p. 1009.

in the most immediate need of electrification) as 10 per cent of the total gross ton-miles carried over the rails. Under these conditions the electric locomotive, due to freedom from coal and water requirements, is inherently capable of hauling 10 per cent more average train tonnage with no increase of weight upon the driving axles.

Data are now available for several railway systems showing that the cost of conversion to electrical operation in the case of roads with a reasonable amount of traffic is amply justified from the financial standpoint. The Butte, Anaconda & Pacific Railway, which was electrified in 1913 at an initial cost of $1,201,000, showed a total net saving per year over steam operation of $242,300, exceeding 20 per cent upon the entire cost of electrification. In addition to this definite money saving the road secured a greatly increased capacity and a great improvement in the service. These facts being well established, it is quite within reason that the Federal Government should take steps to conserve the existing supply of coal and fuel oil by assisting to finance such electrifications as competent engineering authorities should be able to show will make the greatest saving in fuel.

In order to establish a definite ratio of comparison between the efficiency of the steam locomotive and the electric systems, data from various roads have been compiled showing that as an average figure seven pounds of coal on the steam locomotive tender is equivalent to a kilowatt-hour of electricity on the alternating-current switchboard at the power-house. A kilowatt-hour of electrical energy can be produced in a modern power plant with two and one-half pounds of coal. This means that it requires seven pounds of good coal on a steam locomotive to haul the same amount of net tonnage as could be handled with an electric locomotive by burning two and one-half pounds of coal in an up-to-date power house. It is necessary to use net tonnage figures to

Fig. 7. Passenger Train on a Mountain Grade Hauled by Five Steam Locomotives

POWER CONSUMPTION OF ELECTRIFIED RAILROADS IN UNITED STATES AND EQUIVALENT COAL SAVING

Railroad	Trolley Voltage	Miles Electric Track	Steam or Water Power	Kilowatt-hour Consumption per Year at Power Station	Equivalent Coal in Tons at 7 Lbs.	Tons of Coal Saved per Year
Long Island R.R.	600 D-C.	208	Steam	78,652,000	275,280	183,500
New York Central Elec. Div.	600 D-C.	253	Steam	92,000,000	322,000	215,000
New York, New Haven & Hartford	11,000 A-C.	531	Steam	90,500,000	317,000	212,000
Penn. R.R.—N.Y. Terminal	600 D-C.	97	Steam	49,347,000	172,715	115,000
West Jersey & Sea Shore R.R.	600 D-C.	150	Steam	30,018,400	105,000	70,000
Butte, Anaconda & Pacific	2,400 D-C.	90	Water	23,408,270	82,100	82,100
Erie R.R.—Rochester Div.	11,000 A-C.	38	Water	1,894,860	6,315	6,315
So. Pacific—Oakland, Alameda & Berkeley Div.	1,200 D-C.	138	Water	27,844,800	97,457	97,457
Baltimore & Ohio	600 D-C.	8	Steam	7,014,000	24,549	16,400
Grand Trunk—St. Clair Tunnel	3,300 A-C.	12	Steam	3,396,453	11,880	7,900
Detroit River Tunnel	600 D-C.	20	Steam	7,431,000	26,000	17,300
Gr. No. Ry.—Cascade Tunnel	6,600 A-C. 3-phase	7	Water	4,980,000	14,280	14,280
Boston & Maine—Hoosac Tunnel	11,000 A-C.	21	Steam	7,727,000	27,045	18,000
Norfolk & Western	11,000 A-C.	90	Steam	50,410,552	177,000	118,000
Penn. R.R.—Paoli Div	11,000 A-C.	95	Steam	23,400,000	82,040	54,700
Chicago, Milwaukee & St. Paul Ry.	3,000 D-C.	600	Water	134,400,000	470,400*	470,400*
		2358		608,124,335	2,129,021	1,643,652

* Oil burning locomotives were used on a large part of the sections now electrified, so that this figure is tabulated for comparative purposes only. Three and one-half barrels of oil are ordinarily considered as equivalent to a ton of coal.

secure a fair basis of comparison, since there is a much greater percentage of non-revenue freight with steam than with electric haulage owing to the handling of company coal for the steam locomotive.

These assumptions are based on a good quality of coal both on the locomotive and in the power station. Experience has demonstrated that there is no economy in attempting to use low-grade fuel on the locomotive, but with stationary boilers and equipment it is possible to materially reduce the cost of power by burning low-grade coal. For purposes of comparison, the ratio of 7 to 2½ is a conservative figure.

On systems where hydroelectric power can be used practically the entire coal consumption of a road may be conserved by electrification. Where steam power stations are required, nearly two-thirds of the present coal consumption may be saved.

In the table on page 862 there are 2358 miles of track which has been converted from steam to electric haulage. Figures for the kilowatt hours consumed have been tabulated and the equivalent coal calculated on the basis of 7 lb. of coal per kilowatt-hour. These figures represent the amount of coal that would be required were these electrified roads operating with steam engines. Assuming that all of this coal would be saved where water power is used, and two-thirds where electricity is produced in steam stations, the amount of coal saved is calculated in the adjoining column.

While the total track miles included in the table is less than one per cent of the steam road mileage of the United States, it should be noted that the calculated savings exceed a million and a half tons of coal or equivalent fuel oil as a result of electrical operation. The most conspicuous savings are shown by the Chicago, Milwaukee & St. Paul electrification which has secured a saving of fuel equivalent to nearly half a million tons of coal per year. The electrification of the Cascade division of this road consisting of 221 miles of track is being pushed vigorously and when in operation will also add 364,500 barrels of oil to the saving now being made.

The Operation of Railway Substations without Attendants

By W. D. Bearce

Railway and Traction Engineering Department, General Electric Company

The author gives a brief historical review of the progress made during the past three years in the equipment of automatic substations for railway service. While about thirty automatic railway substation equipments are under construction at Schenectady, the following description is mainly confined to railway systems which are now actually operating attendantless substations.—Editor.

The automatic railway substation, as it is being equipped today in rapidly increasing numbers, was first put into commercial operation about three years ago in the stations of the Elgin & Belvidere Electric Company near Chicago. After one of these stations had been tried out, the other two stations operated by this company were also equipped for automatic operation.

The operation of substations without attendants was first tried out by the Detroit Edison Company and the equipment installed in 1912 was a forerunner of the present automatic station. This installation consisted of a 500-kw. synchronous converter connected to the lighting system in the city of Detroit for the purpose of maintaining the proper voltage in the outlying districts. A new station was installed instead of additional feeder copper and was controlled by the operator of the main alternating-current supply station. Control was effected entirely from this main station over the 4400-volt, three-phase, alternating-current line. A similar installation was made in 1914 by the New South Wales Government Tramways in one of the outlying substations of Sydney, Australia. The scheme of control was quite different, however, the starting, shutting down, etc., being effected by the use of pilot wires. This station, however, was connected to a railway load and was subject to the fluctuating peaks common to railway service.

As a matter of general information, it should be stated that the stations installed at Detroit and in Sydney were of the remote control type while that put in operation on the Elgin & Belvidere system was strictly automatic. The automatic equipment is essentially different from the remote control system in that the machines are started up connected to the line and shut down without the assistance of an operator either in the station or in any remote station. These

Fig. 1. Spring Lake Passenger Station, Automatic Substation and Freight House, Grand Rapids, Grand Haven and Muskegon Railway

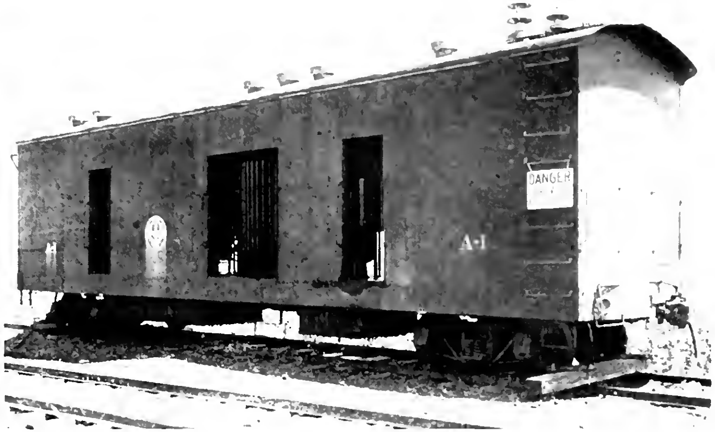

Fig. 2. Portable Substation in Operation on the Interurban Railway, Des Moines, Iowa

Fig. 3. Interior of the Automatic Railway Substation shown in Fig. 6

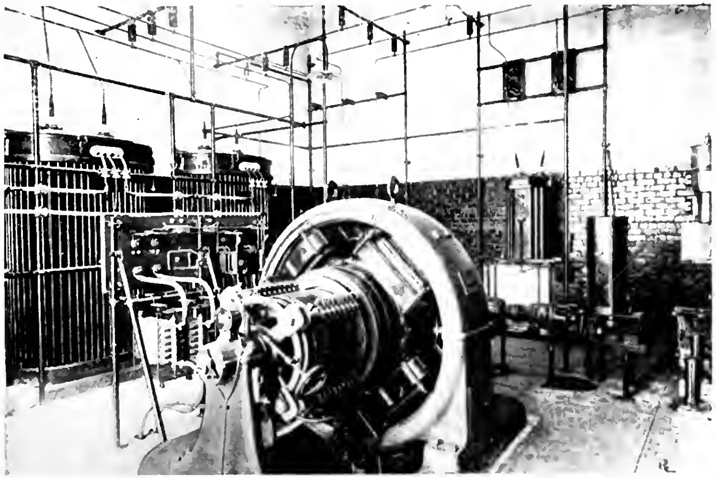

Fig. 4. Interior of the Automatic Railway Substation shown in Fig. 5

functions are performed in accordance with the requirements of the load on the system whereas with the manually operated or remote controlled station the starting, loading, and shutting down of the converting apparatus is either left to the judgment of the substation attendant or performed in accordance with a set schedule. With automatic control, sensitive relays are relied upon to observe the conditions of load on the trolley feeders and the control equipment acts automatically in response to the movement of these relays.

In order to eliminate the possibility of the circuit being opened by overload circuit-breakers, a current-limiting resistance is installed as a part of the automatic equipment. This resistance is adjusted to be connected into circuit when the current drawn from the substation machinery reaches certain predetermined overload values and the output of the station is thus limited to the desired amount. While the remote control substation makes some savings in the cost of attendants' services, the automatic station goes still further and makes appreciable savings in the cost of power. The current-limiting feature furnishes an additional safety feature which prevents injury to the substation machinery and thus assists in keeping the converter machinery always ready for service.

Fig. 5. Automatic Railway Substation (Brennan) Interurban Railway Company, Des Moines, Iowa

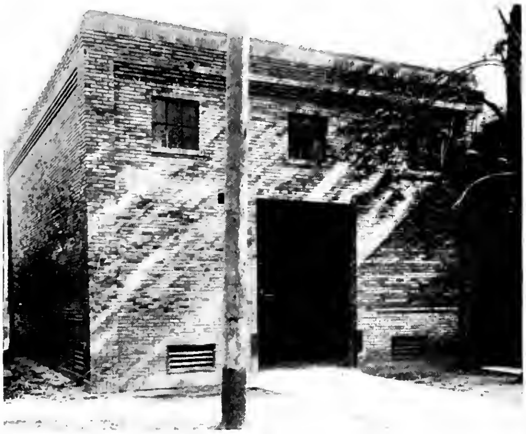

Fig. 6. Automatic Railway Substations (12th and High Streets), Des Moines City Railway Company

Elgin & Belvidere Electric Company

The Elgin & Belvidere Electric Company operates a single-track road 36 miles in length handling a 600-volt interurban service. Power is purchased at 26,000 volts, three-phase, 25 cycles and delivered to three substations located at Gilberts, Union, and Garden Prairie. Each of these stations contains a 300-kw., three-phase synchronous converter with the necessary transforming and switchboard equipment. The first automatic equipment was installed in the Union Station; and after a short experience, the two remaining substations were similarly equipped. Automatic operation on the last two stations was started in August, 1915.

The essential features of the installation are a motor-operated drum controller arranged to make the necessary connections for starting and connecting the synchronous converter to the line; the direct-current exciter forming a part of the same set so connected that it gives the proper polarity to the synchronous converter fields before connecting the converter to the line; the necessary controlling and protective relays; and the load limiting resistance. The converter is started up when the potential on the trolley falls to 450 volts or below. This low voltage causes a contact-making voltmeter to start up the drum controller which, in turn, energizes the actuating coils of the starting and running alternating-current switches, the field switch, and the direct-current line switch. As soon as the converter reaches full speed and full voltage, the drum controller comes to rest and the station thus operates until the current which it is supplying to the trolley circuit falls below some predetermined value, at which time a current relay operates and shuts down the station.

The series current-limiting resistors are placed between the positive terminal of the converter and the station bus, and they are automatically cut into circuit at predetermined overloads.

The operation of these stations on the Elgin & Belvidere Electric Company's lines has been viewed by a large number of railway men and, as a result, automatic equipments have been installed and are in operation on half a dozen other systems in the United States. There are also under construction in the Schenectady plant of the General Electric Company about thirty equipments ranging in capacity from 200 to 1500 kw.

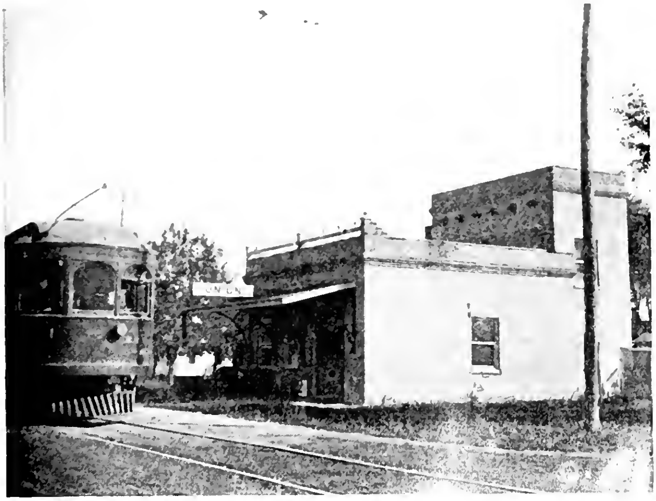

Fig. 7. Automatic Railway Substation at Union, Elgin and Belvidere Electric Company

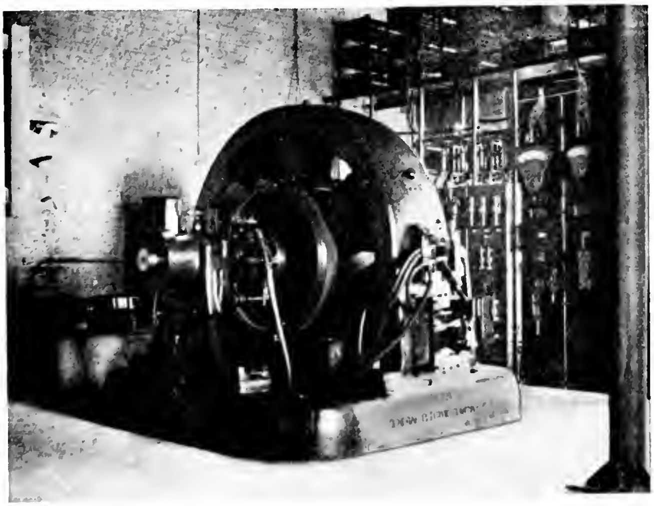

Fig. 8. Interior of Automatic Railway Substation, Elgin and Belvidere Electric Company

Des Moines Railway Properties

Two of the most ardent advocates of the automatic substation are the Des Moines City Railway Company which operates 85 miles of city trackage and the Interurban Railway Company which operates 74 miles of interurban line. Both of these lines have installed a number of automatic equipments, and plans have been completed for seven additional automatic stations on the city lines and three on the interurban lines. Several more stations are under consideration. In general, the scheme of operation of these substations is the same as that employed by the Elgin & Belvidere Electric Company. One of the novel features is a portable automatic station containing a 500-kw. synchronous converter which is at present in use on a spur of track reaching out to a gravel pit. This portable substation is completely equipped for operation either on the 23,000-volt interurban transmission lines or the 4400-volt city supply. Automatic substations on the city lines are located at Twelfth and High streets, 500-kw. with a second 500-kw. unit projected; East Second and Walnut streets, 500 kw.; East Fourteenth and Lyon streets, 500 kw.; East Fourteenth and Florence streets, 500 kw.; 33rd and Easton streets, 500 kw.; Waveland, 500 kw.; and 20th and Clark streets, 500 kw.

The suburban stations are located at Brennan and Hyperion, each of 300-kw. capacity. The portable automatic substation of 500-kw. capacity is in operation between Herrold and Moran.

One of the remarkable features of the Des Moines installation was the saving effected in feeder copper by the use of automatic equipment. A detailed estimate furnished by the Railway Company shows a saving of more than $140,000 in favor of the automatic plan. Table I shows the comparative costs of the automatic and the manually operated equipment.

TABLE I

DETAILED ESTIMATE OF COST OF INSTALLING ADEQUATE DISTRIBUTION SYSTEM

Feeder Plan

Present feeder copper at 25c. per lb.....	$112,800
Additional copper necessary for proper voltage regulation at 25c. per lb......	172,500
Two 1000-kw. synchronous converters installed in power house, building extension, switchboard, equipment, etc..	60,000
	$345,300

Automatic Substation Plan

Present feeder copper.................	$112,800
Seven synchronous converters and control equipment.....................	98,000
Installation of seven equipments.......	8,500
Seven substation buildings.............	21,000
Seventeen miles 4400-volt transmission line	34,000
Miscellaneous material.................	10,000
Auto-transformers for stepping voltage from 2200 to 4400, labor, cable, switching equipment, etc..................	9,500
	$293,800
Credit feeder copper taken down at 20c...	90,200
	$203,600
Manually-operated substations plan, total	$345,300
Automatically-operated substation plan, total............................	203,600
Difference.......................	$141,700

Although no operators have been displaced owing to the fact that all automatic substations are new, the Des Moines lines are making a large saving on operators' wages since the several automatic stations dispense with attendance which would have been required for manually operated stations. Considerable savings are also being made from the elimination of light-load losses as well as the reduced maintenance on the equipment and the lighter duty secured by the load-limiting resistance.

Milwaukee Electric Railway & Light Company

The first 1200-volt automatic substation was put in operation during last summer on the Interurban division of the Milwaukee Electric Railway & Light Company's lines at East Troy. This substation is at the end of the interurban division 28 miles distant from West Allis, the nearest substation, and contains four 300-kw., 25-cycle, 600-volt synchronous converters arranged to be operated two in series for 1200 volts. One set of these machines has been equipped with automatic control and is now handling the load without assistance. The other set is being retained for standby use. Some modification of the equipment used in former stations was necessary, in order to take care of the 1200-volt service and to provide for the operation of the two machines in series. The equipment is arranged to cut in the two machines when the trolley voltage drops to 950 and the current relay operates to shut down the station when the current falls to 25 amperes. The dashpot effect is used to prevent the station from dropping out during the ordinary passenger stop which requires about five minutes after the power drops to the 25-ampere point. Since there is a two-hour schedule on this division, the station is shut down quite a large part of the time. Estimates on the approximate saving effected by the elimination of two operators and the reduction in the no-load and light-load losses give an annual saving of more than $1700 per year for the single station.

Grand Rapids, Grand Haven & Muskegon Railway

Another station recently put in operation is the Spring Lake Station of the Grand Rapids, Grand Haven & Muskegon Railway Company containing a 500-kw., six-phase, 600-volt synchronous converter. This is a new station and was put in operation with automatic equipment in May, 1917. The line is equipped for the most part with an over-running third-rail, and handles considerable freight and express service in addition to the regular passenger and summer resort traffic. The automatic equipment is similar in general to the other 600-volt stations now in operation; and it is expected that considerable savings will be effected from the elimination of operators' wages and light-load losses on the machine.

Other automatic equipments are in operation in different parts of the country and among the several stations now under construction is one automatically controlling two units in the same station, the second unit being put in service to take care of load peaks during rush hours at morning and night while the first unit handles normal loads.

The Large Turbo-Generator

PART II

By R. H. Rice

Turbine Engineering Department, General Electric Company

In the first installment of this article a comparison is made, on the basis of first costs and operating costs, between three types of power plants for steel mill and blast furnace operation; viz., a steam turbine plant, a gas-engine plant with steam reserve, and an all-gas-engine plant. A battery of four blast furnaces is assumed, each furnace having a capacity of 550 long tons of pig iron per day, and the power plant is designed to supply all blast furnace demands for air, water, steam and electricity, and in addition to furnish 20,000 kw. of electricity for steel mill operation. The result of the comparison is very favorable to the steam turbine plant and shows that, contrary to the usual case, the plant with the lower first cost has the lower running charges. In other words, by spending only 50 per cent of the cost of an all-gas-engine plant an operating economy of 30 per cent is effected. In this installment brief specifications for the several plants are given and portions of the discussion of the paper by David S. Jacobus of the Babcox and Wilcox Company and Alex. Dow of the Detroit Edison Company are included.—Editor.

APPENDIX A

Specifications for Blast Furnace Plants

The figures in the paper apply to an installation of blast furnaces in a steel mill, of which the principal constituent elements are given below. The data upon which all the values depend were set forth in a paper read before the Engineers' Society of Western Pennsylvania, except that economizers have been added and the details of the feed-water heating system re-arranged for the steam plant to bring the efficiency up to that of the latest practice.

Blast Furnaces

Four blast furnaces have been included, in which it is expected that carbon will be consumed with a total amount of 12,835 short tons per furnace, per average month of 730 hours. This figure corresponds to an output of 550 long tons of pig per day with a coke rate of 1800 pounds per long ton, considering 85.2 per cent of the weight of coke as net carbon passing into the gas.

By means of the following formula the quantity of air and gas produced for each pound of carbon leaving the furnace in the gas is determined. These computations are derived from a gas analysis and the values obtained are in cubic feet at 14.7 lb. per sq. in. and a temperature of 60 deg. F., and this quantity is substantially equal to cubic feet at 30 in. mercury and 62 deg. F. temperature.

N_2 = percentage of N in the gas.
C = the sum of the percentages of gases containing carbon.

Then, $39.6\ N_2/C$ = cubic feet of air per lb of carbon.
$3140/C$ = cubic feet of gas per lb. of carbon.

The air as computed is actual air after allowances have been made for slip, etc., and is the figure indicated on the governing beam of a turbo-blower with a properly calibrated air governing apparatus.

The carbon is the carbon in the gas and consists of the net carbon in the coke and in the limestone, etc., less the carbon in the pig, flue dust, etc.

The gas analysis used for this case is:

	Per Cent
CO	26.2
CO_2	12.9
CH_4	0.1
C = Sum of gases containing carbon	39.2
H_2 =	3.5
N_2 = Nitrogen by difference	57.3
	100.0

The lower or net heating value of this gas is computed to be 95.5 B.t.u. per cu. ft.

Substituting in the formulæ the value of N_2 and C for the gas analysis, we have for these furnaces:

Cu. ft. of air per lb. of carbon = 57.9
Cu. ft. of gas per lb. of carbon = 80.1

The total heat in the gas will then be:

$$12{,}835 \times 2000 \times 80.1 \times 95.5 \times 4/730 = 1076$$

million B.t.u. per hour.

All the gas produced passes through primary washers, and 30 per cent of the gas is assumed to be used in the stoves.

General Characteristics of the Plant

The plant is designed to supply all blast furnace demands for air, water, steam, and electricity, and also during week-day hours to supply to steel mills, per furnace, 5000 kw. of electricity, or a total for the plant of 20,000 kw. of electricity. If, and when, the gas is insufficient to generate sufficient power for the full output of the steel mills, coal must be used to make up the deficiency. The cost of this coal is included in the figures of Table I, last item under "charges," at $2.00 per long ton delivered at fire-room door, and containing 13,500 B.t.u. per pound, plus 50 cents per ton for firing and ash-handling.

The gas-engine plant has apparatus provided for burning this coal in such emergencies.

The entire plant in either case is assumed to be located on a river or a great lake, and includes apparatus for unloading ore, storing it, and delivering it to the furnaces; and water is supposed to be of such quality that it is proper for use without purification. There is also included in the figures a water intake system with conduits and standpipes.

APPENDIX B

Four-furnace Combined Gas-engine Plant with Steam Reserve

This plant includes a gas-electric and a gas blowing station, and also an electric pumping station. There are steam spares provided in all cases for emergency use. These include a boiler house supplying regularly a small amount of steam for various purposes about the plant, but with sufficient reserve capacity so that by coal firing, steam for the emergency spares may be supplied when necessary. Gas holders are provided to store a comparatively small amount of gas, and furnace gas can be turned on or off and used under steam boilers as occasion demands, coal being used to make up any deficiency. The average amount of coal used for make-up is small.

The system includes a reserve of boilers and steam spares which have been found necessary in practice, so that the blast furnace, steel mills, and pumps will seldom have to be shut down.

Boiler Plant for Gas Engine Station

The following table shows the steam used in million pounds per month in this boiler plant:

Operation of electric station steam turbines	23.57
Power station, miscellaneous	2.13
Gas washer station, miscellaneous	0.47
Blast furnace, miscellaneous	9.47
Total steam	35.64

The following quantities are used:

Heat added in boilers—1135 B.t.u. per pound of steam.

Heat consumption of boilers at 65 per cent efficiency — $1135 \times 35{,}640{,}000/730 \times 0.65 = 85$ millions B.t.u. per hour.

Coal used in addition to gas—8800 long tons per year at $2.50 = $22,000 (same as in Plant C).

Normal coal to make margin same as in Plant C as found later, 43,000,000 B.t.u. per hour. Normal coal cost

$$\frac{43{,}000{,}000 \times 24 \times 6 \times 52 \times 2.50}{13{,}500 \times 2240} = \$26{,}600$$

per year. Total coal cost, $48,600.

TABLE 1

COMPARATIVE COSTS OF FOUR-FURNACE PLANTS

First Costs	All-Gas	Gas Engines with Steam Reserve	Steam Turbine
Secondary washers and pipes	$ 120,660	$ 120,660	
Electric station	2,094,450	2,164,450	$ 709,640
Blowing station	1,001,350	1,085,350	536,304
Pumping plant	246,000	246,000	121,496
Boiler plant	30,000	104,500	656,240
Gas producers	100,000		
Gas producer auxiliaries	40,000		
Total first cost	$3,632,460	$3,720,960	$2,023,680
Running Charges, per Year			
Secondary washers	$ 11,300	$ 11,300	
Electric station	72,000	72,000	
Blowing station	34,000	34,000	$ 21,920
Pumping plant	5,000	5,000	2,400
Boiler plant	5,000	6,000	54,190
Gas producers	10,000		
Running charges, total	$ 137,300	$ 128,300	$ 124,906
Coal at $2.00 ton, $0.50 firing	22,000	48,600	60,400
Fixed charges at 13 per cent	472,220	483,725	263,078
Total charges, per year	$ 631,520	$ 660,625	$ 448,384

Gas-Electric Station

Alternating current circuits are provided which are supplied by gas-driven electric generators. One of these circuits has steam turbines floating on the line at light load which are capable of taking greater load in emergencies. Gas engines are installed with a maximum capacity of 30,000 kw. and a steam turbine with a capacity of 2000 kw.

Power Distribution in Kilowatts

	Kw.
Blast furnace, miscellaneous	850
Pumping station	720
Secondary gas washers	642
Blowing station	58
Electric station, miscellaneous	650
Steel mills	20,000
Total power	22,920
Steam turbine power	725
Gas engine power	22,195
Total power	22,920

As already explained, 20 per cent efficiency is assumed, giving a gas engine consumption of 22,195×3410/0.20=378,000,000 B.t.u. per hour.

The maximum amount of electric power which is needed for week-day working hours in the steel mill is 20,000 kw., that is, 5000 kw. per furnace. The gas from the furnaces is, on the average, more than sufficient to furnish this amount of power, but on account of fluctuations of both load and gas a greater load than that specified would involve shut-downs of the mill for unduly protracted periods when the gas is bad, or else it would involve undue expenditure for make-up coal.

Gas Blowing Station

Seventy-four cu. ft. of blower displacement has been provided per pound of carbon. The blowing engine gas consumption is taken at 8534 B.t.u. per gas i.h.p. hour. This is a test figure for the best plant investigated with an engine having limited overload capacity. Another plant gave 15,000 B.t.u. per gas i.h.p. hour. The average ratio of theoretical adiabatic air card to gas indicator card is 0.844. The air-tub displacement per furnace is 12,835×2000×74/730×60=43,400 cu. ft. per min. The average theoretical power for adiabatic compression (at 15 lb. per sq. in. air pressure) is 5 h.p. per 100 cu. ft. of air per min. Gas blowing engine i.h.p. per furnace is 434×5/0.844=2571. Gas blowing engine heat consumption is 8534×2571×4 = 88,000,000 B.t.u. per hour.

Pumping Station

Water Distribution in Gallons per Minute

Secondary washers	920
Electric station	5,310
Blowing station	2,080
Blast furnaces	6,667
Make-up and miscellaneous	1,000
Total plant water	15,977

Heat balance for complete gas-engine plant with steam reserves:

	Million B.t.u. per hour
Boilers	85
Electric station	378
Blowing station	88
Stoves at 30 per cent of total gas	323
Margin	245
Total	1,119
Heat from normal coal	43
Heat from gas	1076,

The cost of the complete plant, including reserve boilers and steam spares in electric blowing and pumping station, is given in the first column of Table I.

APPENDIX C

Four-furnace All-gas-engine Plant

This plant has no steam blowing or electric units, and one steam pump used only for emergencies. Reserve gas producers are provided, which normally relieve the open hearth producers, so that both sets are running light. For emergencies, the regular producers are run on their furnaces at full load, and the reserve producers are diverted to the gas engines. There is thus no heat used during normal operation by the engine producers. Emergency coal, $22,000 per year.

A boiler plant supplies steam as in B, except for steam turbines, giving 12,070,000 pounds per month and requiring 1135×12,070,000/730×0.65=29,000,000 B.t.u. per hour. The electric station will have gas engines exclusively, supplying the entire power of B and requiring 22,920×3410/0.20=391,000,000 B.t.u. per hour.

Heat Balance for All-gas Plant, in Million B.t.u. per Hour

Boilers	29
Electric station	391
Blowing station	88
Stoves	323
Margin	245
Total	1,076

APPENDIX D

Four-furnace Steam Turbine Plant

This plant is equipped with large; modern boilers, with all improvements and with economizers. The boilers can burn coal as well as gas. The steam conditions are such as would be used in modern stations, 235 lb. per sq. in. gauge, 200 deg. superheat, 28.5 in. vacuum. There are motor-driven circulating pumps directly attached to the generator steam turbines, and not included in the general pump station. Throughout the plant motor-driven auxiliaries are also used, with enough steam-driven auxiliaries for emergencies and to heat the feed water to an amount consistent with the best efficiency of the boiler economizers. Plant service and blower circulating pumps are condensing steam driven.

Turbo-Electric Station

There are three turbo-generators rated at 12,000 kw. continuous load; two of these to be operating continuously for regular week-day load, and one to be a spare. There are small motor-generator and turbo-generator sets for excitation, feed-water heating, etc.

Power Distribution in Kilowatts

Blast furnace, miscellaneous	850
Auxiliary power, exciter losses, etc.	320
Steel mills	20,000
Total power	21,170

Water rate for average load, 12 lb. of steam per kw-hr. Average steam consumption of turbo-generator, $12 \times 21{,}170 = 254{,}000$ lb. per hour.

Turbo-Blowing Station

Five turbo-blowers are provided, one for each furnace and one spare. Allowing 3 per cent for time out and stove losses, and using 57.9 cu. ft. of air per lb. of carbon, as previously deduced in Appendix A, we have as the capacity of the blowers, $12{,}835 \times 2000 \times 1.03 \times 57.9/730 \times 60 = 35{,}000$ cu. ft. per min. Steam consumption of a high efficiency centrifugal compressor at average air pressure 15 lb., 1.08 lb. of steam per 100 cu. ft. of air. Total steam consumption of blowers $350 \times 1.08 \times 60 \times 4 = 90{,}800$ lb. per hour.

Pumping Station for Steam Turbine Plant

Water Distribution—Gallons per Minute

Make-up and general losses	600
Blast furnace water	6,667
Turbo-blower water	1,200
Electric station	500
Total plant water	8,967
Turbo-generator circulating water	43,700
Turbo-blower circulating water	12,400
Total water	65,067

The circulating pumps are directly connected with the generators and blowers, and their costs are included therewith.

Boiler System for Turbine Plant

Boilers rated at 2500 h.p. each are used with economizers and feed-water heaters using exhaust steam from auxiliary apparatus.

Steam Consumption Table—Lbs. per Hour

Total non-condensing steam lost	12,800
Total non-condensing steam for heating feed water	20,000
Turbo-generators	254,000
Turbo-blowers	90,800
Condensing pumps	6,300
Total steam	383,900

The temperature of feed water at entrance to economizers is 143 deg. F., and 6 per cent of the total heat of the gases is counted as available in the economizer. The main boiler raises the water from 233 deg., utilizing 75 per cent of the heat in the gases, corresponding to 75 per cent boiler efficiency. Total heat of the steam above 233 deg. is 1113 B.t.u. per lb. Total heat in the gas $383{,}900 \times 1113/0.75 = 570{,}000{,}000$ B.t.u. per hour.

The steam-turbine plant, therefore, by these figures requires more heat than the gas-engine plant.

The heat storage capacity in the boilers is considerably more than exists in the gas-engine plant, so that probably no more make-up coal will be needed than in the gas-engine plant. However, in order to make this comparison conservative, no consideration is given to this and enough coal is provided for, in addition to that provided for in the gas-engine plant, to make the apparent surplus or margin the same. This calls for an additional 62,000,000 B.t.u. per hr., requiring coal costing $38,400 per year additional to that in the gas-engine plant.

Heat Balance for Complete Steam-Turbine Plant

	Millions B.t.u. per hour	Previous Value of Gas Plant
Pumps, generators and blowers	570	508
Stoves	323	323
Margin	245	245
Total	1,138	
Deduct heat from coal	62	
Heat from gas	1,076	1,076

The costs of the complete plant are given in the second column in Table I of the main body of the paper and need not be here repeated.

APPENDIX E

Segregated Gas Electric Station

In order to enable a better comparison to be made of the electric stations in the steam and gas plants, all of the items in each case pertaining directly to the electric station are brought together. This, therefore, provides an electric station using gas-engine-driven generators fed by blast-furnace gas and including the necessary gas washing station and pumping station to supply the exact amount of gas and water for the gas-electric station only. In the complete plant, as already mentioned, there were boilers for supplying the amount of steam regularly needed about the plant and for reserves for emergencies. That fraction of these boilers which is proportionate to the amount of gas used in the electric station is herein included in the cost of the gas-electric station. This is necessary to give a station which will supply the requisite amount of electric power in any emergency.

Segregated Steam-Turbine Electric Station

In the same way as the gas-engine electric station was segregated, we segregate the steam-turbine electric station by including that fraction of the boilers and auxiliaries which belongs directly to the electric station.

DISCUSSION

By DAVID S. JACOBUS

Advisory Engineer, Babcock & Wilcox Company, New York City

Mr. Rice's comparison of the results obtainable with large steam turbines and gas engines is a most interesting one. He shows that the thermal efficiencies of the two types of prime movers will be about the same for the power plant considered, where blast furnace gas is used for fuel, together with coal which is used in small amounts during occasional deficiencies of gas supply. When it comes to figuring the total charge for the plant per year, the balance is strikingly in favor of the steam turbine.

Mr. Rice states that by using the most modern equipment of boilers, superheaters and economizers, with gas which is passed through primary washers, an efficiency of 81 per cent can be obtained. This figure may be reached with the proper equipment and the best sort of operation for a continuous load.

To obtain the best efficiencies with blast furnace gas there must be but little excess air supplied for combustion, and the gas must be completely burned before the products of combustion pass upward between the boiler tubes. To accomplish this there must be a sufficient furnace volume so disposed that there will be a proper path of travel for the flames, and the gas burners must be arranged to give the proper proportions of air and gas and the proper mingling of the air and gas. Recent developments with burners arranged so as to bring the pressure of the gas up to the outlet and so designed as to give an intimate mixture of the air and gas before entering the furnace have shown that higher furnace temperatures can be maintained than in the older practice, and that the gas can be burned with a shorter flame than in certain of the older forms of gas burners. Higher furnace temperatures and the ability to burn the gas within a given furnace volume, and the proper design of the boiler and its economizer make it possible to obtain the efficiency given by Mr. Rice

Mr. Rice deals with the possibilities of future development showing that an increase in economy can be secured through an increase in the steam pressure and the steam temperature and by paying attention to certain features of economizer operation. As time goes on undoubtedly the trend of progress will be in this direction, as the increase in the cost of fuel will make it possible to install more elaborate and expensive systems than those which now give the best commercial returns.

In the comparisons made in the paper the gas engine plant includes a reserve steam plant for carrying a portion of the load in case of emergencies. It would be interesting from a thermodynamic standpoint to compare the efficiency obtainable from the best engine plant with no steam reserve plant with that obtainable from the best modern steam turbine plant, the efficiencies being based on the heat in the gas used by the gas engine, and on the heat in the coal or gas used by the steam turbine plant.* It would also be inter-

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* This has been done in the revision as published in the GENERAL ELECTRIC REVIEW.

esting to make a comparison on the basis of the heat of combustion of coal, the coal in one case being gasified in producers and the gas supplied to the gas engines, and in the other burned under the boilers. Such a comparison would not be a commercial one, as all fixed and operating charges would be eliminated, and further it would not form the basis of a fair comparison as the reserve steam plant is necessary to secure the same approximate degree of reliability for the gas engine plant as for the steam turbine plant, and the fuel required for the reserve steam plant should be included. The comparison nevertheless would give interesting data respecting the thermodynamic possibilities apart from reliability and fixed charges. It would appear that the results will indicate a somewhat greater coal consumption for a gas engine plant where the coal is gasified in producers than for a steam turbine plant, which is contrary to the ideas of many. It would add to the value of the paper if figures could be given by Mr. Rice to cover these cases.

Mr. Rice speaks of combined gas engine and steam turbine plants, pointing out that a steam turbine plant operated by the waste heat from a gas engine involves such a large expense in comparison with the increase of power as to make it unattractive under existing conditions. Should the cost of fuel be great enough a plant of the sort might be commercially practicable, but it seems that this will not be the case for a long time to come.

In the gas engine we obtain high efficiencies at the high temperature end of the cycle but are unable to utilize the low temperature end. In the steam turbine with modern condensing apparatus the low temperature end of the cycle is utilized to the fullest extent. It would therefore appear that there are great possibilities in combining the two. On working out an actual case it will be found that the work of the steam turbine would be comparatively small, amounting to, say, 10 per cent of that of the gas engine, and it can be seen that the large amount of additional expense and complication involved would offset the saving in the cost of fuel unless the fuel is comparatively expensive.

Time and time again those of inventive minds have proposed new cycles for the production of power. In most cases these have been impractical, or if promising from a thermodynamic standpoint, have not been so commercially. Mr. Emmet, who has done so much for the steam turbine is, as most of you no doubt know, working on the development of a cycle where the work at the high temperature end is done by a turbine driven by the vapor of mercury and the work at the low pressure end is done by a steam turbine. This combination promises as high or even higher efficiencies than are obtainable through the combination of a gas engine and a steam turbine plant. It is eminently fitting that a man who has done so much in the development of the steam turbine should lend his energies to the development of a system of the sort.

It behooves us to look into the future in our endeavors to improve. Should we develop highly economical systems which are not immediately adopted our work is not in vain; we shall be pointing out a way for those who will succeed us, who will have to go much more seriously than we do into the great problem of saving and conservation.

By ALEX. DOW

President, The Detroit Edison Company, Detroit, Mich.

The most useful response which I can make to the invitation to join in this discussion is to give you, first, some personal opinions based on thirteen years' knowledge of big turbines; and, second, the recent costs of a steam turbine station.

The first big turbine for which I was responsible was big in its day, although it would be considered small now. It was a 3000-kilowatt vertical shaft 600-turn machine which went into commission in 1904. It was followed by three others of the same size and speed, and a fifth of the same size but higher speed and more economical. Following these, I have had in the service of The Detroit Edison Company four 9000-kilowatt turbines, three of 14,000 kilowatts, and one of 15,000 kilowatts, all of these being of the vertical type; and three 20,000-kilowatt machines of the horizontal type. We have under contract two turbines of 30,000 kilowatts and one of 45,000 kilowatts, the latter of which is now in transit from the factory.

A word as to the vertical shaft machine. It was pre-eminently a reliable turbine. Its reliability earned the affection of the men who had to live with it. Its inherent limitations are those of the vertical shaft, restraining it to a low rotative speed, which means (in a large turbine) either impracticably large disks or a sacrifice of economy. If some one would discover and apply a force acting horizontally as gravity acts vertically, the limitations would be removed, and I believe the vertical shaft machine would continue to be the favorite of the central station operator.

My first large turbine used just twice as much steam per kilowatt-hour as does the latest one. Of course, that first one is out of service long ago. It was replaced by one of the 9000-kilowatt turbines, and its original string of boilers, rearranged with different stokers and gas passages, serve the 9000-kilowatt machine. The new turbine takes less steam and the boilers now make more steam. The improvement in the boiler room during the thirteen years is less spectacular but quite as useful as the improvement in the steam turbine. Unfortunately it is less known. I confirm Mr. Rice's statement that sustained boiler house efficiencies of 81 to 82 per cent are possible, economizers being used. My justification for this statement is that we have year after year a boiler house efficiency of 76 per cent, all losses by banked fires included, etc., and made *without* economizers.

My observation is that turbine efficiency is too often cancelled, in the total operating costs, by badly designed and badly managed boiler houses, by poor condenser practice and by neglect of station heat balance—the usual fault of heat balance being an excessive or careless use of steam auxiliaries; the less frequent fault being making a fad of electric auxiliaries.

I arrange the conditions of power house design for economy, in order of importance, as follows:

1. Design your furnace and the gas passages of your boiler for the exact fuel you are going to use, or for an intelligent compromise among the different fuels which you may be compelled to use at one time or another.
2. Design the condenser system so as to utilize the full possibilities of high expansion which characterize the steam turbine but without over cooling the condensate.
3. Buy a good steam turbine—remembering that it is possible to refine turbine design, in reaching for thermal efficiency, beyond the point of mechanical reliability.
4. Make your heat transfer as nearly as possible a closed cycle. This requires that you consider condensate temperature, make-up water, auxiliary power, station uses of energy, furnace draft and economizers, as one all together problem, and not as several separate problems to be left separately to the purchasing agent or to the "catalogue engineer."

TABLE I

CONNORS CREEK POWER HOUSE

Production Expense

12 Months Ending June 30, 1916

Production	Total Expense	Expense per kw-hr. Cents
Operation:		
Superintendence	$ 16,841.40	.013
Wages	54,308.36	.043
Fuel	197,554.76	.158
Water	10.00	....
Lubricants	1,416.60	.001
Station supplies and expense	5,562.85	.005
Maintenance:		
Station buildings	7,786.96	.006
Steam equipment	23,826.70	.019
Electrical equipment	3,299.80	.003
Total	$310,607.43	.248
Kw-hr. output	125,158,800	
Maximum demand (30 min.)	35,000	
Average load	14,300	
Load factor	.409	
Coal per kw-hr.—pounds	1.44	
B.t.u. per kw-hr.	19,700	

TABLE II

CONNORS CREEK POWER HOUSE

Production Expense

12 Months Ending December 31, 1916

Production	Total Expense	Expense per kR-hr. Cents
Operation:		
Superintendence	$ 20,521.67	.013
Wages	68,477.62	.042
Fuel	282,135.47	.174
Water	10.00	....
Lubricants	1,055.23	.001
Station supplies and expense	10,037.92	.006
Maintenance:		
Station buildings	$ 11,711.94	.007
Steam equipment	26,670.32	.016
Electrical equipment	4,394.92	.003
Total	$425,015.09	.262
Kw-hr. output	162,117,600	
Maximum demand (30 min.)	36,000	
Average load	18,500	
Load factor	.514	
Coal per kw-hr.—pounds	1.45	
B.t.u. per kw-hr.	19,800	

(Hourly wage and price of coal per ton increased over July, 1915, to June, 1916, figures.)

TABLE III

CONNORS CREEK POWER HOUSE

Production Expense

3 Months Ending March 31, 1916

Production	Total Expense	Expense per kw-hr. Cents
Operation		
Superintendence	$ 4,955.84	.009
Wages	27,460.64	.050
Fuel	144,735.71	.264
Water	....	....
Lubricants	543.43	.001
Station supplies and expense	2,789.67	.005
Maintenance:		
Station buildings	$ 6,972.03	.013
Steam equipment	8,681.11	.016
Electrical equipment	870.18	.002
Total	$197,008.55	.360
Kw-hr. output	54,654,900	
Maximum demand (30 min.)	45,000	
Average load	25,300	
Load factor	.562	
Coal per kw-hr.—pounds	1.56	
B.t.u. per kw-hr.	20,300	

(Hourly wage and price of coal per ton increased over January, 1916, to December, 1916, figures.)

The three tables which follow show our operating cost figures for the Connors Creek Station which went into regular service in June, 1915, with one 20,000-kilowatt turbine, followed presently by a second, and which put its third 20,000-kilowatt turbine into commission in March, 1917. It should be noted that the output from Connors Creek has been limited during the twenty-one months by transmission conditions. That is to say, to increase the output would have involved electric transmission or distribution losses external to the station, and that, therefore, the turbines have not ordinarily been loaded beyond three-quarters rating. The difference between the July to June twelve months (Table I) and the January to December twelve months (Table II) is due to the disturbance of coal supplies and costs in the last weeks of 1916. The same cause, together with the increased use of heat in the buildings during the winter months, has affected the three months' costs, January to March, 1917, (Table III). The difference between 19,700 heat units per net kilowatt-hour of output under normal conditions and 20,300 in the three months period is 600 heat units of which 400 should be charged to disturbance of normal furnace operation by the use of unusual qualities of fuel. It takes time for the best of firemen to discover how to deal with a different coal fed without notice into his stokers. The remaining 200 heat units represent the difference between the midwinter radiation losses and the average for twelve months. A midsummer period for the same station shows 19,200 heat units.

Let it be noted that the Connors Creek figures are for current actually metered out at the transmission voltage of 23,000 to 25,000 volts. They should not be compared with figures of current generated, whereof part is used for station purposes.

Let it be noted also that these figures represent a design of the years 1913 and 1914, and a balance between investment costs and operating costs based upon fuel of 13,500 heat units costing $2.40 per short ton. Were we designing today for fuel at $5.00—which seems to be the probability—we would buy turbines of still higher rotative speed, which would require about 9 per cent less steam than our Connors Creek turbines, and which would be *nearly* as reliable; we would install economizers, for which we have room, but which we have not heretofore thought desirable, and thereby bring our maintained boiler room efficiency up from 76 per cent to, say, 81 per cent; and we would make certain other refinements in our heat balance which might save one per cent of our total fuel. The result of these changes would be a reduction from a normal use of 19,700 heat units per kilowatt-hour to something like 17,000 per kilowatt-hour of net output.

Metal Cutting with the Electric Arc

By Graham Kearney

Canadian General Electric Company, Limited, Vancouver, B. C.

In our June, 1917, issue we published an article on Electric Arc Welding by Mr. H. L. Unland, in which were included some remarks on cutting by the means of the carbon arc and a table showing approximate cutting speeds for sheet steel. The present article is based on observations by the author in a practical application of this method, and some recommendations are given respecting the best arrangement of electrode holder, size and shape of carbon, and methods of securing contact for the positive terminal to the material being worked on. A table is included which is an exact copy of notes taken in the course of an afternoon's work on $\frac{9}{16}$-in. steel plate: The rate of cutting checks very closely with the curve given in Mr. Unland's article. The outfit with which these results were secured replaced an oxy-actylene outfit that had been used to do the same work. The records show that the cost per ton by the gas method was approximately $11.00 as compared with $2.40 for the electric arc method. Besides this economy, the electric arc is much safer, for during the time that the oxy-acetylene apparatus was used two explosions of gas tanks occurred.—Editor.

While the possibilities of the electric arc as a cutting instrument have been generally recognized as a sort of by-product of its principal function as a welding medium there seems to be a considerable field in which apparatus designed for electric welding can be successfully exploited, primarily for cutting purposes. Some data have been compiled regarding cutting speeds, but there appears to be a lack of specific information as to the actual process, and though the method of operation is simplicity itself, there are a few points which are worthy of note by anyone interested in the operation of such equipment.

The data on which these notes are based do not cover a very wide field of observation. The tests were made with a 30-kw., 60-volt standard arc welding set installed in a small rolling mill, and the set has as yet been in operation only a short time, but sufficient work has been done to demonstrate the value of the method. This mill is at present engaged in working up scrap iron and steel into standard shapes. The scrap metal is cut to suitable sizes and made into faggots of a standard size and weight, before being placed in the furnace for conversion into billets. The electric cutting apparatus was installed for cutting the considerable quantity of scrap which is too large to be handled by shears. This consists chiefly of plates of various sizes and thickness, shafting, bars, rails, etc.

In cutting, as in welding, the positive lead of the direct current generator is connected to the piece to be cut, or to the work, while the negative is connected by means of a suitable holder to a carbon electrode. A contact is made between this carbon and the work, and in breaking this an arc is formed which almost instantly melts the metal where it strikes. The molten metal is allowed to run off, and the arc moved slowly along the work, forming a well defined cut. No great skill is required in the manipulation of the arc, as when once formed it is fairly stable, and with a properly shaped electrode it can be controlled with a considerable degree of accuracy.

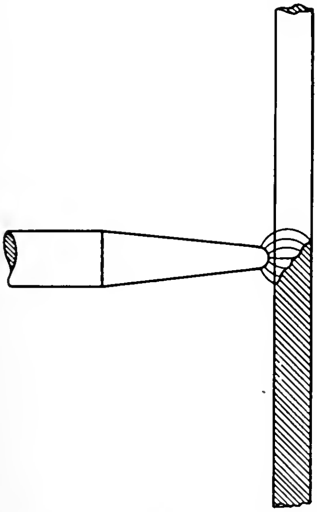
The apparatus on which these tests were made is being operated at from 400 to 500 amperes, and with these current values a carbon ¾-in. diameter having a taper point 4 in. long, tapering to $\frac{3}{16}$-in. diameter, proves quite satisfactory. The carbon, when new, is gripped in the electrode holder about ¾ in. back of the beginning of the taper, and is moved about ¾ in. at a time as it consumes. With this method of operation, the shape of the taper point is well maintained throughout the life of the electrode. Although the carbon becomes white hot, a current of 500 amperes can be maintained, and quicker and more accurate work can be done than with a larger carbon, or with a carbon of uniform diameter.

500-Ampere Arc Welding Set used for Cutting Scrap

With a straight ¾-in. carbon, the tendency of the arc to travel around the circumference of the carbon prevents accurate control, and also, in the case of a deep cut, necessitates the removal of considerably more metal, thus increasing the time and cost of the cut.

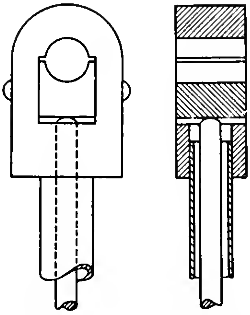
The standard type of electrode holder as used for welding is not suitable for this heavy service, for owing to the high current values a much larger contact must be provided between holder and electrode. It was found that where the carbon is gripped about 4½ in. from the point, as described above, the holder melts rapidly; gripping the carbon further back produces a peculiar action on the electrode. This wastes uniformly throughout its length, resulting in a carbon, at the end of about an hour's operation, approximately $\frac{3}{16}$ in. diameter and 5 to 6 in. long. Naturally, as the diameter of the carbon decreases, the current will also decrease owing to the increased resistance which becomes a considerable part of the total resistance of the circuit. Starting at 450 to 500 amperes with a new carbon, the current drops to a final value of about 150 amps. at the end of the life of the carbon. This of course greatly reduces the cutting speed.

The writer designed a special head for the electrode holder, having jaws bored accurately to ¾-in. diameter, and enclosing practically the entire circumference of the carbon. This head was made of considerable mass and radiating surface to assist, as far as practicable, in keeping the carbon cool. With this holder the desired point is easily maintained on the carbon.



Position of Electrode and Arc when Cutting Steel Plates

An important point in the operation of the cutter is the connection between the positive lead and the work. A good contact is essential and this can, of course, be obtained in an endless variety of ways. Where operations are to be performed on a great number of pieces of different sizes and shapes, however, it is difficult to design a clamp which can be quickly applied, and which will, in all cases, give a satisfactory contact. Scrap metal is usually very dirty, and frequently thickly coated with rust or scale, and unless a suitable device is used a great deal of time will be lost in making connections. The writer found that for this class of work the following arrangement worked out most satisfactorily and economically.



Clamping Head for Electrode Holder

A clamp was made consisting of a copper bar ¼ in. by 2 in. by 6½ in. reinforced on the bottom by an iron bar of the same dimensions. To one end of this bar a lug was attached into which was sweated the positive lead. On the other end was fastened a yoke, or clevis, in which was set a cam lever. A piece of ¼ in. by 2 in. copper bar, 6 in. to 8 in. long, is clamped to the work by means of an ordinary screw clamp. The free end of this piece is inserted under the cam, by which it is then clamped tight to the copper bed of the clamp. A number of such pieces were provided, some perfectly plain and flat, and others having half their length bent into arcs of different radii, in order to fit shafting, etc., of different diameters. Two or more ordinary screw clamps were provided.

This device introduces the apparently undesirable feature of having two separate contacts where one would suffice, but it results in a great saving of the operator's time, and the actual energy loss in the extra contact is negligible. A new piece of work can be cleaned and a copper piece attached by a helper while the operator is working. When he desires to change to the new work, it is only necessary to lift the cam lever, remove the clamp, and attach it to the new connection. The helper then removes the old connection from the finished work. The making of these connections takes only a small part of a helper's time; he can usually be employed chiefly at other work. The clamp used in this particular case, as shown in the photograph, is very crude, and could of course be greatly improved in mechanical design and simplified in construction.

A particularly attractive field for this apparatus is in cutting steel plates, in cases where an accurate or sharply defined edge is not essential. A table of results of operation on a $\frac{9}{16}$-in. steel plate is given; it is an exact copy of notes taken in the course of an afternoon's work. The original plate was 18 ft. by 4 ft. by 4 in., and was cut into seven pieces approximately 26 in. by 52 in., and one piece 32 in. by 52 in. This last piece was then cut in halves across its 32-in. length. The table shows some lost time, a good deal of which might have been avoided, but the total time should represent fair working conditions. It will be seen that the net average time taken per foot checks closely with the curves given by Mr. Unland in the June, 1917, issue of the GENERAL ELECTRIC REVIEW.

Clamps and Copper Bars for Connection to Work. Electrode Holder with Carbon Electrode almost Consumed

Pile of Scrap Plates Cut by Electric Arc

On the same day a very effective job was done in cutting openings in a shell for a steel furnace made of ¼-in. steel plate. This is clearly shown in the photograph, in which will be noticed the bolt holes, also cut by the electric arc. The net time taken to cut a ½-in. hole in the ¼-in. plate was 3½ seconds. On this particular work an accurate fit was not necessary, and the holes were made quickly and cheaply. Some of them are irregular in shape, owing to the fact that the work was done out-of-doors in a strong wind, which rendered the placing of the arc difficult.

Plate can be most effectively cut when it is laid flat, so that the molten metal drops away freely. The most effective method is to start the cut at the side away from the operator, and to cut towards him. The insulating shield of the holder can be rested on the work, greatly steadying the arc and reducing the strain on the operator. In this way a good chalk mark can easily be followed. The point of the electrode should be kept as close to the surface of the plate as possible, but a short distance back from the end of the cut. In thick plates it will be necessary to move it to and fro downward from this position to force the arc to the bottom of the plate. Operating in this manner, the greater part of the arc is hidden from the operator's sight, lessening the eye strain, and with a little practice the operator can determine the condition of the cut by the sound of the arc. When the arc is playing on solid metal, or in other words, when the upper portion of the cut has progressed further than the lower, the arc is practically noiseless. As the metal directly below the arc melts away a slight roaring occurs. In a like manner, when cutting a hole through a plate, the arc will operate silently, but will begin to roar as soon as the hole is through.

In cutting round sections, such as shafting, the most satisfactory method is to start the cut at the bottom, cutting straight across as deep as possible, and, if it can be done, turning the work so as to keep cutting from the the bottom. With a little experience the operator will be able to judge the width at which the cut should be started, depending on the diameter of the shaft. For a 4-in. shaft this need not exceed 1 in., decreasing to about ½ in. at the center of the shaft when using a pointed carbon. It is stated that, where scrap is cut for making billets, the metal which is run off from the cut can be saved, re-melted in an open hearth furnace, and worked into billets. The writer is not prepared to make a statement on this point, but it seems quite feasible, and if so practically all waste in cutting would be eliminated. Where cutting is extensively done for other purposes, the waste metal might easily be sold as scrap. The writer found that a 2½-in. shaft could be cut in 2½ to 3 minutes, and a 4-in. shaft in 10 to 12 minutes, leaving a small piece in the center which can be easily broken when cold. It might be mentioned that this last small piece, in work of any shape, is very difficult to cut, as the arc naturally tends to strike to the larger mass of metal on either side.

Shell for Steel Furnace showing tuyere openings and bolt holes cut by arc. The position of a new electrode in the holder is clearly shown

A statement is given showing the cost of the particular operation described above. The item of power is based on a rate which might be considered low for some localities, though it is somewhat higher than the actual rate in effect at this plant. It will be noted, however, that an increase of 100 per cent in the power rate would only increase the total cost of the work by 26 per cent. This might be partially offset by a difference in labor cost. The cost of electrodes can be reduced by using longer carbons, say 16 in., instead of 10 in. as the percentage thrown away in unburned ends then becomes much less. While it is not practicable, in cutting thick metal, to use a carbon shorter than about 4½ in., the used carbon of this length can be put aside and used down to about 3 in. in length for cutting plates up to ½ in. thick.

Details of Furnace Shell

The cost per ton is mentioned. This is a somewhat meaningless quantity, as it obviously depends on the amount of work to be done per ton, or the extent to which a ton of metal must be divided. It is given here, however, for the sake of a comparison which can be made in this particular case. This equipment replaced an oxy-acetylene outfit which had been installed to do the same work. The cost of this work by the oxy-acetylene method, according to a statement by one of the officials of the plant, approximated $11.00 per ton. In addition to this, two explosions of gas tanks occurred, in which the operators narrowly escaped serious injury.

The writer feels that a word of caution regarding the handling of the electric apparatus should be given to those who are not familiar with the properties of the electric arc. Great care must be exercised by the operator to avoid accidentally striking the arc without having the face and eyes protected by a mask or shield, and the hands and arms must be protected by heavy clothing, or preferably by leather. Exposure of the skin to the rays of the arc results in painful burning similar to a severe sunburn, and the rays from the arc cause a very painful inflammation in the eyes. This effect is noticeable even when using a mask with a window darkened to a point where necessary vision is almost prevented. When other workmen are employed within a radius of 50 ft. or 60 ft. from the arc, it is necessary to provide a suitable screen around the work to prevent serious damage to their eyesight.

The mask, as furnished with the equipment, is simple, light and easily adjusted. In the writer's opinion, however, vision would be greatly improved by painting the inside a dead black; also, when working in a well lighted place, extraneous light could be cut off from the rear by a black veil. The writer used a piece of black cloth, attached to the back of the head strap and to both sides of the mask. The lower end was fastened to a piece of $\frac{3}{16}$-in. round iron, bent to form a circular arc. This rests on the operator's shoulders, keeping the veil close in without interfering with the ventilation, or with the easy removal or adjustment of the mask.

TIME FOR CUTTING STEEL PLATE WITH ELECTRIC ARC. AVERAGE CURRENT APPROXIMATELY 400 AMPERES

Material	Length of Cut Inches	TIME		Time for Cut Minutes	Remarks
		Start p. m.	Finish p. m.		
1—$\frac{9}{16}$-in. steel plate......	52	2.37	2.55	14	New carbon* 4 min. to change carbon
2—$\frac{9}{16}$-in. steel plate......	52	2.55	3.09	13½	
3—$\frac{9}{16}$-in. steel plate.....	52	3.15	3.26	11	New carbon
4—$\frac{9}{16}$-in. steel plate......	52	3.28	3.41	13	
5—$\frac{9}{16}$-in. steel plate......	52	3.46	3.58	12	
6—$\frac{9}{16}$-in. steel plate......	52	4.09	4.24	13	
7—$\frac{9}{16}$-in. steel plate......	52	4.27	4.39	10½	New carbon
8—$\frac{9}{16}$-in. steel plate... ..	32	4.43	4.51	8	6 min. change cut
				95	

* The first cut was started with a ¾-in. copper plated electrode. After cutting about 1 ft. this was found unsatisfactory, as the copper coating had melted away, and a 10-in. by ¾-in. plain carbon with 4-in. taper point was substituted. This style of carbon was used throughout the rest of the work.

Total length of cut.........................	33 ft.
Total time..................................	2 hr., 14 min.
Time actually cutting.......................	95 min.
Total time per foot.........................	4.07 min.
Average net time per foot....................	2.78 min.
Total weight of plate (calculated)...............	1800 lb.

Cost of Cutting

POWER:	
56 kw-hr. (estimated, including free running losses when not cutting) at 1c....	$ .56
ELECTRODES:	
2 carbons at 20c..	.40
LABOR:	
Operator, 2¼ hr. at 40c..	.90
Helper, ¼ hr. at 30c..	.08
Fixed charges on plant..	.22
Total cost, 33 ft..	$2.16
Cost per foot..	.065
Cost per ton	2.40

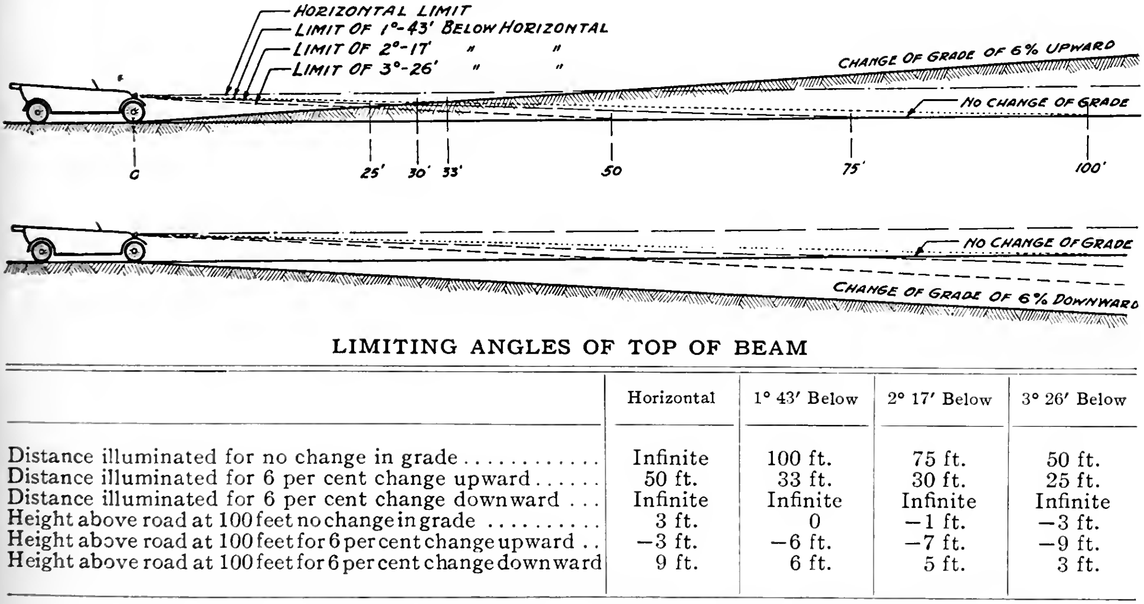
The Automobile Headlighting Problem Again

By Evan J. Edwards

National Lamp Works of General Electric Company

The author treats the problem of automobile headlighting in an unusually clear and comprehensive manner. He first traces the recommendations made for the various common types of illumination to their various types of origin; city driver, rural driver, and laboratory illumination specialist, and then, considers the illumination problem as viewed by each of these persons. Following this, he impartially analyzes the advantages and disadvantages of the fixed, the controllable, and the diffusing systems of lighting, concluding with a recommendation for the controllable system.—Editor.

Much has been written and said regarding the automobile headlighting situation. However, there still seems to be a lack of common understanding of certain fundamental points which can be accounted for only by reason of the different points of view of those who have studied the problem. Speaking only of those who are well equipped in knowledge of illumination matters, and who have not been influenced by a direct commercial interest, it may be of interest to note how these differences of opinion may have come about. One man, we will say, is a driver himself and lives in a large city located in the eastern part of the United States. His judgment may be based almost entirely upon his experience in driving on city streets and much used state roads leading out in the principal directions from the city. In his experience he has been meeting vehicles almost continuously, and there has been light on the road other than that given by his own headlamps, coming from street lighting units or the lights of other vehicles. Another man may be located in a smaller city in the middle west where nearly all of his driving at night is on country roads where there is no street-lighting system and where automobiles are nearly all going in one direction at any particular time of evening and he meets other vehicles only infrequently. There is also a third man, an expert in matters of optics, but who does not, himself, drive a car. It is not difficult to see that the opinions of these men will differ. In the case of the driver who uses his machine only on city streets and much used state roads, it is not surprising that he sees little excuse for a controllable system from which upward light could be obtained. His experience has shown him that an upward light system for his car could hardly ever be put into operation. Furthermore, on account of the light which has come from street lighting units or other machines, he has experienced little difficulty in seeing objects above the roadway.

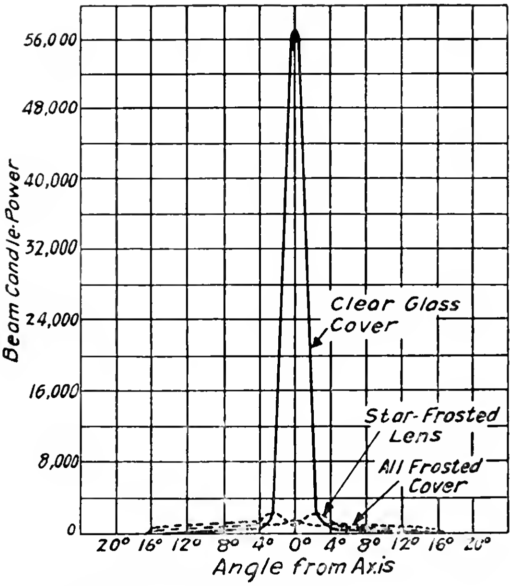


LIMITING ANGLES OF TOP OF BEAM

	Horizontal	1° 43′ Below	2° 17′ Below	3° 26′ Below
Distance illuminated for no change in grade	Infinite	100 ft.	75 ft.	50 ft.
Distance illuminated for 6 per cent change upward	50 ft.	33 ft.	30 ft.	25 ft.
Distance illuminated for 6 per cent change downward	Infinite	Infinite	Infinite	Infinite
Height above road at 100 feet no change in grade	3 ft.	0	−1 ft.	−3 ft.
Height above road at 100 feet for 6 per cent change upward	−3 ft.	−6 ft.	−7 ft.	−9 ft.
Height above road at 100 feet for 6 per cent change downward	9 ft.	6 ft.	5 ft.	3 ft.

Diagram from article "The Automobile Headlighting Problem," by Evan J. Edwards, Electrical Review, Sept. 29, 1917

In the second case of the man who drives mostly on country roads he has constantly felt the need of upward light when attempting to get along without it, and it appears to him entirely unreasonable that he should not be allowed to drive with full safety and comfort as long as there were no eyes ahead to be blinded. For the third case of the man who has not himself had the experience of driving at night, he is likely to miss entirely some very important points in his theoretical consideration of the problem. It is not unusual for such a man, for example, to think of the machine as being on a road which is nearly level. Although the mathematics of the case are entirely simple, it is only by driving on the road that a person gets a real appreciation of the variations in the height of a beam above the roadway due to the changing road curvatures off profile. The theoretical man seems inclined to assume that when the beam is limited to angles below the horizontal the approaching driver will be exposed at the worst to only occasional flashes of glare. A slight experience on the road brings out the fact that these are not occasional flashes of glare but are frequent and sometimes continuous over a period of one or two minutes. The height of the beam is so sensitive to changes in road curvature that with a system limited to the horizontal the beam is as high as the approaching driver's eyes, perhaps as much as a fourth of the time the machine is on the road.



(From *Illuminating Engineering Practice*)
Beam Candle-power of Parabolic Automobile Projector with 6–8-volt 3.0-ampere Mazda C Lamp

These same natural differences of opinion enter into the question as to the allowable upper limit of candle-power which can be allowed to reach the approaching driver's eyes. The man who drives only on the lighted city streets believes this limit to be relatively high. The man who drives only in the country has experienced serious interference with vision even when approaching the lowest intensity dimmed lights. The laboratory optical expert is likely to base his opinion too much on the results of a laboratory method which neglects certain conditions of practice.

There is little doubt that each of these experts is right insofar as concerns the solution to the problem as he sees it—but it should be recognized that no solution can be fully successful unless uniformly and widely applied. There is little satisfaction in equipping for no glare if others on the road are not equipped in a similar manner. The solution to be ultimately successful must not only be right but must be the only one generally recognized and practised.

Judging from what has been written and said, the existing difference of opinion can be sifted down to an advocacy of one of two general solutions. Without complicating matters by introducing the fine points of detailed distribution of these two systems and a third at present much used they may be characterized as follows:

1. The single fixed system of distribution where the light in the upward angles is presumably reduced to the point where it cannot cause serious glare.
2. The double or controllable system by which it is possible to get near road light without glare, as well as a combination of upward and downward light somewhat as is obtained from the unmodified paraboloids placed with their axes parallel to the plane of the road on which the machine stands.
3. In addition, of course, there is the diffusing headlight system widely practised, but the advocates of which have been heard from only through display advertising.

A brief method of discussing these fundamental systems is to enumerate the most important inherent advantages and disadvantages of each.

1. The single fixed system having the high intensity beam only in the lower angles.

Advantages

a. The possibility of excellent road surface illumination without producing serious glare on a level road.
b. No manipulation depending upon the knowledge or intentions of the driver.
c. Constancy of characteristics once properly installed and adjusted.

Disadvantages

a. Varying height of beam due to road curvature causing serious glare—a part of the time.
b. Resulting difficulty for the driver in anticipating the direction of the road due to absence of light on trees, telephone poles, and fences.
c. Practical difficulty in reducing the upward intensities to a sufficiently low value to eliminate glare on the darkest roadway.
d. Limited range of illumination when approaching the foot of a hill.

2. Controllable system capable of giving either downward light only, or both upward and downward light.

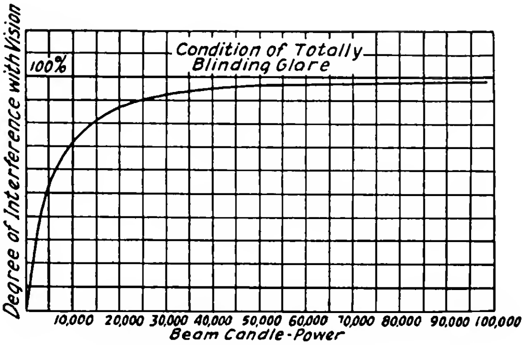
Advantages

a. Overcomes disadvantages b. and d. as noted above, except at such times as there are approaching vehicles.
b. Permits a good road surface illumination at all times.
c. Gives warning to the driver of a vehicle approaching on the cross-roads.
d. More likely to render visible danger signs such as at railroad crossings.
e. Gives the roadway pedestrian warning at a great distance.
f. Permits of the full pleasure and feeling of security in night driving that comes as the result of strong upward light, at times when there are no approaching vehicles.

Disadvantages

a. With the control of the system left to the discretion of the driver there is sure to be some abuse, although this possibility is diminished by the assumption that the controllable system will be capable of giving good road surface illumination at the time of passing.

3. The diffusing system where the beam intensity is cut down and the light is scattered through a wide angle symmetrically as regards up and down.



(From *Illuminating Engineering Practice*)

Nature of Relation Between Beam Candle-power and Visibility of Objects Viewed against Beam where the Background is Totally Dark

Advantages

a. It seems that the only advantage to this system is the ease by which the results can be accomplished. Almost any kind of a diffusing transmitter in the door of the headlight can be used with any kind of lamp and reflector with any kind of adjustment.

Disadvantages

The disadvantages are so great that it seems as though this scheme was as far from the best solution as anything could be.

a. The beam intensities are not sufficiently reduced to do away with glare except on well lighted streets.
b. Beam intensities, however, are reduced far below the point of even fair road illumination.
c. The light is scattered through such a wide angle that it is effective in producing glare in all positions forward of the car, where the background is dark.

It has been the observation of the writer that practically all who have studied this problem agree on the main points as outlined above, and further that those who drive machines a great deal over a wide variety of road conditions agree that the single fixed systems, no matter how carefully worked out and adjusted, can never be satisfactory. There is left but one point of serious difference of opinions and that is in the matter of whether the control of the lights can be left to the discretion of the driver. The disadvantage of doing so is sure to appear more serious to some than to others. If the point is to be settled in advance it must be decided by opinions, and the proof can come only as the result of experience; not experience with one experimental equipment on the road but by experience with a simply understood and uniformly applied practice.

The writer believes the best solution to be a controllable system which is capable of giving high intensity road illumination up to say fifty feet forward of the car as measured on a level road at times of passing, and of strong upward light in addition at other times. This necessarily brings in the disadvantage of allowing discretion to all drivers, but this is parallel to the present discretion of drivers in the matter of controlling the speed of his car. With uniform equipment, as above outlined, there would be little incentive to abuse, first, because the driver is still able to see his way in passing after cutting out his upward light; and second, because he knows that the other fellow is equipped to serve him the same kind of mistreatment in return, should he feel inclined to disregard the rights of others.

The Phantom Circuit Remote Control System

By H. H. Reeves

Supply Department, General Electric Company

The system dealt with in this article was assigned to provide a simple, reliable, and economical means for turning on in the evening and off in the morning those groups of street incandescent lamps which are located at a distance from the central station and are fed by local transformers. The author describes the theory and operation of the system, the various component pieces of apparatus, and analyses its merits. The article is based upon a paper delivered by the author at the convention of Municipal Electricians, Niagara Falls, September, 1917.—Editor.

Introduction

Everyone is familiar with the recent developments which have improved the efficiency of the incandescent Mazda lamp. The use of the gas-filled lamp with its high efficiency has had far reaching results, especially in street lighting where certain evolutionary, if not revolutionary, changes are in progress. A few years ago the Mazda lamp was used in street lighting only as a sort of "filler in," i.e., its use was limited to unimportant streets or districts where an excuse for illumination was all that was required. Today, it has replaced large numbers of arc lamps and has forced its consideration for all classes of street lighting.

Practically all arc lamps used for street lighting were operated on series circuits, as arc lamps built for and operated on constant potential circuits were in general less efficient due to the power consumed in the steadying resistance. These series circuits were supplied with a constant current by a movable-coil transformer in the station; and when incandescent lamps replaced the arcs, they were installed on these same series circuits. In

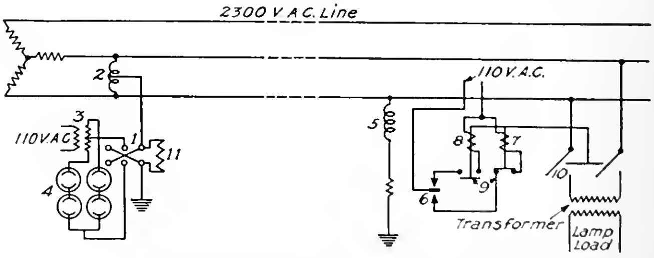


Fig. 1. Connection Diagram of Phantom Circuit Remote Control System as applied to an Ungrounded Neutral Line

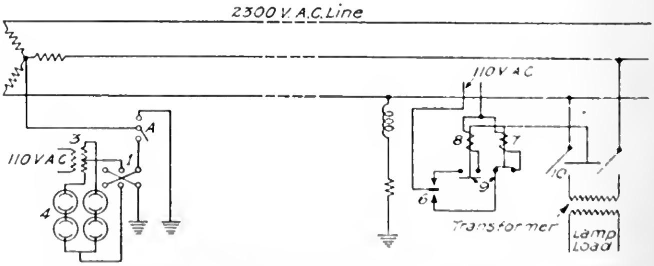


Fig. 2. Connection Diagram of Phantom Circuit Remote Control System as applied to a Grounded Neutral Line

new installations, however, there is a tendency toward using lamp circuits supplied and controlled by transformers sometimes remote from the station, these transformers being mounted on poles and connected directly to the 2300-volt light and power feeders. This arrangement is possible with incandescent lamps but was not practicable with arc lamps owing to the inherent characteristics of the latter.

Irrespective of whether the lamps are connected in series or in parallel in these pole installations, some means must be provided for connecting the lamps to the feeder at night and for removing them in the morning. There were two methods available for accomplishing this; first, by manual operation; and second, by time-switches mounted on the pole with the transformer which supplies the lamp circuit. Both of these were open to certain objections, in consequence of which there has been developed* and made commercially available a system of control from the station or some central point. This system is known by the name "Phantom Circuit Remote Control System."

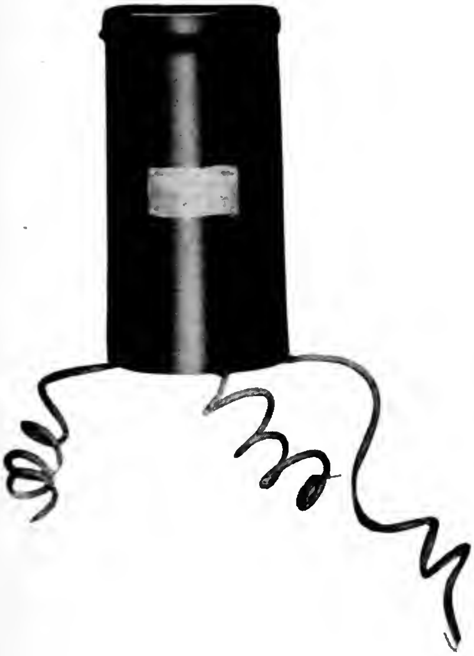


Fig. 3. Station Reactance

The designation "Phantom Circuit" is used because no separate circuit is required for the control, the impulse for operating the switch being sent over the feeder wires. It is called "Remote Control" because the operator at the station has absolute control of the street lights, deriving power from his high-voltage feeder wires ten or fifteen miles away.

Fig. 4. Aluminum Rectifier Cells for Providing 125-volt Direct Current where no Other Source of Direct Current is Available

Theory

It is a well known fact that a circuit can be used for more than one purpose at the same time, a familiar example being multiplex telegraphy where several messages are sent over the same wire simultaneously. In the present instance, however, alternating-current power lines are used for transmitting a small direct current without interfering with their function of carrying power. The high-voltage wires are used as one side of the circuit and the ground as the other as indicated in Figs. 1 and 2. It is necessary, therefore, to get the direct-current on the lines without letting the alternating current escape to the ground. This is accomplished on a three-phase non-grounded neutral line or on a single-phase

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* In the Consulting Engineering Department of the General Electric Company.

line by means of a reactance (Fig. 3 and item *2* in Fig. 1) which offers little resistance to the passage of direct current, but offers sufficient impedance to the alternating current to prevent grounding the system.

Fig. 5. Potential Transformer for Use with Aluminum Cell Rectifier

The station reactance is connected between two of the line wires, and one side of the direct-current supply is connected to a tap at the center in order to decrease the resistance at this point.

In the station a source of 125-volt direct current must be provided which can be grounded on either side alternately. If there is such a source available, the rectifier (Fig. 4 and item *4* in Figs. 1 and 2) and the potential transformer (Fig. 5 and item *3* in Figs. 1 and 2) can be omitted as their function is to supply direct current for the control impulse where a direct-current supply is not available.

The direct-current is impressed on the alternating-current lines only for a few seconds —just long enough to operate the oil switch.

A high resistance (Fig. 6 and item *11* in Fig. 1) is connected across the terminals of the knife switch (Fig. 7 and item *1* in Fig. 1) and offers a permanent path to ground for the exciting current of the reactance.

At the line end of the system, a reactance (Fig. 8 and item *5* in Figs. 1 and 2) similar to that at the station is installed. The line reactance, however, is connected between one line wire and ground. A polarized relay (Fig. 9 and item *6* in Figs. 1 and 2) for controlling the solenoid circuit is inserted in the circuit between the reactance and ground. If the direct-current impulse passes through this relay from line to ground, the closing solenoid (Fig. 9 and item *7* in Figs. 1 and 2) is energized and the street lights are turned on; if from ground to line they are turned off. The solenoids obtain their power from a source of 110-volt alternating current which is usually available. When the oil switch is closed, the contacts (Fig. 9 and item *9* in Figs. 1 and 2) in the closing solenoid circuit are opened, and those in the opening solenoid circuit are closed mechanically, so that the next operation must of necessity be the opening of the switch.

Fig. 6. Resistance Unit for Connection of Cross Terminals of Knife Switch shown in Fig. 7; Ungrounded Neutral System

It requires about 0.05 amperes of direct current to operate the polarized relay. If more than one switch is operated from the same station equipment, the direct current required from the station is increased proportionately. This means that a special reactance of lower resistance is necessary when more than one switch is operated, or the standard reactances can be paralleled.

The closing solenoid requires an instantaneous alternating current of 15 amperes at 110 volts, but this decreases in about 0.1 seconds to 4 amperes. The opening solenoid takes 8 amperes at the start but this falls to three amperes, and it is this lower current at which the contacts open.

The oil switch (Figs. 9 and 10 and item *10* in Figs. 1 and 2) breaks the current of the primary of the transformer or of the circuit which it is controlling.

Fig. 2 shows a three-phase line with the neutral grounded at the station. No station reactance is needed in this case as the direct current can be connected to the transmission line through the grounded wire by a single-pole double-throw switch as indicated at *A* in the diagram.

Fig. 7. Two-pole Double-throw Control Switch

The proper operation of this system of control depends upon the absence of grounds on the alternating-current lines. The control can be used even if the neutral of the system is grounded at the station, providing the ground can be disconnected momentarily while the control impulse is being sent. The average tree ground will not interfere with its operation, as the resistance of the tree ground is so much higher than that of the control circuit that the direct current is not short circuited. If the alternating-current system is grounded through ground detectors, this ground could be removed for the few seconds that the impulse is being sent, or a condenser could be permanently connected in the grounding line of the ground-detector circuit.

Fig. 8. Line Reactance

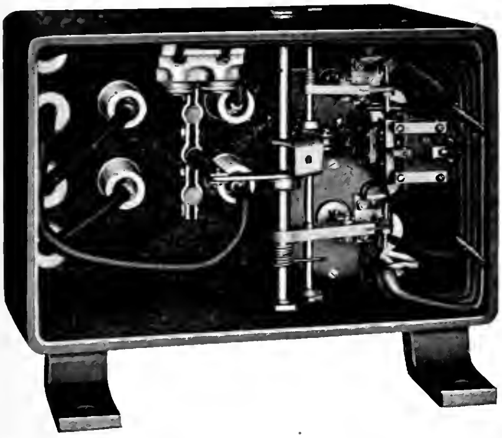


Fig. 9. Top Compartment of Oil Switch showing Polarized Relay and Operating Solenoid and Mechanism

There will be no inductive disturbances in parallel telephone lines, as the alternating current flowing through the ground is infinitesimal.

Description

Figs. 3, 4 (four cells), 5, 6, 7, 8, and 9 show all of the material for a complete 60-cycle 2300-volt system. Figs. 3, 4, 5, 6, and 7 include those parts of the apparatus located at the station, and Figs. 8 and 9 include those parts located out on the line at the point where the switching is to take place.

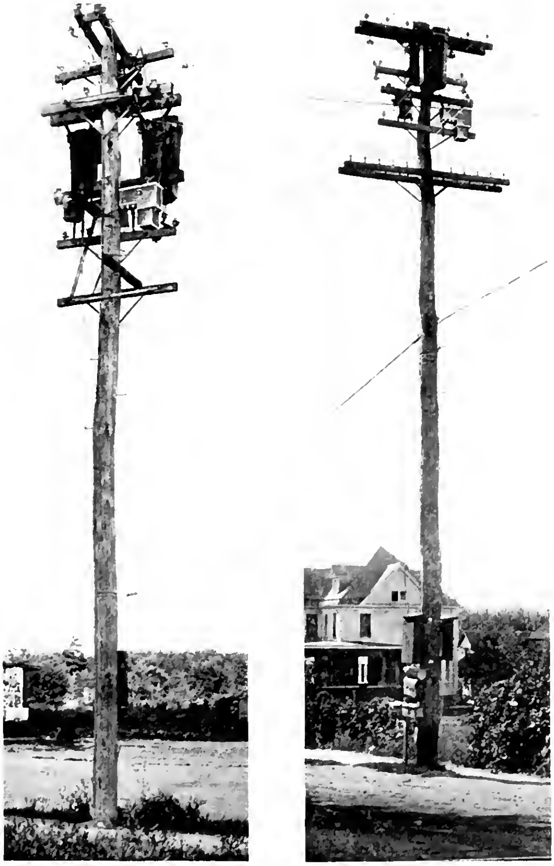
The capacity of the double-pole double-throw reversing switch (Fig. 7 and item *1* in Figs. 1 and 2) is 30 amperes, 125 volts. The incorporation of "safety-first" features led to the selection of a switch which had its blades entirely enclosed in a cast-iron cover leaving only a rubber handle projecting through a slot.

The station reactance (Fig. 3 and item *2* in Fig. 1) is enclosed in a cylindrical sheet-steel case, which gives it a very substantial as well as compact appearance. It is absolutely weatherproof, the three leads which connect to the ends and middle point of the winding being brought out through bushings at the cover end. Also, it was designed for a potential test of 12,500 volts between coil and casing.

Fig. 10. Bottom Compartment of Oil Switch with Tank Removed to show Oil Circuit Breaker

The constant-potential transformer (Fig. 5 and item *3* in Figs. 1 and 2) used in connection with the rectifier for supplying direct current is for use on a 60-cycle 110-volt alternating-current circuit, and the secondary is wound for 500 volts with a tap at the middle point. Its momentary capacity is 500 watts.

The rectifier (Fig. 4 and item *4* in Figs. 1 and 2) is made up of four cells, each cell consisting of a glass jar containing an electrolyte in which is submerged the aluminum terminals. It is capable of delivering 0.5 amperes direct current at 125 volts.



Figs. 11 and 12. Installation of Phantom Circuit Remote Control in Rural Districts Located Four and Eight Miles Respectively from Central Station

The line reactance (Fig. 8 and item *5* in Figs. 1 and 2) is similar to the station reactance.

The solenoid operated oil switch (Figs. 9 and 10 and items *6*, *7*, *8*, *9*, and *10*, Figs. 1 and 2) consists of a 2300-volt 30-ampere double-pole single-throw oil switch, an opening solenoid, a closing solenoid, two sets of mechanically operated contacts, and a polarized relay. These are all mounted in a cast-iron box, the switch blades being submerged in a tank fastened to the bottom of this box.

Conclusion

The operation of the phantom circuit remote control system has demonstrated that its advantages may be classified somewhat as follows:

Reliability

- Ample power for operation under all commercial conditions.
- Strong construction.
- No complicated or delicate mechanism.

Adaptability

- Applicable to any non-grounded alternating-current feeder circuit.
- No auxiliary circuits necessary.

Flexibility

- A number of switches can be controlled simultaneously.

Simplicity

- Auxiliary circuit under control of operator at all times.
- No flicker in house or street lights when switch is operated.
- Negligible attention to switch after installation.
- No necessity for visiting switch to reset, operate, or wind mechanism.
- Control mechanism can be installed in any convenient location such as a City Hall, Police Station, or Fire Station.

Street lighting systems 5, 10, or 15 miles from the station can be connected directly to 2300-volt feeders without running special circuits for each system, and the station operator can control the various systems at will. Less station room is required, the attention which the engineering and operating force must give to street lighting is minimized, and the expensive repair department required for keeping complicated arc-lamp mechanisms in service can be dispensed with. Thus, the phantom circuit remote control system has simplified matters considerably for the central station.

Some Features in the Design of Domestic Electric Ranges

By J. L. Shroyer

Heating Device Engineering Department, General Electric Company

The electric cooking proposition is being received with far more serious consideration than is commonly supposed by the general public. Actually, electric cooking is gaining converts at a truly remarkable rate. A typical example of the success which attends the introduction of electric ranges into the home is given in "Electric Range Campaigning by the Central Station," General Electric Review, October, 1916, p. 778. The production of the electric ranges illustrated in the following article has been made possible only by exhaustive research and skillful application of the principles of mechanics, electricity, and human nature. The description of the requirements of an electric range, the difficulties met and how they have been solved in the ranges herein described, should prove to be of particular interest to the salesman, the central station manager, the dealer, and the housewife.—Editor.

"The electric range has come to stay. These few words effectively sum up the expressions received by your sub-committee from scores of progressive central station commercial men all over the country. Those men who have been selling ranges for the longest time are most enthusiastic about them. They have had an opportunity of determining just how valuable the electric range load is. They have passed through the exploitation period in their respective territories, have placed the sale of ranges on a definite basis, and are making preparations at the time this report is written for the sale of ranges on a scale undreamed of hitherto."

Fig. 1. Electric Range with Four Eight-inch Three-heat Hot Plates and Two Three-heat Oven Units (one for broiling). The side receptacle at the left is for attaching an Electric Flat-iron, etc.

Fig. 2. The Electric Range shown in Fig. 1 with an Electric Cooker substituted for the Left Rear Hot Plate, the Right Front Hot Plate in position for removal, the Fuse Cabinet Front raised, and the Top Oven Unit lowered

The foregoing paragraph is quoted from the report submitted by the Electric Range Committee of the N.E.L.A., June 1, 1917.

Such a report is indeed gratifying to electric range manufacturers. First, it indicates that they have been successful in producing a range which is mechanically and electrically practical; second, that their foundation for this endeavor, i.e., the belief that electric cooking is practical, superior to other methods, and profitable to the central station, has been finally confirmed.

The present success of the electric range has been due, in no small degree, to the helpful co-operation of practical central station men with receptive designers.

This article is intended to discuss briefly, in the light of experience, the important features that must be considered in the design of a modern electric range.

Engineers have been accustomed to design apparatus that is to be operated and cared for exclusively by men. The electric range must primarily meet the approval of women. Further, the electric range must be made for operation by the most unintelligent class of servants, and yet must have the approval of the highly intelligent and critical housewife.

Fig. 3. Electric Range with Four Eight-inch Three-heat Hot Plates, Two Three-heat Oven Units, and a Three-heat Broiling Closet

The electric range designer also had to enter the field of thermal engineering. This was not only a new field to the electrical engineering profession, but involved many new problems that required time and experience for their best solution.

This work therefore presented four distinct kinds of problems; namely, mechanical, electrical, thermal, and those in which culinary and domestic requirements must be considered. Each problem became more involved in proportion to its bearing on the other problems.

The construction of the electric range oven, for example, is not a simple matter. The relatively high cost of electrical energy as a source of heat, and the advantages to be derived from confining the heat required a durable and efficient thermal insulation. This immediately introduced several serious difficulties. First, a suitable heat insulator was required. Compared with other developments, very little had been done towards the perfection of heat insulating materials. A material was required which could be used with uniform results. Non-homogeneous materials, or materials which are apt to settle and leave parts of the walls uninsulated, must be avoided. It must be unaffected by moisture and should be impervious to liquids and vapors. This is important in maintaining an odorless range. The insulation must be heated each time the oven is used, and therefore must have a low specific heat. One and one-half inch of insulation (weighing 0.01 lb. per cubic inch and having a specific heat of 0.195, or 0.1025 watthours per pound per degree C.) around an 18 in. by 18 in. by 14 in. oven will require approximately 325 watthours to raise its temperature 125 degrees C. A good oven of this size may be heated and a pan of biscuits baked with a total consumption of 500 to 750 watthours. It is therefore evident that the efficiency of a domestic range oven depends largely on the specific heat of the insulation.

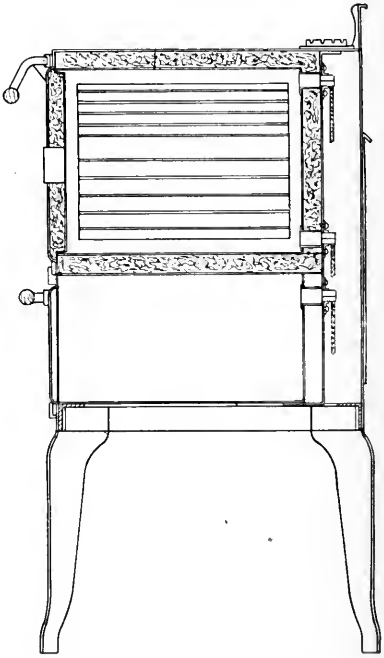


Fig. 4. Cross Section of an Electric Range

The insulation must also have a high thermal resistivity. This is important when the oven is used for longer operations, such as baking bread, roasting meats, etc.

An investigation of known materials discloses that low specific heat and high thermal resistivity are not ordinarily found in materials embodying the other requirements. In fact, they seem to fall at opposite ends of the scale of material characteristics.

The lining of the oven presents another separate problem. A material that will not readily rust nor oxidize, and a construction which will not warp at high temperatures must be used. The heat storage capacity is very important. A 0.024 in. steel lining for an 18 in. by 18 in. by 14 in. oven will require 260 watthours to raise its temperature 225 degrees C. This is a high percentage of the total energy required for most oven operations. A suitable finish for the lining is also a difficult problem. The matter of assembling the vent tubes, the duct for electrical connections, and the lining itself so that it may be readily replaced, must be carefully considered.

The oven door should fit sufficiently snug to prevent fumes coming out about the edge. These fumes are not only objectionable in general, but discolor the range and cause trouble by condensation.

Most persons who are unfamiliar with the electric range do not appreciate the need of adequate ventilation; they are apt to think of it as a fireless cooker. Many baking operations require some ventilation, in order to properly "brown"; the *excess* moisture must be eliminated or things baked may be too soggy. All ovens should be provided with approximately 1-in. vents with close-fitting dampers. Broiling always creates a great deal of smoke and vapor which should be allowed to escape from the compartment as generated. A 2-in. vent is barely large enough for best results. A damper is not necessary in the broiler flue. All flues should connect with a flue chamber which in turn should be provided with a standard fitting to facilitate piping to a chimney when desired. It is important that the pipe fitting be designed and located so that fumes and vapors will be directed away from the wall in case the range is not piped to a chimney.

Control of Heating Units

Provision must be made for connecting the heating units to the electric circuit and for controlling their temperature. For the connection of units a special cable is required. The insulation must have a high dielectric strength, it must be impervious to moisture and unaffected by temperatures too high for rubber, and must withstand considerable mechanical abrasion.

Fig. 5. Electric Range with Four Eight-inch and Two Six-inch Hot Plates, Two Ovens with Two Units Each, and a Warming Closet. All units are of the three-heat type

Rather than mount switches directly on the range frame, it has been found advantageous to use an integral switchboard, which constitutes the complete electrical equipment except for the units.

Appearance

The electrical engineer is also required to consider the design from an aesthetic view point. Most women, in considering an electric range, give considerable thought to the effect it will have on the appearance of their kitchens. The range should therefore have a shape and finish that is pleasing to the eye, and it must not be a dirt catcher. Smooth sheet metal surfaces with plain, though gracefully curved castings, are more desirable than angular parts, or parts embodying elaborate ornamental designs. Plain white enamel splashers add to the attractiveness.

Arrangement

Except where floor space is at a premium, the cabinet type is by far the most popular design. With this construction ranges must be made with the oven on either the right- or left-hand side of the cooking top. The warming closet should be adjacent to the oven, as it is usually dependent on the thermal conduction from the oven for its source of heat. An ideal arrangement consists of the warming compartment above and the broiling compartment below the oven. The cooking top should be smooth.

Fig. 6. Method of Attaching Plug to Hot Plate

An outlet receptacle for attaching miscellaneous kitchen appliances—which has proved a great convenience—should be provided at the end *opposite* the oven. This is important, as the range is usually placed with the oven adjacent to a wall, and it would be very inconvenient to get at that end to attach a plug; nor would a standard cord reach an ironing board placed at a convenient distance from the range.

Easy to Keep Clean

An electric range which is kept clean will create favorable comment of itself. Every effort should be made to construct the range so that it may be readily cleaned. Corners, cracks, ornamental figures in castings, an excessive amount of nickel finish, a shelf beneath the range, etc., increase the difficulty of keeping the range clean. The oven should be constructed so that dirt, which tends to collect in the bottom, may be readily removed.

A shelf beneath the range is invariably made the handy place to keep kettles, pots, pans and miscellaneous utensils. Such a place is not in keeping with the appearance of an electric range, and should be omitted in the construction of the range. It is also difficult to clean both the shelf and the floor beneath it.

Connection of Units

It is important that all heating units be connected in the simplest manner to facilitate cleaning, changing units, locating trouble, and making repairs. An ordinary attaching plug has proved the most satisfactory connection. With this detachable connection any person can remove, exchange, or replace any unit in the range. Such a construction permits central stations to replace defective units through the parcel post at a cost of a few cents, instead of at the expense of an electrician's services. This feature is of especial importance in localities where customers are scattered over a large territory, and where ranges are more generally sold. If units are permanently wired in, the services of an electrician are required to made changes or repairs.

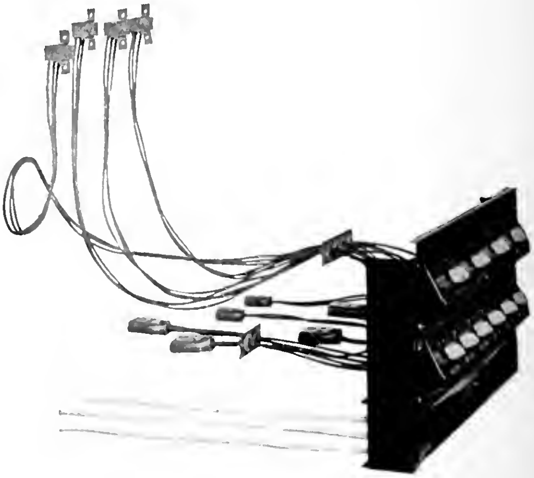


Fig. 7. Switchboard and Connections for the Range Shown in Fig. 5

Separately Fused Units

Though the underwriters do not require that the individual heating units be separately fused, the practice has been found essential to satisfactory operation. It is a serious matter to have the whole range "off" during the preparation of a meal on account of trouble with a single unit. Any cook will manage to complete a meal without serious difficulty with one unit out of order; but if the whole range goes "off" it will require the service of an experienced "doctor" from the central station to get her back to an agreeable frame of mind. Most people will tolerate a certain amount of inconvenience to gain a particular end, but refuse to endure irregularities that interfere with their meals.

Again, separately fused units enable anyone to test any heating unit for open-circuits and grounds. This may be done by inserting an ordinary electric lamp in place of the line fuse and turning the unit to low heat. If the lamp does not light when the fuse connected to the neutral is loosened, the unit is not grounded. Then, if the lamp glows when the fuse is tightened, the unit is "OK" electrically.

This test is based on the assumption that both the range frame and the neutral or one side of the line are grounded. This provision is a very important feature, as the condition of any unit can be determined without the aid of a testing equipment, and without removing the unit from the range. This is a big asset in the mind of the repairman, whose opinion is of no small moment in determining the general attitude of a central station towards a particular type of range.

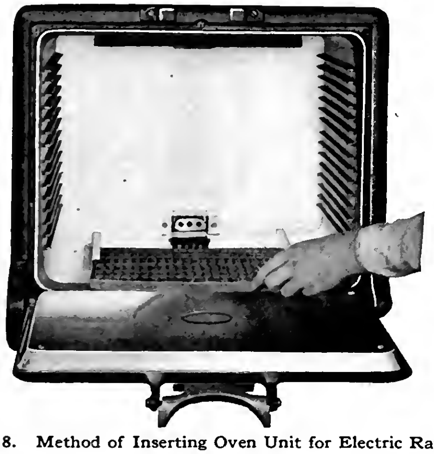


Fig. 8. Method of Inserting Oven Unit for Electric Range

Interchangeable Units

A three-heat open-coil unit should be used in the top of the oven, the bottom of the oven, and the broiling compartment. With the plug connection this enables anyone in the household to interchange the units. The importance of this feature can be appreciated only by those who have been called on to console a customer whose range did not have interchangeable units, and in which the oven unit or broiler unit failed during the preparation of a Sunday dinner. If the broiler could have been substituted for the baking unit, or vice versa, the annoyance would have been avoided.

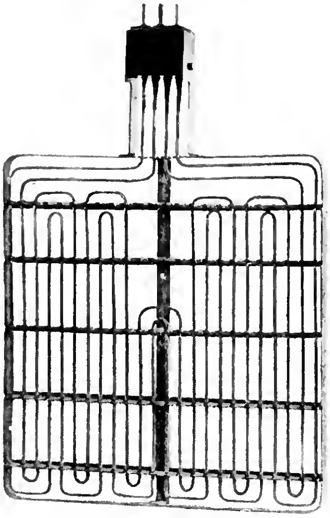


Fig. 9. Oven Broiler Unit

With interchangeable units the central stations need to carry but one style of unit. All confusion which may occur in selecting a particular type of unit is eliminated. There is no possibility of a customer or a repairman putting a unit in the wrong place, with the resulting unsatisfactory service to the customer before the difficulty is discovered. It is likewise desirable to have all units for the cooking top interchangeable as to location, regardless of their size or wattage.

The Importance of Grounding

It has been found that when the neutral is not grounded at the range, a potential of several thousand volts may occur between the wiring and the frame from lightning or other unusual conditions. Tests on actual circuits show that potential strains in excess of 750 volts occur quite frequently.

When used on a grounded system, it is best to connect the grounded busbar direct to the range frame, and to ground the frame to the nearest water pipe. This eliminates all possibility of the operator getting shocks from the range, and reduces the liability of trouble due to electric surges.

It is plain that with a range grounded as specified, the maximum voltage between the wiring or heating element and the frame is limited to the amount required to force the surge through the impedance of the wiring and element.

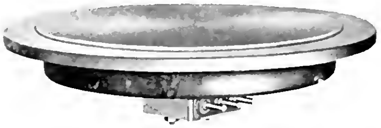


Fig. 10. Eight-inch Cast-in Sheath-wire Hot Plate (all metal)

Except in the case of a direct stroke of lightning, or its equivalent, this method of grounding will protect the insulation of the wiring and prevent the units burning out due to an arc to the range frame.

By grounding the neutral or grounded line at the range, and thereby eliminating the voltage due to a surge passing through the reactance of the line back to the transformer ground, the potential at the range to ground is greatly reduced.

HEATING ELEMENTS

Oven Units

The open-coil sheathed wire oven unit has proven the most durable, practicable, and efficient type that has been developed.

With separate three-heat control of both the top and bottom units, the most efficient oven is the one with a minimum thermal storage. The sheath wire heating unit comes to a temperature above that required for baking during the first few seconds after the current is turned on. Thereafter, all additional energy is effective in heating the air in the oven.

The amount of energy required to pre-heat such an oven is that which will bring the air in the oven to the temperature required for best results. If an oven or an oven heating unit is designed with massive parts which must be brought up to a high temperature before the air will reach a baking temperature, that oven must have a low efficiency. This feature of construction is extremely important for such operations as baking biscuit, muffins, etc., where a relatively small amount of energy is required for actual baking. If the air in an oven is up to the required temperature good results are obtained.

Hot Plates

The most practical hot plate is the one which will give the best service under average operating conditions. Speed, efficiency, and ease of cleaning are prime requisites. With the same input, speed and efficiency depend on the same characteristics of design. A person may place his finger very near the bottom of a hot flatiron without getting burned; but the instant actual contact is made a sufficient amount of heat is instantly transferred by conduction to cause a serious burn. The importance of conduction in the efficient transfer of heat was recognized in the design of the cast-in sheathed wire unit. It has been found that this type of unit gives the best average efficiency.

Hot plates which depend on convection and radiation for the transfer of heat require carefully selected dishes for the best efficiency. For example, it is not possible to boil one pint of water in a small uncovered aluminum sauce-pan placed in the center of a 7½-in., 1500-watt open grill type unit. However, if the bottom and sides of this dish are painted black, the water will boil in about 23 minutes. Some manufacturers of "radiant" type units have found it advisable to recommend that their customers paint the bottoms of their kitchen utensils black. They show figures to prove that for such operations as boiling two quarts of water 25 per cent more energy is required for clean-bottomed dishes than when a dish with a black bottom is used. The use of bright, clean-bottomed utensils on cast-in hot plates does not decrease their efficiency.

For operations requiring only a short time and a small amount of energy, there is a slight difference in efficiency in favor of the radiant type unit over the cast-in type. However, the saving of energy due to higher efficiencies where small total amounts are involved is negligible compared with the saving by a cast-in unit where a large amount of energy is involved.

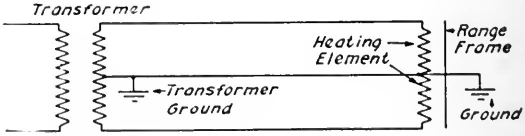


Fig. 11 Diagram showing the Grounding of the Neutral and the Range Frame

Since the radiation of heat varies with approximately the fourth power of the temperature of the radiating body, a unit based on this principle has a very low efficiency when operating at low heat. The amount of heat transmitted by conduction from a heated body varies directly as its temperature. The efficiency of a cast-in unit is, therefore, not appreciably reduced when operated at low heat. This distinction is an important feature in favor of the cast-in unit, for in the preparation of a meal the low heat is used a great deal.

The cast-in unit is, without doubt, the most rugged and indestructible unit yet designed. It is also the easiest to keep clean; it is odorless and sanitary, and is thereby in keeping with the other advantages of electric cooking.

Fig. 14. Detail Parts of the Electric Cooker

Insulated Cooker

The electric cooker is a deep vessel of special construction to retain the heat, and is located in one or more of the rear holes in the cooking top of the range. It is covered by a lid which fits in the hole of the cooking top.

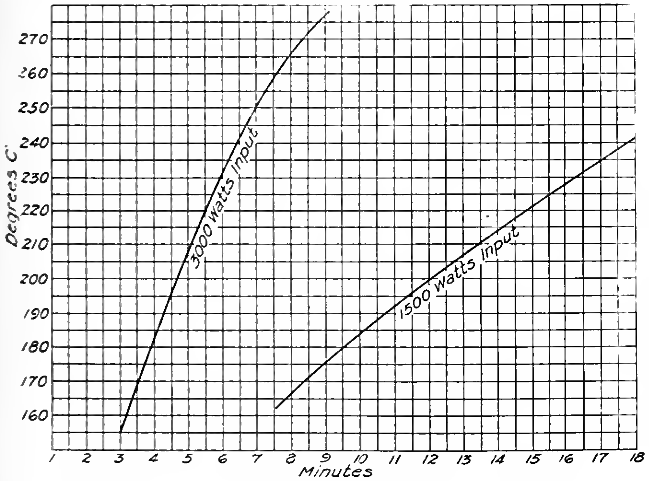


Fig. 12. Time to Preheat a Standard Oven 18 Inches by 18 Inches by 14 Inches

It contains an aluminum cooker pail having a wire handle so that it is easily removed from the cooker. Inside this pail is a perforated bottom rack on which potatoes, etc., are placed to be steamed. A tightly fitting cover prevents the escape of steam from the pail so that the vegetables are cooked with better results than if allowed to soak in boiling water.

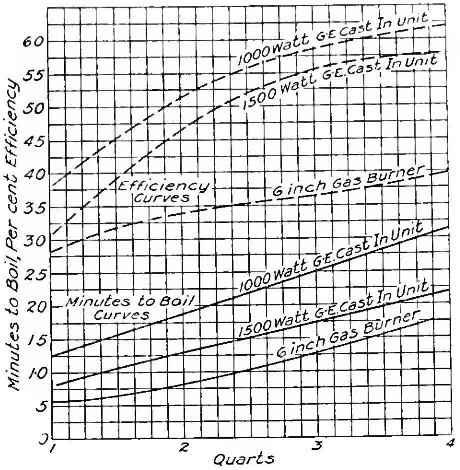


Fig. 13. Minutes to Boil and Efficiencies on Different Hot Plates and a Gas Burner Using a Four-quart Cast Aluminum Kettle

The cookers require very little current, and are useful for preparing stews, vegetables, puddings, pot roasts, cereals, etc., which require steaming or slow boiling.

Cost of Electric Ranges

Most persons have been unable to account for the high cost of electric ranges. In fact, many who are interested in the progress of electric cooking, in comparing the cost of gas ranges with electric ranges, overlook the vast amount of additional equipment required for the electric range, such as hot plates, oven units, broiler units, vegetable cookers, switches, fuse plugs, fuse blocks, special cable, terminals, bushings, connection plugs, oven insulation, etc. To offset this there are only cheap cast-iron burners on the gas range. On account of the increased weight, the electric range must be mounted on a substantial angle iron frame; the whole construction must be more sturdy than for gas ranges. Again, a higher quality of workmanship is demanded on an electric range.

Direct Current Aluminum Lightning Arresters

By V. E. Goodwin

Lightning Arrester Engineering Department, General Electric Company

The direct current aluminum lightning arrester finds its principal application in the protection of street railway equipment. While it was not uncommon to find from 5 to 10 per cent of a railway company's cars out of commission after a severe electrical storm some years ago, the table on page 893 shows that since the introduction of the direct current lightning arrester only a very small percentage of motors protected by this device are damaged. When we read that one Massachusetts company had 78 armatures damaged by lightning and other electrical disturbances during the summer of 1916, with an average expense for repairs of $50, and compare this with item No. 3 where 181 arresters have been installed over a period of five years with no damage to motor equipment by lightning, there appears no justification, economical or otherwise, for failure to install this type of protective apparatus.—Editor.

A few years ago it was not uncommon for electric railway repair shops to find 5 or 10 per cent of the company's cars out of commission after a severe electrical storm. In order to avoid these failures some companies were forced to employ the expedient of shutting off the power from the lines and pulling down the trolleys on all cars which were in service.

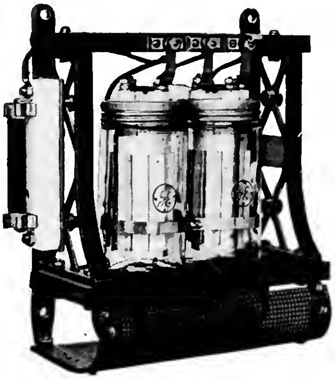


Fig. 1. 600-Volt Direct Current Aluminum Arrester for Station Service

Ten years of experience in service and a longer period of laboratory investigation with the direct current aluminum lightning arrester has done a great deal to relieve this troublesome situation. In fact, where direct current railway equipments are properly equipped with these protectors failures during electrical storms are very rare. Figs. 1, 2, and 3 illustrate some of the forms of this type of arrester.

Fundamentally, the arrester is a combination of excess voltage and high frequency absorber. The films on the plates are formed up to the critical voltage governed by the maximum operating voltage of the system. At voltages below this value the cells are excellent condensers of large capacity. When normal d-c. voltage is impressed a small leakage current flows to ground, which is of the magnitude of one milliampere for each arrester. If an abnormal disturbance of high frequency should occur on the circuit the arrester will allow much larger currents to flow to ground, this discharge current being nearly proportional to the electrostatic capacity and varying as the applied frequency. Since the arresters are in parallel with the motors and other car equipment this feature of the aluminum cell affords an ideal by-pass for high frequency disturbances.

With a disturbance of higher voltage, i.e., voltages above the critical film value, the valve action of the film comes into play and the cell acts like a safety valve on a steam boiler and allows the excess portion of the voltage to go to ground, the discharge being limited only by the internal resistance of the cells.

A consideration of this problem of protection always involves a clear differentiation between normal and abnormal conditions. In the case of the former we have a condition involving a large amount of energy and a reasonably constant voltage and frequency; with the latter we have small and often minute quantities of energy suddenly induced in the form of high voltage or high frequency,

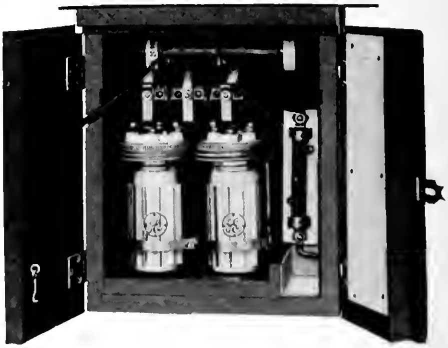


Fig. 2. 600-Volt Direct Current Aluminum Arrester for Car Service

or combinations of both of these distorting elements. The duty of the arrester is therefore to separate these two elements by removing the undesirable ones without in any way affecting normal operating conditions. The direct-current aluminum arrester is the only protector yet developed which practically fulfills these requirements.

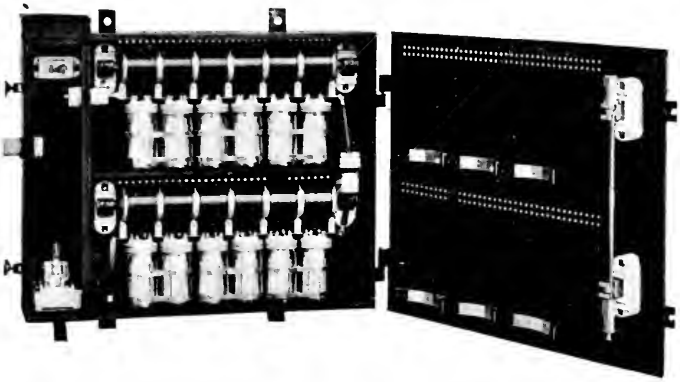


Fig. 3. 3000-Volt Direct Current Aluminum Arrester for Station Service with Series Expulsion Type Operating as Disconnecting Switch

The following tabulation gives the service records of these arresters on several systems. The record is not entirely complete in that it does not show all of the cars damaged by lightning previous to the installation of the aluminum arresters.

The figures in the last column show quite a variation in the annual maintenance expense per arrester. In most cases they include installation in the spring, weekly or monthly inspections, repairs, removal in the fall, and storage in the winter. On some of the southern systems lightning may occur the year round, and hence the arresters are not removed during the winter months. In these cases the expense of removing and storing the cells is avoided, but of course a slightly higher repair expense is incurred.

The cells of this aluminum arrester are connected directly to the circuit and consequently have full line voltage applied while in service. Like all electrolytic cells, there is a constant though slight deterioration going on at all times. The rate of wear on the

Railway Company	No. of Cars	PROTECTION			Years of Service	CARS DAMAGED BY LIGHTNING		Lightning Conditions	Annual Cost of Maintenance per Aluminum Arrester
		Al Arrester	Years of Service	Other Types		Al Arrester	Other Types		
No. 1	44	44	3	0	—	1	—	Very severe	$0.75
No. 2	170	83	4	87	5	0	45	Very severe	1.30
No. 3	2000	181	5	1164	5	0	688	Severe at times not segregated	
No. 4	23	23	4	0	—	0	—	Bad	.50
No. 5	42	40	4	1	4	3	No record	Not severe	1.93
No. 6	90	90	4	0	—	2	—	Severe	3.00
No. 7	40	40	5	0	—	0	—	Very severe	1.40
No. 8	13	13	2	0	—	2	*	Severe at times	.25
No. 9	24	24	3	0	—	0	*	Severe	No record
No. 10	97	81	7	0	—	0	No record	Severe	.90
No. 11	108	108	3	108	2	0	49	Severe	No record
No. 12	25	25	4	0	—	0	—	Not severe	No record
No. 13	65	65	2	0	—	3	—	Very severe	No record
No. 14	72	72	4	0	1	1	† 30	Severe	1.00
No. 15	50	17	1	33	2	0	30	Severe	1.45
No. 16	167	66	4	101	5	0	55	Severe	1.85

* Previous to installation of aluminum arresters, trolleys had to be pulled down and cars stopped during storms because of frequent damage to motors.

† Year previous to installing aluminum cells.

plates and electrolyte depends upon the service to some extent, but principally upon the operating temperature and line voltage. Under ordinary conditions the life of these parts is from two to four years, or even longer.

Even under the worst conditions this maintenance expense is small compared with the saving in maintenance on car equipments. As an example, we might cite a case in Massachusetts where a company lost 78 armatures by lightning and other disturbances during the summer of 1916. The repair of these armatures required an average expense of fifty dollars, to say nothing of inconvenience to the public and the loss of service and prestige to the company. Assuming conservatively that the use of aluminum arresters would have eliminated half of these troubles, the saving of $1900 would have more than paid for 100 arresters during the first year.

This same type of arrester is serving as a by-pass protector for feeder regulators and fields of large alternating machines. It has also proven to be effective in preventing flash-overs on rotary converters as the result of high frequency disturbances. Very little has been published about this arrester and this brief summary of its operating records should be of interest to railway operators.

Developments in Switchboard Apparatus

Polyphase Induction Reverse Power Relays

The reverse power relay shown in Fig. 2 is constructed along the lines of an induction watthour meter—simple and strong.

The operating characteristics are permanent.

The torque is high and the power to operate is small.

There is practically no vibration even at heavy currents.

The reverse power relay is made in single-pole units and with circuit closing contacts. Instantaneous or time delay trip can be obtained. If time delay action is desired the time and current setting of the overload relay which must be connected in series with the reverse power relay contacts will determine the action of the combination.

The relay is operated by three separate driving elements, each having a current coil and a potential coil, irrespective of whether used for quarter or three-phase circuits. The third element is required for delta or ungrounded *Y* circuits in order that each phase may be properly represented in every short circuit. If but two elements were used many single-phase troubles would involve only one of these elements and the benefit of polyphase action would be lost. Although only one element may be involved in case of a ground on a grounded *Y* circuit, the voltage triangle will not have become so badly

Fig. 1. Relay

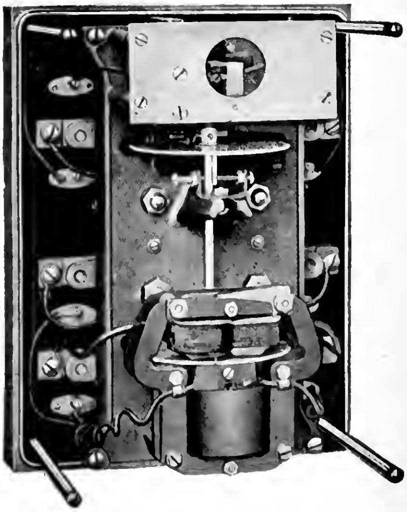


Fig. 2. Relay with Cover Removed

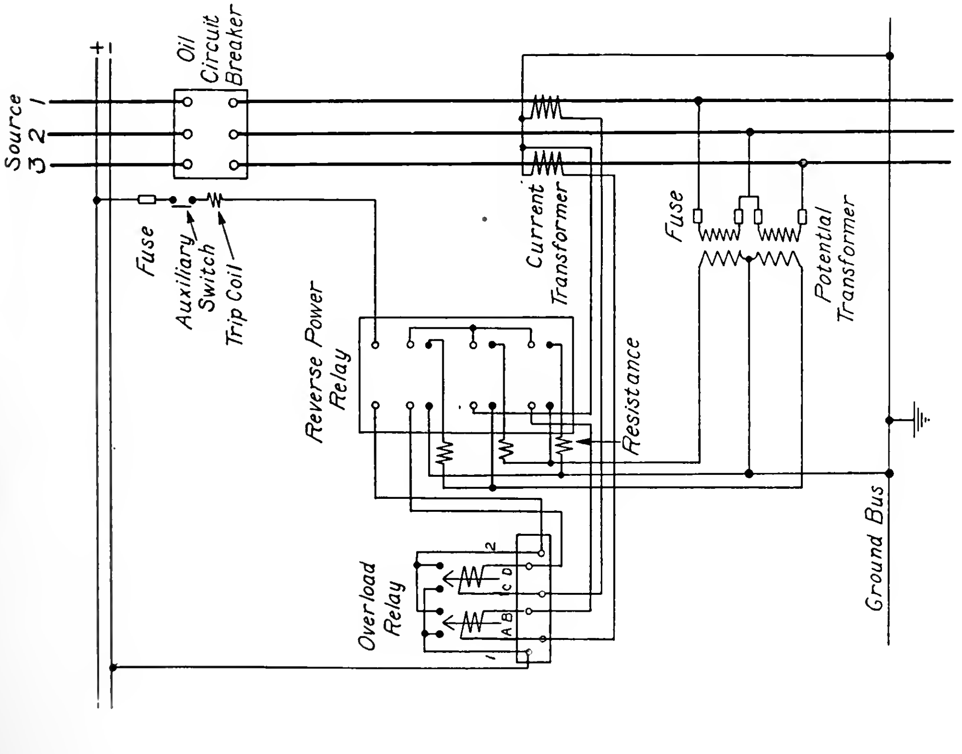


Fig. 3. Connections for Three-phase Circuit, Neutral Not Grounded

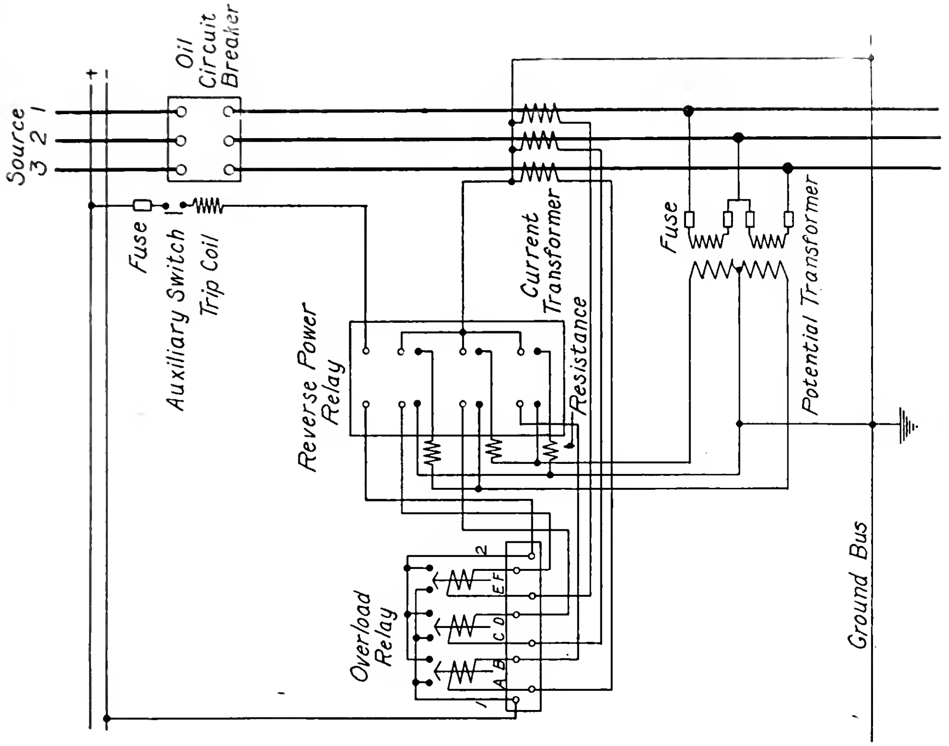


Fig. 4. Connections for Three-phase Circuit, Grounded Neutral, when Two Potential Transformers are Used

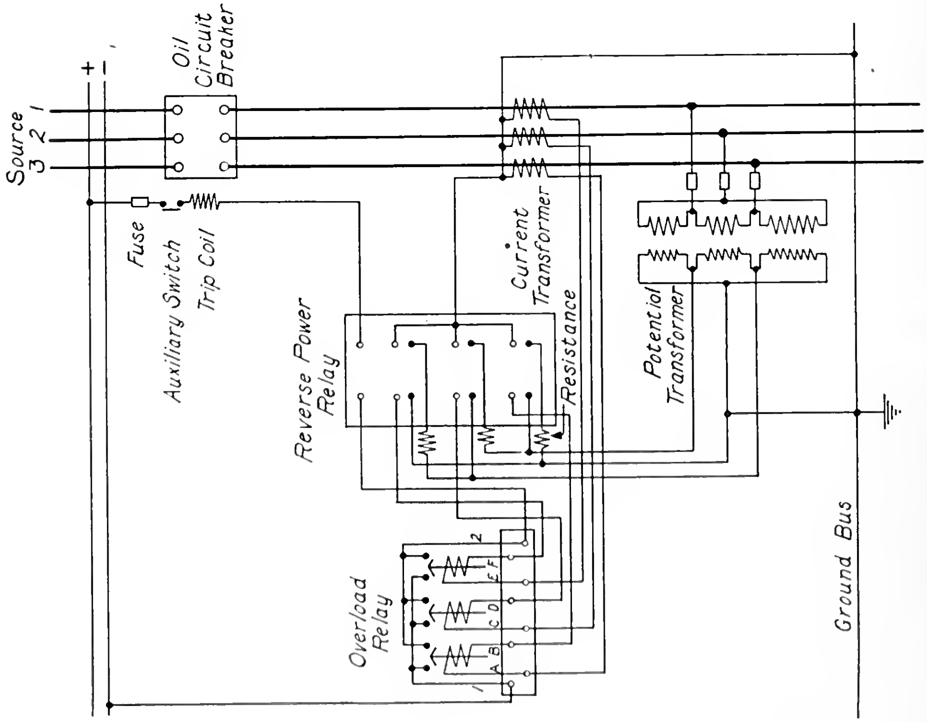


Fig. 5. Connections for Three-phase Circuit, Grounded Neutral, when Three Potential Transformers are Used

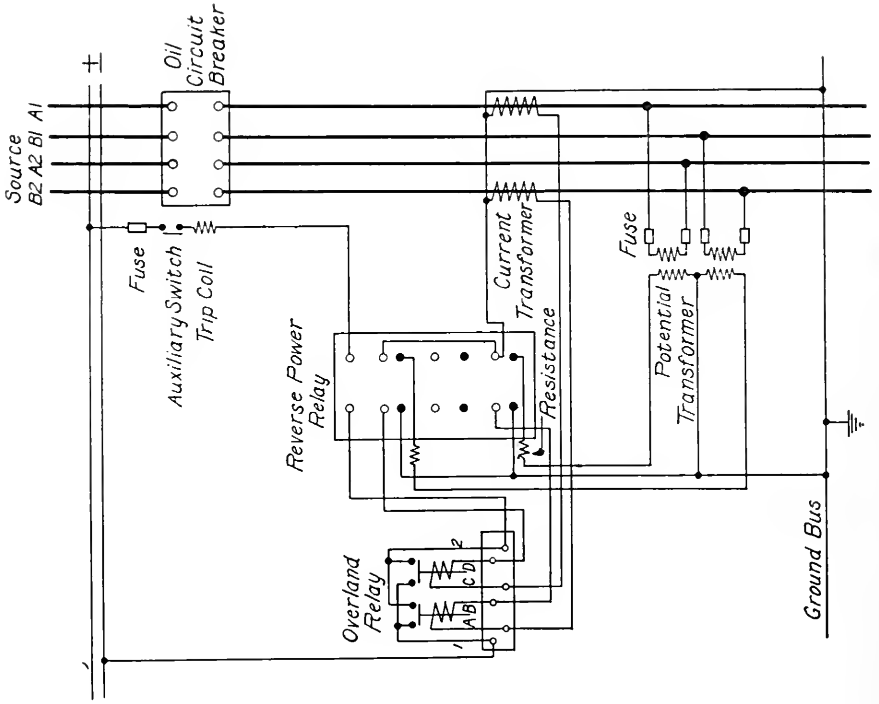


Fig. 6. Connections for Two-phase Circuits

distorted as when a single-phase line-to-line short exists.

For delta or ungrounded Y circuits two current and two potential transformers are sufficient. The third current coil carries the resultant current of the two current transformers and the third potential coil is connected across the open delta of the two potential transformers.

The polyphase construction makes the action of the relay more reliable than could be obtained by means of three single-phase relays because of the fact that any incorrect tendency on the part of one phase is balanced by a similar but opposite incorrect tendency on some other phase. The incorrect tendencies being balanced out, the true power direction will not be overpowered.

The driving elements are all connected to a single vertical shaft with two horizontal disks. The upper disk is driven by one element and the lower disk by the two remaining elements, one in front and the other in back of the relay.

One set of contacts is opened or closed, depending upon the direction of rotation of the relay shaft.

Under normal direction of power the disks tend to rotate to the right and allow the contacts to remain open. Reversal of direction of power flow causes the disks to rotate to the left and close the main contacts. These contacts are automatically relieved of the tripping current by the heavier contacts of an auxiliary relay inside the case. This auxiliary relay, which closes instantly, remains automatically locked in contact by its actuating coil as long as the tripping current flows. Although the main contacts carry the tripping current for only an instant, they are for additional safety constructed of heat-resisting metal. The relay, when properly installed, will operate correctly on practically all single-phase short circuits, even though the voltage between two lines which are short-circuited may fall to zero. The relay will operate correctly on balanced three-phase short circuits with 10 amperes secondary and one percent normal voltage remaining. The relay will operate properly in practically every case for balanced short-circuits, with a voltage of one-half per cent normal. When voltage falls to such a low value, however, system conditions are apt to be distorted so that positive operation cannot be assured in every case with any type of relay.

The polyphase relay should not be used on systems having the neutral grounded, except after proper investigation, unless two or more parallel lines are involved and the relays are interconnected in a balanced group. In such a case the power currents are balanced out and the faulty current controls the operation of the relay.

Figs. 3 to 6 show approved methods for wiring the relay. Other methods which are electrically equivalent and which for particular installations may result in more convenient or economical wiring are possible. Connections differing from these are sometimes called for in combinations of several devices and on diagrams showing switchboard wiring.

Overload relays connected as shown are necessary to prevent the reverse power relay from tripping the circuit breaker except when power reversals of definite magnitude occur. The contacts of these relays are connected in series with the reverse power relay contacts. Any type of overload relay may be used, but a plunger type relay is recommended when instantaneous action is desired.

An auxiliary switch which will be opened by the tripping of the circuit breaker must be connected in series with the tripping studs of the reverse power relay, provided the overload relay contacts are not capable of breaking the tripping current.

A resistor must be connected in series with each potential coil as shown in the wiring diagram. For this purpose three resistors of 500 ohms are furnished with each relay, for use on circuits of from 25 to 60 cycles.

The relays are designed for use in the secondary circuits of potential transformers for voltages above 600, and in the secondary circuits of current transformers having a normal rating or continuous current carrying capacity of 5 amperes.

The current coil of each element requires but 5 volt-amperes and the potential coils take 30 and 35 volt-amperes for 60 and 25 cycles respectively.

Outdoor Fuse and Disconnecting Switch for Vertical Mounting

A combined disconnecting switch and fuse has been employed extensively in connection with small outdoor apparatus on transmission lines operating up to 4500 volts.

The combined fuse and disconnecting switch is used nearly always to protect transformer banks where no switches on the primary side of the transformers are required. The fuse is suitable for opening exciting current of transformer banks not exceeding

300-kv-a. in capacity. Secondary switches should always be provided so that the load can be removed by means of these switches in case it should become necessary to open the primary side in which the fuses are connected.

Fig. 7. Combined Fuse and Disconnecting Switch

The switch shown in Fig. 7 is made in single-pole units only and should always be mounted in a vertical position. A hook is provided for opening or replacing the fuse holder. To open the circuit the holder is lifted completely out of the contacts by the fuse hook; then, if desired, the upper end of the fuse holder may be inserted into and hung from the lower contact clips. To close the circuit the upper contact of the holder is placed in the upper clips by the operating rod and then the lower contact is pressed into the lower clips by the hook.

The construction of the fuse holder supports is such that the entire operation is simple and easily completed.

The fuse holder is constructed of built-up porcelain petticoat insulators so spaced as to provide ample creepage surface. These contact parts at the ends of the fuse holder are of brass, and when the holder is in normal operating or closed position they engage with the stationary contacts on the supporting insulators.

The contacts are protected against the affects of ice, sleet, and snow by mounting them at an angle and by means of a punched hood attached to the top of each insulator.

The fuse passes through the center of a specially treated fiber tube within a porcelain fuse holder. The fuse is attached to the upper or closed end of the fuse holder by means of an adjustable clamp, and to the lower or open end of the fuse holder by a ring which, when tightened, holds the fuse firmly in place without the possibility of its shearing off. The cross section of the fuse is less near the closed end of the fuse holder than at any other point and melts here when an overload occurs. The explosion consequent upon the expansion of the gases formed, effectively expels the arc downward through the open end of the holder and instantly opens the circuit. New fuses may be readily inserted.

This fuse and disconnecting switch is made for 15,000, 22,000, 35,000 and 45,000 volts. The maximum current rating is 50 amperes.

No special arrangements are needed for mounting. The unit is bolted to the cross arm.

Some General Notes on the Protection of Eyesight

By W. S. Andrews

Consulting Engineering Department, General Electric Company

Ether vibrations between the limits of 3900 and 7600 Angstroem units create the impression of light, but on each side of this band of the spectrum are vibrations which, while they are not visible, may injure the eye. The longer, or heat, rays emanating from such mechanical operations as electric welding and furnace work should be guarded against by the use of an appropriate shield. A table is given showing the heat absorption properties of a number of substances that are available for the purpose. With visible light, three conditions are injurious to eyesight, namely, intense glare, insufficient light and flickering. The rays at the other extreme of the spectrum, which are commonly known as ultra violet rays, are most injurious to the eye, and are specially dangerous because they do not make themselves manifest through visibility or other sensation. Fortunately, the more injurious of these rays are completely absorbed by moderate thicknesses of ordinary glass, and where the existence of such rays is suspected ample protection may be obtained by goggles provided with common glass windows. Lenses made of clear quartz, however, do not intercept the ultra violet rays.—Editor.

It is commonly known that visible light is a sensation produced in our eyes by vibrations or waves in the ether of space. These waves are so exceedingly minute that their length from crest to crest is generally expressed in "Angstroem Units," each unit being one ten-millionth part of a millimeter.

Ether waves that measure 7600 to 6500 A.u. from crest to crest are manifested to the eye as red light, and those that measure 4200 to 3900 A.u. are seen as violet light. Between these extreme limits of wave-lengths we find visible light of all the colors in the rainbow, the blending together of which in daylight produces what is known as white light, being thus named because it shows all objects in their true colors. Light that is artificially produced by flame or incandescence usually contains a preponderance of red and yellow rays, so that it does not show colors as correctly as does daylight.

Just as there are no sharp lines of definition between the different colored bands in the rainbow, so also do visible and invisible radiations gradually merge one into the other; and for convenience it may be roughly stated that the average human eye perceives visible light between wave-lengths from 7600 to 3900 A.u.

Ether waves that measure more than 7600 A.u. (up to about 3,000,000 A.u.) constitute the infra-red or heat rays, and those that measure less than 3900 A.u. (down to about 500 A.u.) are known as ultra-violet rays. We have, therefore, three divisions of radiation under consideration that are manifested respectively as infra-red or heat rays, visible light, and ultra-violet rays, the first and last being invisible. All of these radiations which have a common origin in the almost unthinkably minute waves in the universal ether, differ from each other only in wave-lengths and frequency, but yet they affect our senses very diversely. Let us, therefore, proceed to examine their physiological effects with special reference to safety of eyesight.

Infra-red or Heat Rays.

The greater part of the radiation from the sun consists of invisible heat rays; but as these are also accompanied by very bright light rays, the direct influence of which the eye naturally avoids, no special protection is required excepting under unusual conditions.

In various mechanical operations, however, such as in furnace work, iron welding with the electric arc, etc., the operator should carefully guard his eyes against heat rays by some appropriate shield. Various kinds of glasses are sold for this purpose, some of which are wonderfully efficient in absorbing heat rays while they are fairly transparent to visible light. Dark mica also makes a very efficient screen for heat rays but it also absorbs a large percentage of light. Ordinary clear glass absorbs some amount of heat, but it is not sufficient protection against any intense source.

TABLE I

Material of Screen	Thickness in Inches	Percentage Heat Absorbed
Clear white mica	0.004	19
Clear window glass	0.102	26
Flashed ruby glass	0.097	31
Blue glass	0.093	57
Emerald green glass	0.100	64
Dark mica	0.004	67
Corning G124J glass	0.095	90

Table I shows the heat absorption of different glasses and mica as based on recent tests. However, owing to the fact that glass varies very much in its chemical constituents, as well as in its depth of coloration, the figures presented can only represent general approximate results. The thickness of the material also naturally influences its absorptive power, although not in a direct ratio. It is worthy of note that dark mica only 4/1000 of an inch thick absorbs heat rays better than green glass that is 1/10 of an inch thick. The source of heat used in this test was a 200-watt gas-filled tungsten lamp operated at a little below normal voltage.

As the surface of our bodies is sensitive to heat rays, we are thereby warned; but it is to be remembered that the delicate tissues of the eye are more liable to be injured by these rays than the coarser tissues of our skin, and common prudence will dictate a reasonable amount of precaution, when the eyes are exposed to heat rays, especially if these rays feel uncomfortable to the skin.

Long continued proximity of the eyes to even moderate sources of heat may easily produce bad effects by cumulative action. In this way, glass workers who operate with unprotected eyes near to their gas jets are subject to cataract which might be entirely prevented by the use of protecting goggles.

Visible Light

There are three very important features in connection with visible light that should be carefully avoided to preserve good eye sight; viz., intense glare, insufficient light, and flickering. A very bright light naturally exerts a great strain on the delicate muscles of the eye, which endeavor to contract the pupil abnormally to shut out as much as possible of the glare, and under this condition the eye soon gives warning of fatigue. Also, reading or working in a dim light such as twilight can only be done at a risk of injury, as in this case the muscles of the eye are strained to expand the pupils to the fullest possible extent. With a flickering light these effects are greatly aggravated, as the involuntary muscles of the eye try to keep pace automatically with the variations in brightness, and eye strain of more or less severity ensues. A flickering light above all things should be avoided in reading, or in fact in doing any work requiring the continuous use of the eye.

In all mechanical operations that involve the use of high temperatures and consequent intense glare, suitably colored glasses should always be worn. Many different kinds of glasses have been put on the market by manufacturers; and, in selecting from these, it should be borne in mind that the particular shade and depth of coloring which gives the *clearest definition combined with sufficient obscuration of glare* should be chosen. The selection must therefore be necessarily governed by the character of the work and the intensity of the light; but as the eye is more sensitive to yellow-green light than to other combinations, it will generally be found that glasses inclined to this shade will give the best results. When used for protection against very bright light, such as that produced in electric arc welding or in the manipulation of melted quartz, etc., a smoky effect is usually introduced into the glass to help the absorption. Certain tints of dark mica have been found particularly effective in this respect, and this material is all the more valuable on account of its efficiency in absorbing heat rays as previously noted.

Special optical glasses are now commonly employed in goggles that are used for small work, but in heavy welding operations with large current it is necessary to protect the entire face and neck from the intense radiation produced; and in this case masks made of light vulcanized card or fiber are employed, having comparatively large openings through which to see the work. The expense of fitting these large apertures with special optical glasses is considerable, so combinations of ruby and green glass plates are in common use and have proved to be an economical and effective substitute. Combinations of ruby and blue glass have also been tried for this purpose, but better definition and general good results are to be attained with the red-green combinations. If dark mica can be procured of a proper size and uniform in tint and thickness, it would constitute a very effective material for use in masks; but for mechanical reasons, it would necessarily require facing on both sides with sheets of clear glass.

In standardizing glasses for various operations, it is to be emphasized that the main features to be considered are the attainment of a maximum of definition with a sufficient diminution of glare, and certain color combinations fill these requirements, but the particular depth of tint may perhaps be best decided by the operator, as there is a considerable individual difference in acuteness of vision, thus making it impossible to lay down an exact standard for general use under definite conditions.

Ultra-violet Rays.

These are by far the most dangerous of all radiations to the eye, and the more so because they are not only invisible but also because we are unprovided by nature with any organ or sense for detecting them, so we know of them only by their effects. Fortunately, the most deleterious of the ultra-violet rays, i.e., those rays having a wave-length of about 3400 A.u. and less, are completely absorbed by a moderate thickness of almost any ordinary kind of glass, so that, when their existence is known, their harmful effects on the eye can be easily guarded against.

The electric arc between carbon and iron, and iron and iron, is one of the most prolific generators of these harmful rays, and operators on arc welding must necessarily be extremely careful in the employment of protective screens. Indeed, it may be stated that electric welding calls for eye-sight protection against intense heat rays, glare, flickering, and ultra-violet rays. Notwithstanding this fact, however, complete immunity from bad effects to the eyes of operators can be assured by the proper use of protective lenses. The masks that are commonly used by operators not only are necessary for the protection of the face and neck from direct dangerous radiations but for the protection of the eyes from reflected ultra-violet rays; these rays together with heat rays can be reflected from a surface in the same way as visible light, so that complete protection can only be assured by cutting off all light from the eye excepting that which passes through the lens.

For the same reason arc welding should not be carried on in an open shop or even behind screens closed only at the sides. The reflection of the vivid and flickering flashes from the walls and ceiling may easily affect the eyes of other operators who are not engaged in welding, and are therefore unprovided with any protective device.

The light from mercury-arc lamps is also rich in ultra-violet rays, but when these lamps are made of glass the rays are absorbed, thus rendering the light harmless excepting for the glare. When made of clear quartz, however, they should never be used excepting when thoroughly screened by suitable glass shades, or very dangerous eye trouble will be sure to ensue since clear quartz is transparent to ultra-violet rays. Spectacles or eye glasses made with so-called pebble or crystal lenses, (i.e., natural clear quartz) therefore afford no protection to the wearer; but the rays cannot pass through the ordinary lenses of plain clear glass.

Ultra-violet rays produce the effect known as "fluorescence" in certain chemical substances. When these substances are seen by a mixture of visible and ultra-violet light, such as that emitted from the iron arc, their apparent color is changed. Thus, soda salicylate in tablet form or in powder changes its color from pure white to a bright blue while it is illuminated by the mixture of rays, unless the visible light is so strong that it overpowers the fluorescent color. A high-tension disruptive discharge of electricity between iron points is an excellent source of ultra-violet rays for producing fluorescent effects, because it emits an excess of ultra-violet rays as compared with its visible light. A pebble or crystal lens can be readily distinguished from one of plain glass by this light, for if the lens is interposed between the iron spark discharge and a fluorescent substance, such as soda salicylate, the blue color will immediately vanish and the salicylate will assume its natural white; but if the lens is made of quartz, the blue fluorescence will remain unchanged.

Fig. 1. (A) Spectrum of Iron Spark
(B) Spectrum through Ruby Glass
(C) Spectrum through Green Glass
(D) Spectrum through Blue Glass

There are numerous substances that show different fluorescent colors under the influence of ultra-violet light, but soda salicylate is mentioned here because it can be procured at any drug store, whereas many of the other substances thus affected may be more or less difficult to obtain.

Fig. I shows the full spectrum of the visible light emitted by a disruptive iron spark discharge and also the absorption effects of various colored glasses when interposed between the spark and the photographic plate on which the spectrum is recorded.

It may be stated that the apparatus for producing ultra-violet rays as described and illustrated in the GENERAL ELECTRIC REVIEW, April, 1916, p. 317, is especially suitable for testing spectacles or eye glasses to ascertain if the lenses are made of natural quartz or ordinary optical glass.

Life In a Large Manufacturing Plant

PART IV. RESTAURANTS

This installment of the series is interesting as showing how engineering methods have been applied to a restaurant service where it is necessary to serve 1700 meals in approximately thirty minutes. It also illustrates what can be done in the matter of reducing costs by quantity production and a proper consideration to the buying of food stuffs. The price of the noon day meal at the Schenectady Works of the General Electric Company is twenty cents, and we are safe in stating that this is less by from 50 to 100 per cent than the cost of a similar meal at any of the popular lower price commercial restaurants.—EDITOR.

MENU

Roast Beef — Mashed Potatoes
Stewed Tomatoes — Bread and Butter
Milk (or Coffee)
Coconut Pudding
Price 20 cents

This bill of fare is typical of the noonday meal that is being served today to employees of the Schenectady Works of the General Electric Company. It is a full equivalent of the meals that were served in this restaurant five years ago, despite the steep increase in the cost of all food stuffs during this period. The ability to serve this meal today at the price in force five years ago is the result of skillful application of engineering principles in the kitchen and in the method of serving customers.

The following table, which was prepared by a food expert, shows that this midday meal provides one-third of the nourishment required for a day's hard work.

A Million Meals a Year

The figures below show that the popularity of this restaurant is increasing, owing as much to the improved facilities as to war conditions.

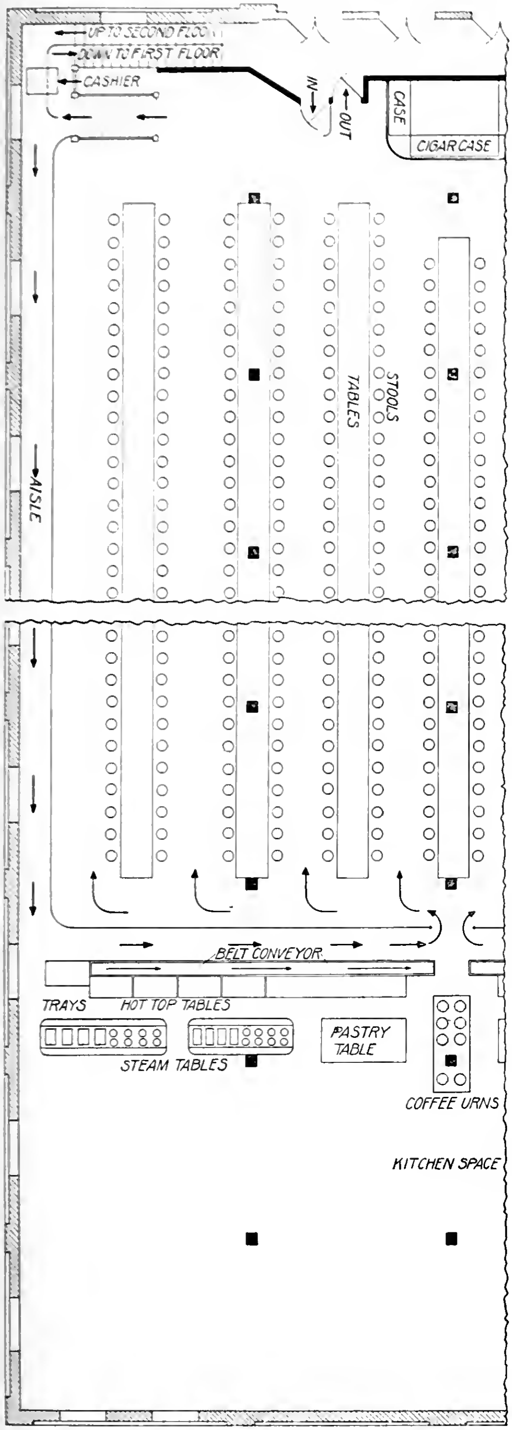
Year	Number of Employees in Schenectady Works	Number of Customers Served Annually
1908	11,359	324,377
1909	11,361	467,779
1910	16,462	626,178
1911	16,107	592,765
1912	17,487	611,525
1913	19,977	710,570
1914	16,823	580,081
1915	15,347	499,706
1916	20,985	707,415
1917 (9 months)	21,000	619,201

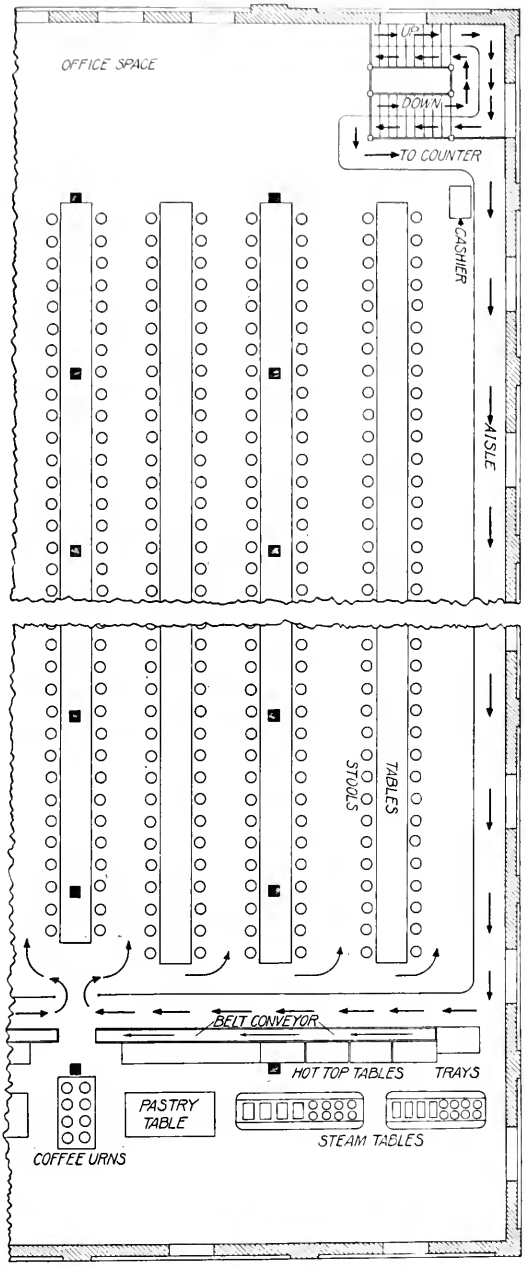
The meals for 1917 will probably amount to 800,000, as almost 20,000 meals were being served every week during September, 1917. If this rate is kept up without any further increase the year 1918 will show over a million customers.

CALORIES IN 20-CENT MIDDAY MEAL

Dish	Amount Oz.	Calories Protein	Calories Fat	Calories Carbohydrates	Total Calories
Roast beef	2.4	69	81	0	150
Gravy (brown sauce)	2	7	24	19	50
Mashed potatoes	5	13	80	75	168
Stewed tomatoes	2	5	2	18	25
Coconut pudding	3	17	46	45	108
Bread	2.25	20	8	112	140
Butter	0.5	0	100	0	100
Mug of milk	8	30	88	47	165
Sugar	0.136	0	0	150	150
Total	25.286	161	429	466	1056

Average calories needed daily by a man employing muscular strength........................3250
Number of calories in the 20-cent noonday meal at the General Electric Schenectady restaurant ..1056 or 32½%
If a Schenectady workman could eat his other two meals just as economically as the above their cost would be only...41.5 cents
And his daily cost for food would be...61.5 cents





Left. Plan of Portion of First Floor of Schenectady Work Restaurant, showing Arrangement of Tables, Belt Conveyors, Kitchen, and Route of Patrons

Right. Plan of Portion of Second Floor

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1. Schenectady Works Restaurant
3. Kitchen in Schenectady Works Restaurant

2. Pittsfield Works Restaurant
4. Electric Kitchen in Pittsfield Works Restaurant

Centralized Purchasing

It will be inferred that such a restaurant has probably established favorable relations with markets, packing establishments, fisheries and grocers, and that rock-bottom prices should result because of the loyalty of the supply houses to one of their largest spot cash customers. The dealers in Schenectady alone sell $50,000 worth of provisions every year to this restaurant.

The meat is bought direct from a Chicago packing house, and the fish from Boston. In purchasing the groceries, vegetables, etc., the policy is followed of first obtaining the best products possible, and then giving the business to the firms who, service considered, quote the best prices.

Quantity Production

All the meats, vegetables, etc., are prepared in the kitchen; the puddings are made here, and also 700 pies and 600 loaves of bread are baked daily. By providing facilities for these cooking operations the cost has been reduced to the minimum.

Kitchen Equipment

The kitchen is equipped with aluminum pots, kettles, and other utensils, for although it has been found that these utensils cost more, their durability and the ease with which they can be kept clean justifies this initial extra expense. From the standpoint of the chef the aluminum kettle will stay hot longer than a copper kettle, and will also produce more satisfactory food. For the same reason aluminum trays are used in the restaurant; they are light in weight, rugged, and easy to keep clean. Wherever possible the mechanical processes, such as cutting bread, chopping meat and vegetables, artificial refrigeration, etc., are performed by electric motors.

Another example of thrift is found in the simple fact that the flour is not purchased in barrels but in bags; for each flour bag, after being emptied, furnishes two towels for the restaurant employees.

Restaurant Service

Of the 3500 meals served daily, 500 are breakfasts, and 200 are midnight lunches; 300 are suppers, and 800 meals are delivered to the shops. Thus 1700 meals are served during the noon hour in the main restaurant building. This situation involves mechanical difficulties which can be economically met only by mechanical means.

In 1916 the seating capacity of this restaurant was 802 and the maximum meals possible to serve during the luncheon hour was 950. In 1917 the seating capacity had been increased to 1110, and 1400 meals have been served in half an hour. The maximum number which can be served during the entire noon hour has not yet been ascertained in practice, as the new system has never been worked to its full capacity. In fact, the second floor is serving practically as many meals as were served in the entire building before the improvements were made.

This increase in seating and serving capacity has already been accompanied by an increase of 1000 meals served per week without any addition to the payroll. This largely accounts for the fact that the restaurant is self-supporting at the extreme prices prevailing for food products.

Engineering in Restaurant Service

The increase in seating capacity was a simple architectural detail; but the increased serving capacity required the skill of the engineer for its solution—a problem of quantity distribution in limited time. The essential feature of the new service was the installation of a "serve-self" system, expedited by four conveyor belts. Before the adoption of the serve-self plan in 1917, it had been opposed on the grounds that one slow man can delay a hundred who are waiting the opportunity to serve themselves. But the conveyors are so arranged that they not only eliminate all physical efforts in connection with serving oneself, but they likewise speed up the process and avoid the objection of the slow man delaying those behind him.

When operating under the old plan, fifty waitresses served approximately 1000 meals, each waitress delivering food for twenty customers. With the new arrangement 1700 men serve 1700 meals, thus making each person serve only one meal. Obviously, one person can serve one meal quicker and better than one person can serve twenty meals. The progress of the restaurant patrons is routed so that there is no retracing of steps or doubling back. The traffic does not interfere with the serving, as was the case when waitresses were moving back and forth with heavily loaded trays. Looking at the matter in a different way, the serve-self system brings the man to the food, whereas the waitress was compelled under the old system to bring food to 20 men.

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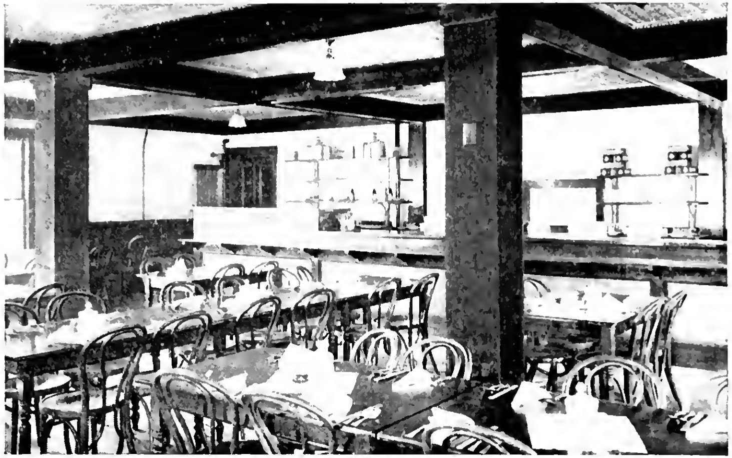

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1. Schenectady Works Restaurant, showing Tables and Seating Arrangement
3. Conveyor Belt and Steam Tables, Schenectady Works Restaurant

2. Pittsfield Works Restaurant, Self-service Room
4. Shop Lunch Room, Building 69, Schenectady Works

Meals Served in One Minute

The average time required by a customer, from the pay-as-you-enter cash desk until he is served and seated, is less than one minute. The progress is as follows:

Promptly upon the blowing of the whistle at noon, four lines of men form in front of four cash registers to purchase their luncheon tickets. Few of us have ever had the opportunity of watching a cashier make change and sell 29 tickets per minute, yet this is the rate of speed at which each of the four cashiers operates. Anyone who hears the clang of a cash register bell every half second can appreciate how rapid must be the food distribution necessary to keep pace. After the men file past the cash register, they approach at right angles to the end of one of the four belt conveyors. Adjacent to the nearer end of the belt conveyor the ticket is exchanged for an aluminum tray which is laid on the conveyor belt. These belts travel at the rate of 65 feet per minute and allow 15 seconds for the customer to select his food. Following his tray he helps himself to either meat or fish; then potatoes, tomatoes, pudding or pie, and milk or coffee, all awaiting him on a hot steam table, parallel to the belt. By this time his tray is within five or six feet of the end of the belt, where the checker o.k.'s the contents of his tray.

After removing his tray from the conveyor belt the diner takes it to his seat. It is perfectly proper to say that he takes it to his reserved seat, because tickets are only sold up to seating capacity; but the capacity of the restaurant is much greater than would be indicated by the number of seats, because many men have finished their luncheon by 12:10 p.m., and the process of removing the dishes begins immediately. At 12:10 service again begins in the restaurant until all comers have been fed.

The intermittent plan of service assures a seat for all who have entered and thus prevents congestion. One of the benefits of this system is the fact that the trays, dishes, silver, and glasses used by the early arrivals are promptly washed and used by the late comers. Thus it is possible for 1700 people to be served within an hour with only 1300 trays, glasses and sets of silver and dishes. Incredible as it may seem, so many men complete their meal and leave the restaurant in 10 minutes that their dishes can be washed and dried and used by the second set of diners who begin serving themselves at 12:10—ten minutes after the blowing of the factory whistle.

Each of these conveyors serve from 30 to 40 people per minute, and since there are four of them 120 to 160 meals can be served each minute during the noon period. Thus the opportunity has not yet appeared for testing the new arrangement at its maximum number of meals.

To form a conception of this service imagine a file of soldiers, standing at the regulation distance of 40 inches from each other, reaching up Fifth Avenue, New York, from 26th Street to 50th Street; these 1700 men—more than a regiment—are served in less than 10 minutes.

Reduction in Payroll

In 1916, under the old system, 150 employees were required to serve approximately 950 regular meals. In 1917 the number of employees has been reduced to 66, and despite this economy 1400 regular meals are served quicker and better. It is this increased speed of the mechanical self-serving system which has lessened the unit cost of the noonday meal to an extent exceeding the fondest expectations of the advocates of the conveyor installation.

Office Building Restaurant

In the basement of the main office building of the Schenectady Works is another restaurant which served over half a million customers last year. All of the cooking is done electrically, and the following equipment is installed:

16 electric toasters,
2 large electric toasters—hotel size,
13 electric ovens for baking and roasting,
12 electric stoves for boiling, stewing, and grilling,
6 electric coffee urns,
3 electric exhaust fans with ventilating ducts to the roof,
2 electric dishwashers,
1 electric hot table,
1 electric dough mixer,
1 electric potato peeler,
1 electric potato masher,
1 electric food chopper,
1 electric aluminum soup kettle—the largest electric kettle ever manufactured,
1 electric machine for ice and refrigeration.

With such modern equipment as this the cuisine is of the best. This restaurant is not only of great convenience to the office employees, but it provides a ready and

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1. Dining Room Administration Building, West Lynn Works
3. Dining Room, Main Office Building, Schenectady Works

2. Foremen's Dining Room, West Lynn Works
4. Dining Room, Harrison Works

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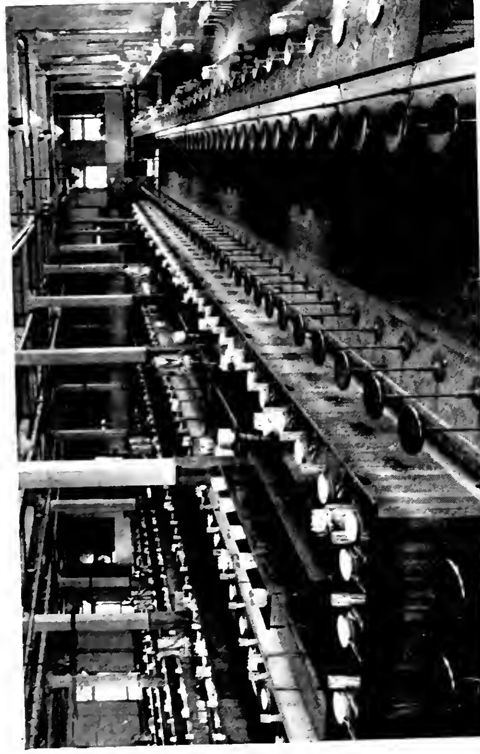

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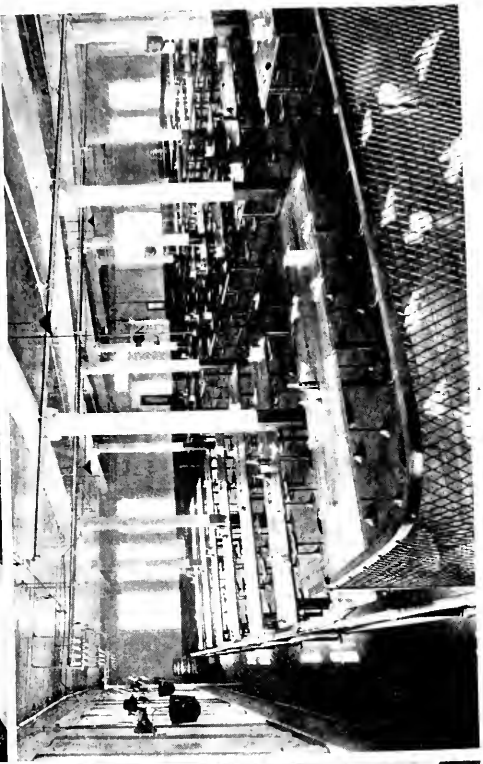

1. Schenectady Works Restaurant Prior to Installation of Cafeteria System
3. Lunch Counter, Office Building Restaurant, Schenectady Works

2. Erie Works Restaurant
4. Factory Restaurant, West Lynn Works

agreeable means of entertaining visitors and customers.

Lynn Works

At the Lynn Works there are four restaurants. One of these is located in the Administration Building, where the department heads, engineers, and other office employees have their noonday meal. In another building is the foremen's dining room, which is patronized also by the foremen's assistants, clerks, etc. There is also a lunch room serving meals on the serve-self plan, which can accommodate from 1500 to 2000 employees during the noon hour. In the West Lynn Works there is a girl's cafeteria serving soup, light sandwiches, ice cream, and hot cocoa. In all of these restaurants the same quality of food is served to all.

Pittsfield Restaurant

At the Pittsfield Works the restaurant conditions are somewhat different. Owing to the proximity of the homes of many of the employees the demand for meals is not so great as in the case of some of the other factories. However, as electric cooking devices form an important part of the product manufactured at the Pittsfield Works, it was found desirable to equip a small restaurant where electric cooking devices could be shown in actual operation and where a first-class meal could be served at practically cost.

The Pittsfield restaurant is furnished with a large electric kitchen, the ranges, bake ovens, broilers, and toasters being operated electrically. The meat cutters, dishwasher, potato peeler, and refrigerating equipment are all driven by electric motors.

Harrison Lamp Works

Due to space restrictions at the Harrison Works three types of service are rendered. There is an office and staff dining room accommodating one hundred and twenty-five employees, where a substantial course dinner is served at noon. A factory cafeteria is maintained, serving two to four hundred people, and a considerable number of meals are delivered on trays to manufacturing departments.

The food service is identical in all cases and it is sold at the lowest possible prices, the average cost per person being under sixteen cents. Meat and potatoes, with bread and butter, for instance, cost the employee ten cents; ice cream cones, three cents; milk and soup, two cents, etc.

At the Other Plants of the Company

All of the other Works of the Company have ample restaurant facilities, but those described are typical and further description would only lead to repetition.

GENERAL ELECTRIC REVIEW

A MONTHLY MAGAZINE FOR ENGINEERS

Manager, M. P. RICE
Editor, JOHN R. HEWETT
Associate Editor, B. M. EOFF
Assistant Editor, E. C. SANDERS

Subscription Rates: United States and Mexico, $2.00 per year; Canada, $2.25 per year; Foreign, $2.50 per year; payable in advance. Remit by post-office or express money orders, bank checks, or drafts, made payable to the *General Electric Review*, Schenectady, N. Y.

Entered as second-class matter, March 26, 1912, at the post office at Schenectady, N. Y., under the Act of March, 1879.

VOL. XX, No. 12

DECEMBER, 1917

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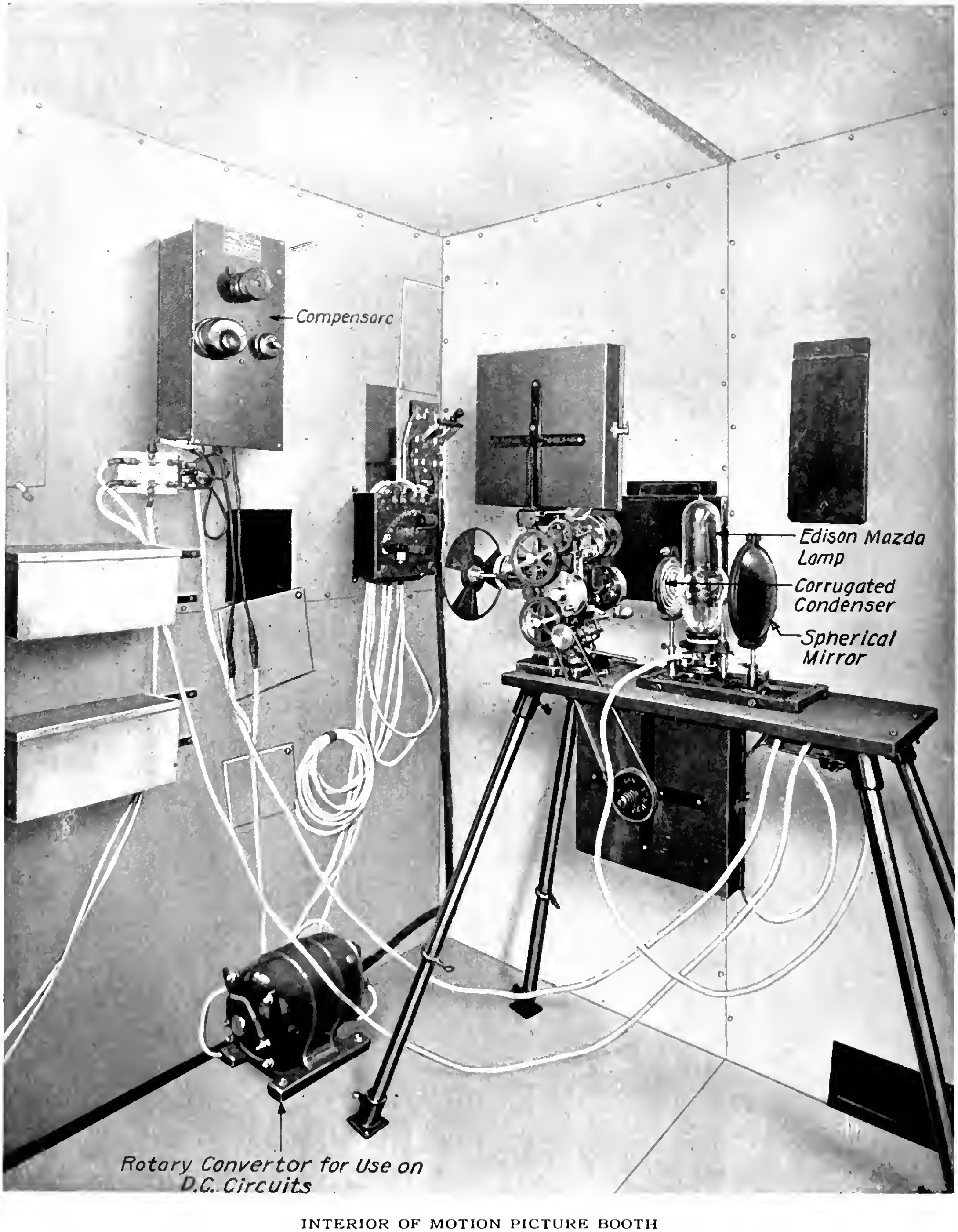

INTERIOR OF MOTION PICTURE BOOTH
(See article, page 979)

GENERAL ELECTRIC
REVIEW

THE STATUS OF ILLUMINATING ENGINEERING

Adequate illumination is one of the most potent factors in the safeguarding of life, limb, and property. The importance of good lighting for this purpose is not fully appreciated, as is indicated by the fact that while public appropriations for police protection, being regarded as an obvious necessity, are at least sufficient and are often even generous, the lighting budget is generally subject to minute scrutiny from the standpoint of economy, with the result that it is in many cases extremely difficult to provide really adequate illumination with the funds available. When it is considered that the police are seriously handicapped without the aid of proper street lighting, and that such lighting is about the best way of breaking up gangs and rowdyism on the streets, the great desirability of providing liberal appropriations for public lighting is apparent.

Although probably all practical forms of artificial illuminants have been utilized for street lighting at various times and places, the electric light, which found its first considerable applications for such installations, proved by far the most suitable and successful and has become paramount in the field. In fact, at the present time statistics show that nearly one-tenth of all the current generated in the central stations of this country is used for the lighting of public streets, parks and thoroughfares. This does not include the large amount of energy that has of late been utilized to an increasing and far reaching degree for the decorative illumination of public and private buildings, statues, flags, fountains, and spots of scenic beauty, to say nothing of the remarkable development of various flood lighting installations for protecting and enhancing the efficiency of munition and industrial plants, railroad terminals, shipping docks, aviation fields, shipbuilding yards, railroad bridges, and ship canal locks, and for lighting playgrounds, athletic fields, skating rinks, foundation excavations, new building operations, fire fighting, and other applications too numerous to mention.

This marked advancement in electric lighting activities is undoubtedly due to the great strides that have been made in bettering the efficiency of electric illuminants during the last few years, and to the large amount of constructive work that has been accomplished in the last decade in the field of illuminating engineering, particularly in the way of devising practical means for securing greater effectiveness of light distribution.

In this connection it is interesting to note that the science of illuminating engineering was not thought of as such and did not come into use until lamps reached a state of development where they gave enough light and could be operated cheaply enough so that it became necessary to really plan for general lighting effects. When the total time is considered which elapsed between the first known use of artificial light and the time when illuminating engineering came to be recognized as being worthy of a specific name, it may be said that illuminating engineering sprung up overnight from actual necessity.

To the Illuminating Engineer "light" is raw material. By his knowledge, experience, and skill he first calculates the amount of light that is necessary to produce a required degree of illumination, and then after selecting lighting units of proper size and light quality and equipped with distributing mediums of specified dimensions and characteristics, determines by exact computation the correct height and arrangement of the light sources to give the results desired. It is hardly necessary to state that, due to the large number of different types of artificial illuminants, many available in various ratings, each possessing peculiar characteristics of color, intensity, distribution, steadiness, adaptability, size, initial and maintenance cost, etc., and all capable of varied performances by means of a great variety of light-directing accessories, the problems of the Illuminating Engineer are by no means simple and obvious of solution.

The article entitled "Street Lighting with Modern Electric Illuminants" by Messrs. Rose and Butler that appears in this issue presents well arranged and clearly explained data which can be used by the operating engineer to obtain a general understanding of his street lighting problems, enabling him to handle without outside assistance his ordinary street lighting installations and to determine when the services of an illuminating engineer are required, due to the size or special features of the problem. It must not be overlooked that these data cover the subject from the standpoint of illumination only. The comparison of installation and maintenance costs can only be made by taking into consideration the various local conditions which govern each case. With parallel improvements in the efficiency of arc and incandescent lamps and the large variety of fixtures and mediums of diffusion, reflection and refraction now available for both types of illuminants, the problem of the selection of just the proper lighting unit and equipment to best meet the conditions at hand becomes increasingly difficult.

A great deal of needless trouble and expense, both to central stations and municipalities, have been caused in the past by faulty or loosely drawn street lighting contracts which led, in some cases, to serious misunderstandings and even litigation. For this reason the subject of contracts is receiving more and more attention as its importance is becoming recognized. It is not an easy matter to draw up such a contract which will provide for every contingency that may arise, but a frank discussion of all the factors entering into the problem, including the various local conditions to be met, greatly simplifies the work of drawing up an agreement satisfactory and equitable to both parties. Above all things the contract should be specific on all the points it is intended to cover. One very important provision that should not be omitted is a paragraph stating the basis for changing from one type of unit to another, should this become desirable or necessary during the life of the contract; in any event a change should not be made without the written consent of the municipality in order to avoid the possibility of future controversy. S. H. Blake.

The Automatic Hydro-Electric Generating Station of the Iowa Railway and Light Company

By L. B. Bonnett

Lighting Engineering Department, General Electric Company

The automatic hydro-electric generating station has been successfully developed—now who can specify what will be the limitations of its possibilities? It is very easy to conceive that many relatively small automatic hydro-electric generating stations will supplement the large hydro-electric stations and steam-electric stations which will feed the vast and interconnected transmission networks of the future. On a smaller scale the automatic hydro-electric generating station described in this article supplements a large steam-electric station.—Editor.

Many automatic substation equipments controlling synchronous convertors for railways have been put into service in this country. Descriptions of these substations have appeared from time to time in the technical press. Impressed by the successful performance of these *substations*, the Iowa Railway and Light Company has recently put into operation an automatic *generating* station. This station is hydro-electric and is controlled in a manner fundamentally similar to that which has proven so satisfactory in automatic substation operation. It is located at Cedar Rapids, Iowa, and contains three vertical generating units with space for a fourth. The generators are each rated 500 kv-a., 2 phase, 60 cycle, 2300 volt, 60 r.p.m., and the water-wheels operate under a ten-foot head.

Power is obtained from the Cedar River by a concrete dam above which there are automatic flashboards for raising the level an additional three feet to make a total head of ten feet. Each wheel is equipped with a motor-operated gate and no oil-pressure governor is used, the load being controlled through the motor-operated gate by a contact-making ammeter. Excitation is obtained from either one of two induction-motor driven exciter sets, each one being large enough for exciting the entire station equipment. These exciters are rated 100-kw. at 125 volts, and are driven by 2300-volt, 2-phase, 1200-r.p.m., squirrel-cage induction motors.

The hydro-electric plant is some 3000 ft. from the main steam generating station of the Company where there is an installed capacity of about 20,000 kw. in turbine-generators. The hydro-electric plant feeds its entire output into the steam station buses from which distribution is made. The tie between the two stations consists of two single-phase, concentric, 600,000 cir. mil cables operated at 2300 volts. In the steam station there is a bench-board upon which are mounted indicating instruments showing both the load on individual generating units and the total output of the hydro-electric plant. As there is only one main cable between the two stations carrying the combined output of the three units it was necessary, in order to read individual loads, to carry leads from the secondaries of the current transformers in the hydro-electric plant to the indicating instruments in the steam plant.

Fig. 1. Front View of the Automatic Generating Station of the Iowa Railway & Light Company

The control is so arranged that any generating unit or units will start entirely automatically depending upon the height of the water in the forebay; or by remote pull-button control in the steam station. The units have individual float switches set for slightly different levels. If the water rises to a certain level it closes the float switch of the first unit, and that machine is started and put into service. If the flow of the river is such that the water continues to rise, the second float switch closes starting the second machine. The third switch is set still higher. The machines are shut down in the reverse manner as the water level falls. In parallel with these float switches there are control buttons in the steam station so that any hydro-electric unit can be started from the steam station, independently of the height of the water. For each hydro-electric unit there is also in the steam station a control button which, when opened, shuts down that generator and prevents it from starting again either from the steam station or the float switch until this button is reclosed.

The correct sequence of operations in starting is obtained by properly placed segments on the drum of a motor-driven controller. This arrangement definitely determines the proper time-spacing between the different steps of starting the unit and connecting its generator to the bus.

The closing of the float switch or of the remote control button in the steam plant starts the motor driving the controller drum. The first contact made closes a contactor which throws full voltage on the induction motor of one of the exciter sets. The motor is properly designed for this duty and comes to speed in two or three seconds, requiring about six times normal current. The exciter rheostat is set to give about 125 volts and the exciter builds up to this voltage.

Shortly after the exciter is started, another segment of the controller causes the motor-operated gate of the water-wheel to open a sufficient amount to give a free running generator speed of about 70 cycles. After opening the gate this amount the controller stops and waits for the generator to come up to a speed of about 55 cycles. A centrifugal switch mounted on the shaft of the generator is adjusted to close at about 55 cycles (55 r.p.m.). The closing of this switch starts the controller again, and after a definite interval of about two seconds, the generator is thrown on the bus without field but in series with a reactance of about 20 per cent. The gate is open a sufficient amount to cause the speed to be slowly increasing, and the interval between the closing of the centrifugal switch and the throwing of the generator on the line is adjusted so that the speed of the generator is approximately 60 cycles at the time it is connected to the bus.


Fig. 2. Forebay Side of the Automatic Generating Station

The controller continues to rotate, first exciting the field at a low value (pulling the generator into exact synchronism), then strengthening the field to normal full-load value and, shortly afterward, short circuiting the reactance.

In the meantime, as soon as the generator is pulled into synchronism, the control of the gate opening has been taken up by a contact-making ammeter connected to a current transformer in the generator leads. This is adjusted so that it opens the gate until full-load current is flowing.

After having performed its function of closing the different contactors in proper order the controller motor stops, leaving the drum in the full running position. Since the generators are rated at 500 kv-a. and revolve at only 60 r.p.m. they have considerable inertia. However, only 39 seconds is required from the beginning of the opening of the gate until the generator is connected to the bus

Fig. 3. Panel Cabinets and Automatic Equipment for Control of the Generating Units

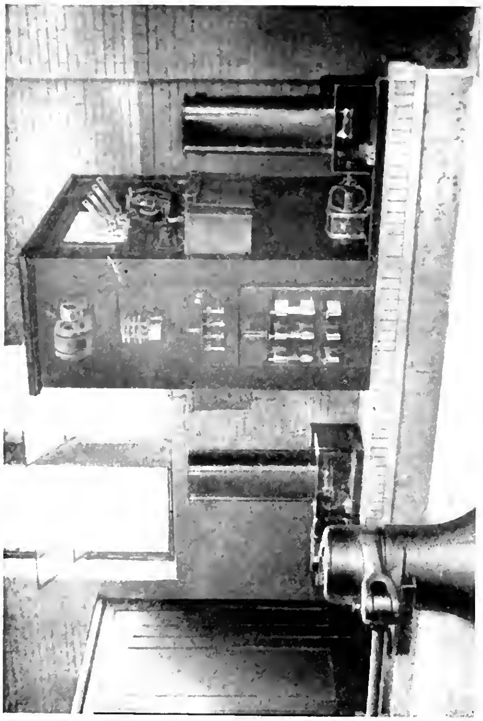

Fig. 4. Near View of the Exciter Control Cabinet and Drum Controllers shown in Fig. 3

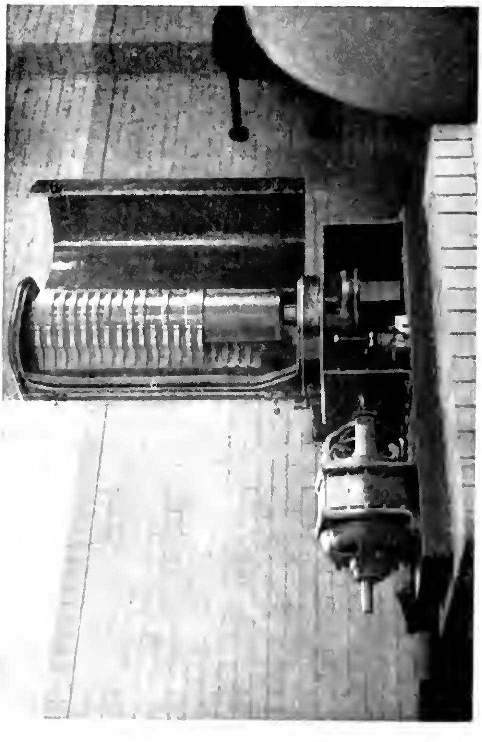

Fig. 5. Near View of One of the Motor-driven Drum Controllers with Cover open to show Contacts

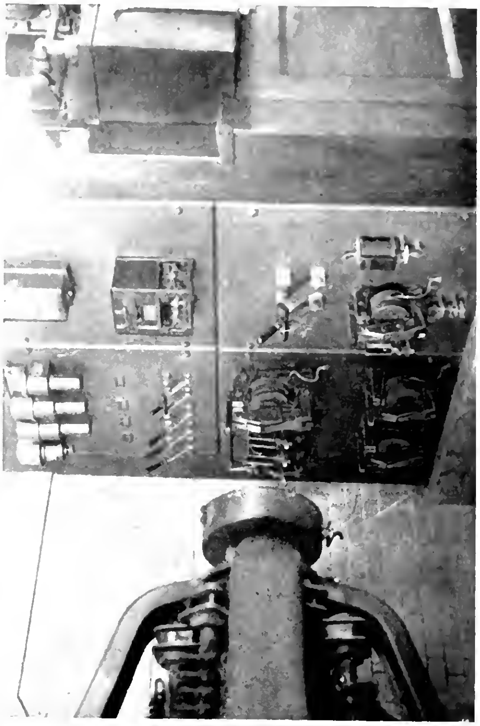

Fig. 6. Near View of Part of a Generator Panel

with the reactance short circuited. Within 45 seconds the generator is carrying full load. In spite of the speed with which these generators are connected to the bus, there is no mechanical jar perceptible. The generator causes only about twice normal current to flow when it is first connected to the bus without field, and the applying of the weak field pulls it into synchronism without serious surges.

An oscillogram taken of the current at the time one of the generators was thrown on the line is shown in Fig. 10. The first part of the film is of the current flowing when the generator is connected to the line without field, the next is of the current when the weak field is applied which soon pulls the machine into step. The field is then strengthened to normal. There now seems to be a tendency for the current to pulsate (this is presumably caused by the heavy reactance in series with the machine). As soon as the reactance is short circuited, the current quickly steadies down. The wave amplitude at the end of the film is somewhat less than normal load as the contact-making ammeter was set for holding less than full load on the day this film was taken. The time from the connecting of the generator to the line to the short circuiting of the reactance is about eleven seconds.

When the float switch opens or the proper control button switch is opened, the contactors drop out disconnecting the generator from the line, the gate closes and the controller runs to the *off* position ready for the next operation.

Fig. 8. General View of the Interior of the Automatic Generating Station. A Motor-driven Exciter is shown in the Lower Left-hand Corner

Fig. 7. Waterwheel Gate Control in the Foreground and Automatic Control Cabinet Panels in the Background

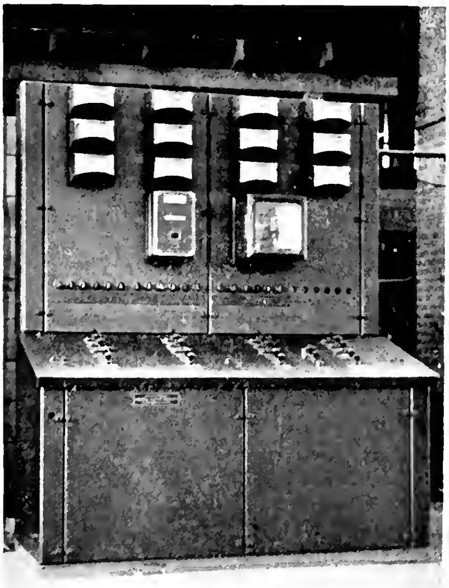

Fig. 9. Benchboard on which are Mounted all the Indicating and Totalizing Meters and supplementary Remote Control Equipment of the Hydro-electric Station. This Benchboard is located in the Main Generating (steam) Station

The generators operate with a fixed excitation adjusted for normal full-load value. If the water level is so low that with full-gate opening normal load cannot be obtained, the generator due to its high excitation takes care of part of the wattless kilovolt-amperes of the system. The speed and voltage are, of course, determined by the steam turbine-generators.

Thermostats or their equivalent are installed in the bearings so that if any overheating occurs the machine in difficulty will be shut down.

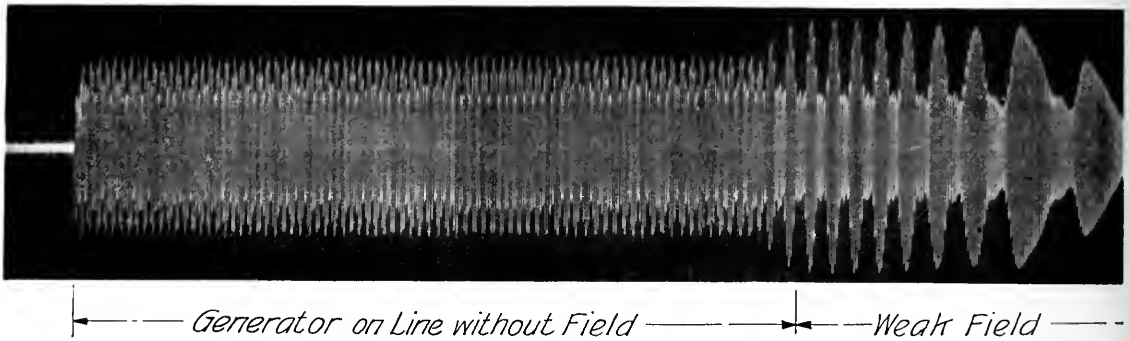

Fig. 10. Oscillogram of the Current Flow between Generator and Line when a Unit is being placed in Service

A number of tests were made to see what would happen in case of wrong operation of the control buttons or failures of the equipment. In the steam station there is another control button switch, the opening of which transfers the control from the contact-making ammeter to two other buttons to allow remote control of the gate opening by hand if desired. In one test the contact-making ammeter was left in control of the load, and an attempt was made to control by hand at the same time. The operators could increase or decrease the load, but as soon as the hand-control buttons were released the ammeter returned the load again to the proper value.

The operator opened one of the other control-button switches and then immediately closed it again. The opening tripped all the contactors and started the closing of the gates. The immediate reclosing again of the button switch did not immediately close all the contactors; the control waited until the speed of the machines had dropped to a fraction of normal. The regular sequence of starting was then repeated, and the machine connected to and loaded on the bus.

One of the generators was operating under full load when the exciter was purposely shut down. The generator within a couple of seconds was disconnected from the bus, and the water-wheel gate started to close. As the control buttons were in the running position, the controller tried to start the machine again but could not until the exciter was again running at normal voltage.

The oil switch connecting the tie cable to the steam station bus is equipped with inverse time-limit relays set for a current exceeding that which the hydro-electric generators are capable of giving on short circuit. This switch, therefore, will trip only in case of a short circuit in the cable between the two stations. If this happens, all contactors drop out because of low voltage on their coils. In the hydro-electric plant there is an emergency throw-over switch which, in case of failure of voltage on the main cable, transfers the control circuits to a separate source of power from the steam station. This furnishes energy for closing the gates of the water-wheels, and the machines are shut down until the voltage returns on both phases of the incoming cable. Then, provided the control buttons are in the correct position, the generators start again and pick up their load.

The operator accidentally tripped the switch in the steam plant when one of the generators was carrying load. In less than two seconds the generator tripped out its contactors because of over-speed, and the gate was closed obtaining power from the separate source by means of the automatic throw-over switch.

Recently, the exciter of the steam station failed while the automatic plant was running. As the hydro-electric plant is much too small to carry the total load, it should not only disconnect itself from the load but should close its water-wheel gates. This is exactly what happened. The failure of the exciter in the steam station caused increased current to flow in the hydro-electric generators. The contact-making ammeters on these generators immediately started the closing of the gates, and almost completely closed them before the voltage of the system dropped too low.

Under normal conditions the load was found to be steady, varying only as the water level changes, so that there was no tendency of the contact-making ammeters to keep the gates in motion. The steam station takes care of all fluctuations of load.

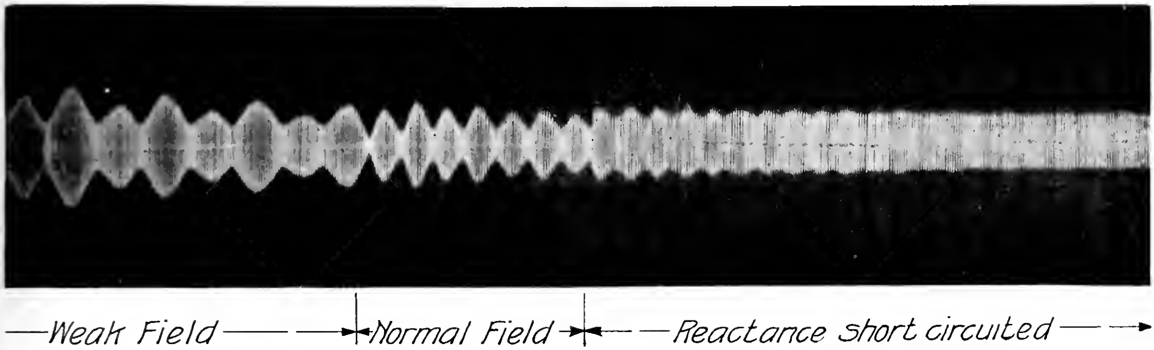

Fig. 10 (Cont'd) The length of the Oscillogram is equivalent to about 15 seconds and extends from the time the generator was first connected to the line to the time the machine is satisfactorily carrying its share of the load

The station is very attractively designed; the building is of Indiana limestone, and the interior is finished in cream color pressed brick. The foundation and water wheel pits are of concrete. The automatic equipment for the control of each generator is grouped beside that generator and is arranged in mahogany-finished cabinets. All the control wiring is inside the cabinets, the doors of which can be locked. Each cabinet and motor-driven controller rests upon a pressed brick pedestal raised six inches from the tiled floor. The photographs appearing in this article were taken before the finishing floor was laid.

There are no instruments in the hydro-electric plant, all indicating and totalizing meters being in the steam plant at the other end of the tie cable, and are located on the bench-board shown in Fig. 9.

The station will be operated at its full capacity at times of peak load, being started and stopped from the steam station, so that the latter can be run at a more nearly constant load with consequently more efficient operation of the boilers. At other times the generators will be normally controlled from the float switches so that all water available will be used to generate power, and none will be wasted over the dam. At the same time the pond level will not be dropped so low as to interfere with maximum capacity operation at times of peak load.

It is interesting to note that the cost of an automatic control equipment similar to this is not greatly in excess of that of the ordinary hand-control switchboard. The control equipment is simple, and consists of contactors and other material whose reliability has been proven in many years of use under severe conditions of frequent operation. Where a hydro-electric plant is auxiliary to a larger station, such an automatic equipment with the saving in operating expenses and the most economical use of the water may spell the difference between loss and profit in the operation of the plant.

Methods for More Efficiently Utilizing Our Fuel Resources

PART VII. GENERAL UTILIZATION OF PULVERIZED COAL*

By H. G. BARNHURST

CHIEF ENGINEER, FULLER ENGINEERING COMPANY

This article of the series first briefly reviews the extent of the use of pulverized coal in the Portland cement industry and then treats of its later application in other industries. It is being used more and more extensively in metal heating furnaces, in metallurgical furnaces in the steel and copper industries and for burning lime and dolomite for making furnace refractories. A field in which enormous quantities of this fuel will be used is in the generation of power in stationary power plants. The article refers to many low-grade solid fuels which can be utilized with good results in pulverized form, and states that the dangers incident to the use of pulverized coal have been greatly exaggerated. The preparation and handling of pulverized fuel are discussed in detail in the latter part of the article.—EDITOR.

The availability of a fuel which is of such a nature that it can be applied to a large number of different conditions, is of vast importance to those interested in any development which tends toward economy and reduction of fuel requirements.

Industrial Furnaces

Pulverized coal was first applied successfully for economical reasons in connection with the burning of Portland cement. The growth of the Portland cement industry also had a great bearing on the development and use of pulverized coal, in that it is in this industry that pulverizing machines were brought to the present high state of development, for in the manufacture of cement not only the coal is pulverized but for each barrel of cement manufactured, weighing 380 lb., there are required about 600 lb. of raw material such as limestone shale or cement rock as well as the 380 lb. of clinker produced by the kilns which must be pulverized in order to make the finished product, so that in the neighborhood of 1100 lb. of raw materials, clinker and coal must be ground to produce one barrel of portland cement. As there are a hundred million barrels of Portland cement made in this country annually, these figures will give one a reason why pulverizing machines have been so highly developed during the last few years. Fine grinding of the raw material means reduction in the quantity of fuel required and also makes possible the highest quality of the finished product, so far as the chemical analysis or combination is concerned. Fine grinding of the clinker means increased strength for the reason that the hydraulically active units in cement are in direct proportion to the percentage of fine or impalpable powder in the finished product.

This statement is made to emphasize the fact that equipment for preparing and handling pulverized coal has long since passed the experimental stage, and has now been developed to a high state of efficiency and is readily obtainable.

Somewhere between thirty to fifty million tons of pulverized coal have been used to date in the manufacture of cement alone.

The application of this ideal form of fuel has been gradually taken up by engineers connected with other industries, who have speedily recognized its value to such an extent that the steel industry today is using in the neighborhood of two million tons of pulverized coal annually in various types of furnaces such as open-hearth, heating, puddling, soaking-pit, continuous heating, reheating, annealing, forging, and furnaces of practically every description where heat is required, and *is being used successfully.*

It is very evident that the future possibilities of the application of pulverized coal are now being recognized by the large steel companies as a subject worthy of their careful investigation; this is proven by the number of applications now operating and contracted for. The results already obtained make it very apparent that this form of fuel will replace other methods of firing in a great many cases.

A great development is now going on in the application and use of pulverized coal in connection with the copper industry; ore roasting furnaces, reverberatory and copper

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*Read before the Cleveland Engineering Society, Cleveland, Ohio, September 25, 1917.

melting furnaces of all types are now successfully operating with this form of fuel, and between one and two million tons of pulverized coal is used in this industry alone each year.

Another large field in which pulverized coal is commanding attention is in its application to rotary kilns for the desulphurizing and roasting of various grades of ores, and also nodulizing flue dust so as to make available products heretofore rather expensive to recover. In one installation ore is now being treated at the rate of 800 to 1000 tons daily, requiring from 250 to 300 lb. of coal per ton of ore desulphurized and nodulized.

In another large installation ores carrying as high as 40 per cent *moisture* and of rather a soft nature are being successfully handled, requiring from 400 to 500 lb. of pulverized coal per ton of ore nodulized.

Pulverized coal is being successfully used today in the burning of lime in rotary kilns for making oxide of lime for use in open-hearth furnaces. Also for burning dolomite to replace magnesite used for furnace linings. The shortage in the supply of magnesite has been responsible to a certain extent for this development.

Power Generation

A very important development is now going on, which will, when it attains its growth, require more pulverized coal than probably all of the other industries combined, and that is in its application to locomotives, particularly in the West.

There is still another field in which enormous quantities of this fuel will be used, a field in which all are concerned, and that is in the generation of power in stationary power-houses. There are quite a number of installations in successful operation using in the neighborhood of one hundred to two hundred thousand tons of pulverized coal annually, and the success obtained by these plants has created so much interest, and has brought out so strongly the desirability of the use of this fuel for power purposes, that today there are a number of new installations being made, and by engineers of national repute.

The peculiar conditions existing today, on account of the war and other reasons, such as the gradual disappearance of sources of fuel like natural gas, and the shortage in supply of crude oils, which have become of too much value to be used for ordinary fuel purposes, have compelled those interested to carefully investigate the possibility of adopting pulverized coal to replace their present expensive methods of operation and lower the fuel cost.

These statements have been of a rather general nature to bring out forcibly the fact that coal in pulverized form is going to become one of the most important fuels. The results thus far obtained have shown that, with installations properly designed and installed, it is not only a desirable fuel from an operating standpoint but one which will eventually become necessary on account of its economy.

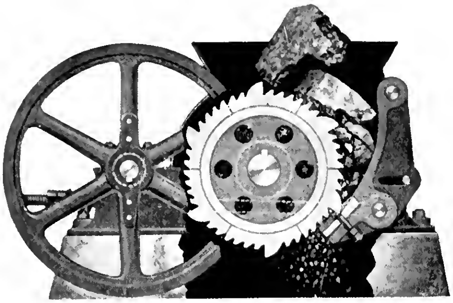

Fig. 1. Single-roll Coal Crusher

At the shops of the Missouri, Kansas and Texas Railway pulverized coal has been used under boilers for over a year with very satisfactory results. These boilers have been operating continuously day and night—for short periods daily at from 150 to 180 per cent rating. Practically no repairs to furnace arches or walls have been made during the year's operation. *Absolutely smokeless operation* has been accomplished. The flue gas analysis during some of the recent tests has shown from 15 to 17 per cent CO_2. Coals carrying, on an average, from 10 to 22 per cent of ash with a moisture content varying up to 17 per cent, as fired, are burned satisfactorily. The furnace efficiency has been very nearly perfect; three tests made in June showed a furnace efficiency of 98.4, 98.6 and 99.4 per cent.

Burning Various Grades of Coal

Practically any coal can be burned in pulverized form with a proper furnace and burning equipment. Each application, however, must necessarily be governed by the quality of the fuel available in the district in which it is made. Generally speaking, however, the coals which would give the most satisfactory results would be those in which the ash content would be less than 10 per cent, the volatile averaging between 30 per cent and

40 per cent and the fixed carbon between 40 per cent and 50 per cent. The sulphur content should be low, although coal with a sulphur content running as high as 5 per cent is being burned in pulverized form under boilers without any detrimental results. The ash should have a high melting point. These statements, however, are tentative, as most excellent results have been obtained from all sorts of coals, differing widely from the ideal analysis stated.

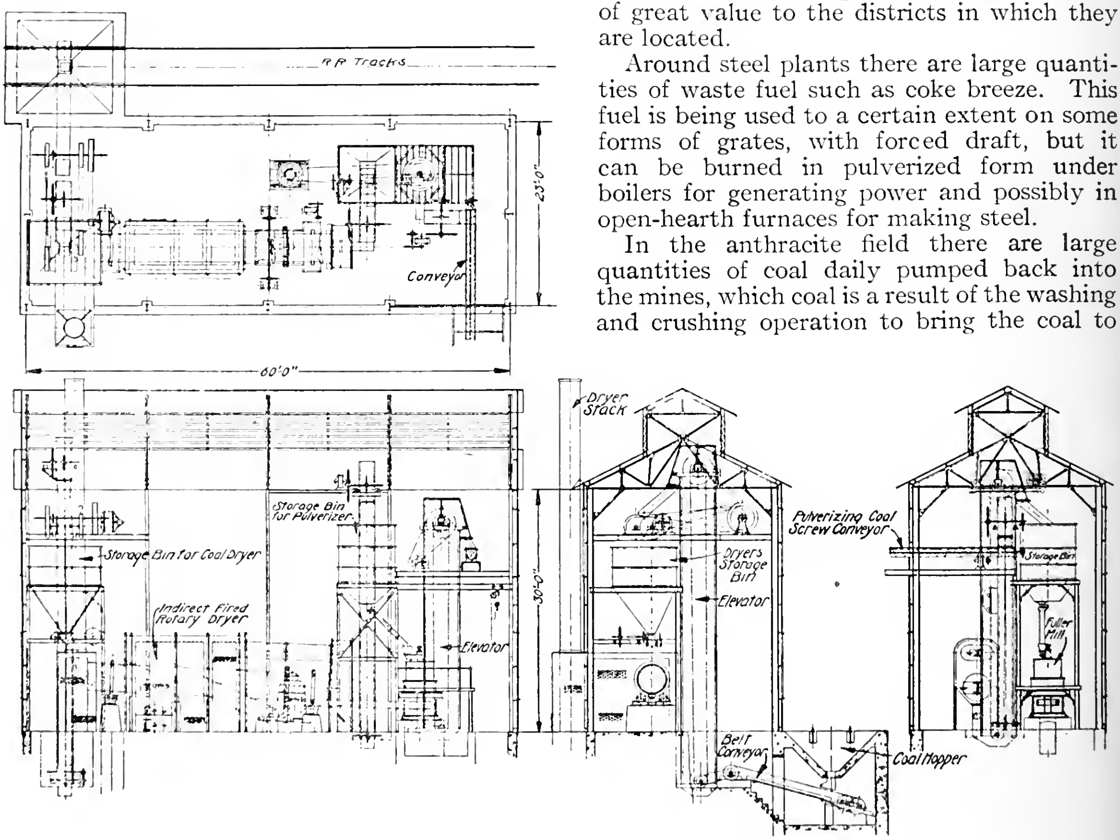

Fig. 2. Plan and Elevation of Plant for Pulverizing Coal

It is very apparent that the development in this method of burning coal has brought coals from which heretofore very inefficient results have been obtained within reach of a great many consumers. For instance, from Texas to Edmonton, Alberta, the country is underlaid with various grades of lignites, low-grade mineral coals with high moisture content and of such a nature that the ash would melt or flow down on the grates, thereby preventing the highest efficiency from being obtained. They are of such a nature that their use in gas producers is not very satisfactory, so that until the development and burning of these coals in pulverized form was an assured success they were not used in as large quantities as is now possible.

The largest deposits of lignite and mineral coals appear to be in the Northwest awaiting future development when proper means are at hand for obtaining the highest possible economy from their combustion, and the location of these large deposits will now be of great value to the districts in which they are located.

Around steel plants there are large quantities of waste fuel such as coke breeze. This fuel is being used to a certain extent on some forms of grates, with forced draft, but it can be burned in pulverized form under boilers for generating power and possibly in open-hearth furnaces for making steel.

In the anthracite field there are large quantities of coal daily pumped back into the mines, which coal is a result of the washing and crushing operation to bring the coal to commercial sizes. This silt, or washery waste coal, carries as high a heat value normally as the coals which have been operated upon. The President of one of the large coal companies in the East said that in the neighborhood of eight or ten million tons of this silt annually was pumped back into the mines to fill up old workings.

A number of the coal companies are now carefully investigating the application of anthracite, or low volatile coals, with a view to using this waste coal in pulverized form to obtain power, thereby releasing for the market the coals of higher grade which they are firing at the present time.

Pulverized anthracite is now being burned in one or two installations, and the writer has burned pulverized anthracite in a special form of furnace.

PREPARING AND HANDLING PULVERIZED COAL

The coal, as received, is either in the form of slack, lump, or run of mine, and as it comes to the pulverizing plant it should be crushed so that it will go through approximately a one-inch ring. A single-roll coal crusher of approved make is usually the equipment employed. The coal should then be dried at low temperature to eliminate the moisture. Ordinarily it should be dried so it will not contain more than one per cent moisture. A low moisture content in the pulverized coal as fired in metallurgical or other furnaces leads to uniform temperature conditions which are highly desirable. This condition is also necessary in order to obtain a product of the highest quality. The highest efficiency is also obtained with *dry* coal.

The drier is of the rotary type; that is the coal is fed into an inclined shell mounted on rollers and is gradually passed through the drier by gravity. The firing chamber is usually located under the shell, or so arranged that the products of combustion from the drier can be used not only to heat the shell of the drier but also to pass through it in order to obtain the greatest economy from the fuel burned for drying the coal.

The drier should be so arranged that the gases of combustion coming from the furnace do not come in contact with the coal being dried until they are reduced in temperature so they will not ignite the coal. The temperature of the coal being dried should only be sufficient to drive off the moisture; if the coal is allowed to become too hot, the volatile content may be reduced, thereby sacrificing some of the heat value of the coal. This condition is very readily obtainable, as practice has shown. A pyrometer should be installed to indicate to the operator the temperature to which the coal being dried is exposed. An evaporation of from 5 to 7 lb. of moisture from the coal being dried can be readily obtained per pound of coal burned on the grates in the drier. The amount of evaporation however naturally depends upon the quality of the coal being handled in the driers. The driers can also be fired with pulverized coal if desired.

A magnetic separator of some standard make is installed, either before the crusher or after the drier, so as to remove what may be called tramp iron which consists of pick points, railroad spikes, coupling pins, links, hammer heads, sledges, tobacco cans, nails, etc., all of which have been accumulated in the mines and in the crushing operation at the mines. The amount of iron per ton will vary in certain districts but it is an item of such importance that magnetic separators are being installed in every first-class pulverized coal plant which is now being erected. The elimination of this iron naturally improves the pulverizing and conveying operation, and prevents breaks, and losses due to intermittent operation, and lessens the wear and tear on the machinery.


Fig. 3. A Coal Drier

Coal as it is passed through a modern pulverizing plant should be elevated and conveyed in dust-tight equipment. After crushing, the coal should be elevated to bins above the driers. These bins should be of ample capacity and arranged with variable speed feeding mechanism so that the driers at all times will have uniform feed. This is very important in order that the moisture content be reduced uniformly and thereby allow close furnace regulation where the fuel is burned. Leaving the drier the coal is elevated and discharged into storage bins above the pulverizers. These storage bins should be of such capacity that the pulverizing machinery will at all times receive ample feed to prevent them from running empty. All storage bins should be of dust-tight construction, and equipped with deep hopper bottoms so that the coal is constantly in motion while being drawn off. It is in coal lying dormant or stationary that spontaneous combustion or smouldering action is generated, particularly so where coals are under pressure.

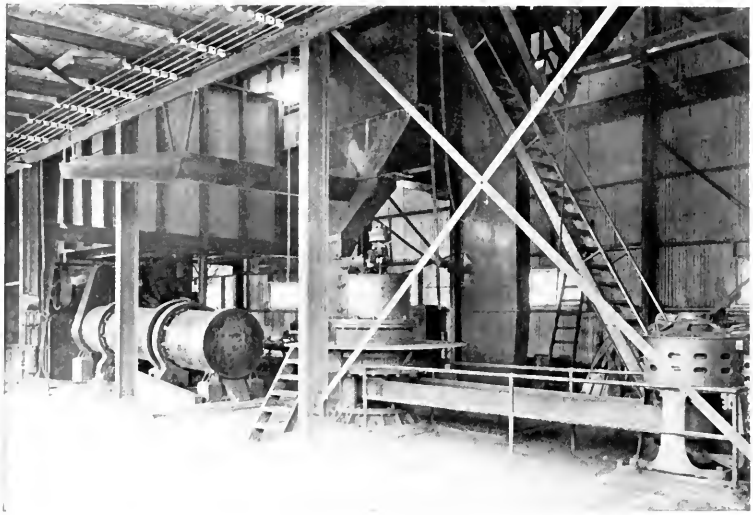

Fig. 4. An Installation for Drying and Pulverizing Coal

Danger of Spontaneous Combustion no Greater Than with Other Forms of Coal

The danger of spontaneous combustion of pulverized coal has been greatly exaggerated. It has been considered that the matter of pulverization increases this danger, but it is a matter of fact that practically nothing more than the usual ordinary precautions taken with all fuels are necessary to guard against it. The mere factor of pulverization is not of any unusual importance as is readily shown in the commercial production of lamp black, which is handled very much like pulverized coal, without dangerous results. This lamp black is probably 30 to 50 times finer than the average size particles found in commercial pulverized coal.

In the lamp black industry, by the way, it has been found that only partially filling the barrels when shipping gave much better results than when packing the material to the top.

Spontaneous combustion results simply from the absorption of oxygen. If this absorption becomes too rapid, heat will be generated and incandescent combustion will result. The presence of pyrites tends to oxidation to a rapid extent in any fuel, with the probable disengagement of light carburetted hydrogen, and spontaneous combustion results. In the case of lamp black, this condition of course is removed as the lamp black contains practically no sulphur. Certainly not in the form of pyrites.

Pulverizing

Pulverizers of ample capacity to take care of the fuel requirements should be of such a nature that their cost of operation, attendance, power, and repairs are at a minimum. A first-class pulverizer should be one which can operate if necessary over a period of from one to

Fig. 5. A Near View of the Pulverizer shown in Fig. 4.

three months continuously without shutting down even for oiling. The pulverizers should also be of a type that normally delivers a product containing the highest percentage of impalpable powder. Coal should be pulverized so that ordinarily 95 per cent will pass a 100-mesh sieve. The machinery in the pulverized coal plant, where possible, should be driven by electric motors. The drives should be standardized and the motors interchangeable. Back-geared motors are successfully used in a great many installations, and the pulverizers can be driven either by motors with belt drives or gear driven with a flexible coupling between motor and pulverizer.

Dust collectors are sometimes installed in connection with driers. This dust is formed by the action of the coal passing through the drier, as the coal falls down a certain amount is ground to dust and this dust, being in suspension, is carried along by the air currents through the drier; the dust collector will recover it. Dust collector should also be arranged in connection with the pulverizers.

Cost of Preparation

The adoption of pulverized coal for any particular operation naturally depends on the cost of preparation or handling, which is a charge in addition to the fuel itself. However, in a great many cases the original cost of the fuel is less than that where lump coal is used. The power required in a first-class pulverized coal plant, per net ton of coal handled, is in the neighborhood of 17 h.p.-hours per ton produced. Since the efficiency of the motors will average about 89 per cent, the corresponding power consumption will be 14.3 kw.-hours. This includes the power for crushing, drying, elevating, conveying, and delivering the pulverized coal to the conveyors leading to the point of use. The repairs vary slightly with the quality of the coal, but generally speaking the repair costs for the pulverizing plant should be somewhere between 5 and 7 cents per net ton of coal handled.

The drier fuel is practically a constant, as the amount required per ton of coal dried, with a given moisture content and with standard driers, will not vary very much.

In the Lehigh Valley district, where the coals carry from 5 to 10 per cent moisture as received, 25 to 35 lb. of coal are required to be burned on the grates per ton of coal dried.

Fig. 6. A 50-ton Open-hearth Furnace Using Pulverized Coal. The Fuel Bins are shown at each end of the Furnace

The cost of this coal is naturally based on the cost of the coal as received. The great variable in the cost of preparing pulverized coal is then reduced to the labor item. The labor varies inversely with the quantity of coal handled and the time or continuity of operation in the pulverizing plant. In other words, the question of labor cost is one directly affected by the equipment installed. One man can handle quite a number of machines, so that in making up an estimate on the probable cost of pulverizing coal, careful consideration should be given to these statements.

Generally speaking, coal in fairly large quantities, from 50 to 100 tons and upwards per day, can be pulverized and delivered to the furnaces at a cost from 20 to 50 cents per ton, depending upon the quantity handled. Nothing has been said, however, as to interest and depreciation, taxes, overhead, and other burdens entering into the ultimate cost of preparation, as these are items which have to be considered in each specific case. For instance, the cost of a pulverizing plant, if it is to be operated 10 or 12 hours per day, would be considerably greater than an installation to turn out the same production in 24 hours. The cost of preparation will vary also with the investment, for a given production, done in one shift, will naturally be accomplished at less cost than if it required two or three shifts.

To make a positive statement as to the cost of any given sized pulverized coal plant today is rather difficult, in that the conditions governing every installation vary. Generally speaking, however, an ideal plant with a daily capacity of 100 tons of pulverized coal will cost today, with the present prevailing high prices, in the neighborhood of from $300 to $400 per ton of capacity. The cost of a plant for 250 tons daily capacity of pulverized coal will be from $250 to $300 per ton. These are just general statements to give some idea as to the cost of pulverized coal plants. Information on this subject can be readily obtained from those familiar with the matter.

Fig. 7. Iron Caught by a 12-inch Magnet (Placed in Chute Back of Coal Dryer) between November 20, 1913, and July 16, 1914. The quantity was about one barrel

To the cost of the pulverizing plant there must naturally be added the cost of the conveying system to the furnaces, also the storage bins, burners, etc., as well as the air supply.

When making comparisons between different methods for burning coal, in order to be fair and just, the cost of each equipment should be considered from the time the coal is received on the track until it is delivered into the furnace. The storage of the raw coal is a condition always necessary; the conveying and handling of this coal from storage to the plant is also a necessity. The handling of any coal at furnaces, particularly with boilers, requires the installation of bins and spouts. These items are the same whether stokers or pulverized coal is used for firing. The cost of preparing pulverized coal, as stated above, would sometimes lead one to believe that the cost is excessive and that it is a cost due entirely to the pulverizing of the coal; but the cost of preparation, as just outlined, includes items which are common to any system of mechanical firing.

For instance, the distribution of coal in certain plants requires hand labor, so in each case a careful study should be made of the conditions governing the installation, the cost of the present operation, and the cost of the pulverized coal installation, and its cost of operation, before arriving at a decision as to the advantage of one system over another.

There are too many pulverized coal plants in existence today to allow a careful engineer to be misinformed as to the ultimate cost of the preparation. The cost sheets of plants using pulverized coal for years are readily obtainable.

Conveying Systems

The subject of pulverized coal handling from the pulverizers to the point of use is also important. The application of any particular method depends upon the distance to which coal must be transported as well as the quantity to be handled per hour. The general practice in plants where pulverized coal has been used for a number of years, and in plants where the capacity would be from about 50 tons per day upward, is the use of screw conveyors for conveying the coal. These screw or spiral conveyors are mounted in dust-tight troughs. The gudgeon forming the connection between the different sections of the conveyor runs in chilled bearings and when properly installed its upkeep is very low. They do not require much attention, and the bearings last for years, the coal itself acting as a sort of lubricant. Coal after being pulverized only weighs from 32 to 38 lb. per cubic foot and is permeated with air and flows along the conveyors like a fluid. The power consumption for distribution with this system is the lowest of any, and when properly installed this system is dustless.

There are other means of conveying pulverized coal, such as carrying the coal is suspension. More power however is required for furnishing air to carry the coal in suspension, and at such a velocity as to prevent its building up in the blast pipes, than is used where screw conveyors are installed. The necessity of closing up every leak, and the possibility of moisture affecting accumulations in the transmission lines, make a system of this kind usually expensive to operate.

Another method now being developed is the conveying of pulverized coal through pipes by means of compressed air. With this system the coal enters the pipes in charges, compressed air being used as a means of propulsion. Relief valves and cyclone* collectors, naturally, must be installed to relieve the pressure after the charge has been delivered at the receiving point. This system is installed in three or four plants. It should be considered where coal is to be transported a long distance, but it is not applicable to short distance transport.

Conclusion

The pulverizing action increases the superficial area of the coal, thereby rendering its combustion far easier of accomplishment and more complete, since each minute particle will be surrounded by sufficient air to insure its combustion. It is evident, also, that the more finely divided the coal is the more readily it can be satisfactorily burned, and under proper conditions *is absolutely smokeless*.

Summing up the whole subject, it may be seen that the use of pulverized coal has no insuperable difficulties to overcome, but merely those which have always hampered the introduction of new methods. Pulverized coal is here to stay, for it is very closely allied to the conservation of our natural resources.

PART VIII. THE PETROLEUM INDUSTRY†

By Walter Miller

Cosden & Company, Tulsa, Okla.

The main product of the petroleum industry was formerly kerosene; but electricity has largely superseded kerosene as an illuminant, except in rural districts remote from electric service. Now, gasolene is the foremost product with lubricating oils as indispensable secondary products. Gasolene may be regarded as our highest grade of fuel; it is refined by intricate processes principally from the higher grades of petroleum. The low-grade oils are largely burned as crude fuel in competition with coal, since they are easier to burn efficiently. Pulverized coal, however, may be efficiently burned with equal facility, and coal is more plentiful in nature, especially in the United States. Its use in pulverized form should release a large proportion of the low-grade fuel oils for increasing the production of gasolene by means of the newer processes for "cracking" the heavy hydrocarbons. The author describes the essential features of the various processes for refining petroleum.—Editor.

The Petroleum Industry may be divided into the following four general classifications:

The production of crude oil.
The transportation of crude oil.
The refining of crude oil.
The marketing and distributing of refined products.

The development of crude oil production, in this country, commenced in the original Pennsylvania oil fields with the development of well-boring methods in the 1850's. Small bottles sold as medicinal oil were the first commercial product.

As the yield from developed fields decreased new sources were discovered. These spread to the Ohio-Illinois field, to Texas, Louisiana, Kansas, Oklahoma, California, and now to Wyoming.

Production of Crude Oil

The experiences in the Pennsylvania fields are to some extent typical of those in subsequently discovered fields. The first wells drilled—and this condition held for several years—frequently flowed at the rate of 400 to 500 barrels per day. As the number of wells increased, and the yield of oil became greater, the rate of flow gradually diminished as the "rock-pressure" (original subterranean pressure) became reduced. When this initial pressure of a field is reduced, by the taking out of oil, the escape of gas, etc., the territory becomes known as "settled production." Wells newly drilled in Pennsylvania fields today will yield from 25 to 35 barrels of crude oil the first day, a reduction of fifty to sixty per cent on the second day, and a further reduction to the normal one-eighth to one-quarter barrel per 24 hours in the course of ten to twenty days. A method of increasing the yield of a group of wells was invented some time ago, and has been put into practical operation comparatively recently. Compressed air is forced into a well located at about the center of the group to be operated. There is little appreciable effect upon the surrounding wells the first day, but as the air pressure is gradually built up a distinct increase in the flow of oil to the other wells takes place. The best results have so far been obtained with an air pressure of 80 to 85 pounds per square inch on the air well. At that pressure, the flow of air through the oil bearing strata of sand is considerable, and is plainly evidenced by the fact

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*"Cyclone" is used to designate the systems for carrying pulverized coal in suspension.

†Abstract of paper read before the Pittsfield Section of the American Institute of Electrical Engineers, October, 1916.

that the gas from the operating wells is appreciably leaner, due to air gradually seeping through and escaping with the natural gas.

A typical Pennsylvania oil farm may consist of 100 wells and yet have only one man to do all of the work connected with its operation. The individual wells require but little attention, beyond pumping from 10 to 30 minutes every 24 hours. The power for pumping the wells is furnished by a gas-driven engine; and mechanisms known as "powers," operating on the eccentric principle, are connected in such a way as to pump from four to sixteen wells simultaneously. The gas for operating the driving engine is obtained from the wells, and therefore it costs nothing.

The yield from the individual wells is often stimulated by "shooting," that is, by exploding a cartridge of nitro-glycerine at the bottom of the well. This has the effect of enlarging the opening at the bottom, crushing the sand structure for some distance, and exposing fresh surfaces. The increased yield is only temporary, however, and the production soon drops back to its former level. The increase can be quite closely estimated and the advisability of shooting or not shooting is largely a matter of market price and arithmetic. The condition of "settled production" can best be decribed by stating that the rate of production from these wells has not decreased 5 per cent in five years.

The Ohio-Illinois fields are having a similar history. The wells are still producing much more than those of Pennsylvania, but are on the down grade, and are producing very much less than in the initial years of their development.

The producing fields which are most in the public eye today, are the mid-continent fields, consisting of those of Louisiana, Oklahoma, Kansas, parts of Texas, and other nearby locations. The Oklahoma fields startled the world two or three years ago, when the cream of the field had apparently been drained, by developing a new yield through the application of the simple expedient of deepening the wells to a new strata of oil-bearing sand. In a few months the production increased from about 100,000 barrels to 350,000 barrels per day. While this high production did not last very long, new drilling and development work in the deeper sand has served to keep the production close to the 300,000-barrel mark for much of the time.

The most promising new field development in this country is in Wyoming. Many thousands acres have already been drilled, and land amounting to over a million acres has been leased for development purposes.

*In 1916 a little more than 6,250,000 barrels were produced. Indications point to a production of 15,000,000 barrels for 1917 and 30,000,000 in 1918.

*Great efforts are being made in all parts of the United States to augment the production of crude oil to keep pace with the constantly expanding requirements of this country and her allies—and thereby assist in winning the war. While most of the new development work is being done in the Western states, attempts are also being made to swell the output in the older oil-bearing territory.

*Table I gives a comparative summary of the crude petroleum movement in July, 1917, representing the operations of 151 pipe lines and refining companies, and was compiled from reports received by the United States Geological Survey.

TABLE I

CRUDE PETROLEUM MOVED FROM FIELD SOURCES (BARRELS OF 42 GALLONS EACH)

Field	July, 1916	July, 1917
Appalachian	1,831,000	2,122,300
Lima-Indiana	300,700	291,100
Illinois	1,471,600	1,367,800
Oklahoma-Kansas	9,607,700	12,240,800
Central & North Texas	875,200	931,800
North Louisiana	969,300	856,000
Gulf Coast	1,224,300	1,637,500
Rocky Mountain	535,200	722,800
California	Omitted because of delays incident to securing first-hand data.	

Transportation of Crude Oil

The transportation of crude oil is an interesting though not a very complicated division of the industry. Until the development of the pipe line on a long-distance scale, transportation was effected by railways, etc., and it was usually a matter of economy to erect refineries close to the producing fields and thus ship only the finished products. The successful development of the pipe line, however, made it possible to build refineries on the Atlantic seaboard and at other localities best adapted for the work and for subsequent distribution of the refined products. *The Tide Water Oil Company was the first organization to bring oil through a pipe line from the oil fields to the ocean.* Since the first line was completed, in 1888, many more have been constructed and

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* Recent statistics added by editor.

the many large refineries now operating on the Atlantic seaboard and on the Texas coast bear witness to the efficiency and economy made possible by that development.

Most of the pipe lines are of six-inch diameter, although there are some eight-inch lines. Large pumps, usually driven by internal combustion gas or oil engines, are used to force the oil through the pipes, an initial pressure of 800 to 850 pounds per square inch being employed. Pumping stations are situated along the pipe line from ten to ninety miles apart, depending on the topographical features of the country traversed and the fluidity of the crude oil. The Tide Water Pipe Line extends from Stoy, Illinois, to Bayonne, New Jersey, a distance of 828 miles, and requires twenty pumping stations to operate for that distance.

It is possible to pump 13,000 barrels of oil through a six-inch line in twenty-four hours for a distance of nearly 100 miles. Probably 400,000 to 500,000 barrels of crude oil are pumped each day from the oil fields to refineries on the Atlantic, Gulf, and Great Lake shores through such pipe lines.

Marketing and Distributing the Refined Products

The village grocer filling the little boy's can with kerosene, the tank wagon which stops at the kitchen door, the garages which take your money when you run out of oil or gasolene, are doing the same thing in principle as the large freight steamer which may take 200,000 cases, holding ten gallons each, to South America, Europe or Asia, or the large tank steamer which may load as much as 4,500,000 gallons of products for one voyage.

To attempt to picture all the ramifications of distribution would involve crossing the Andes in pack trains, exploring the interior of China, and traveling through Alaska on dog sledges.

Classes of Petroleum

Crude oils are divided by some authorities into three, and by others into four general classes: Paraffin, asphaltic, and cycloparaffin, a fourth class being a combination of the first two called semi-asphaltic. As a matter of fact, practically all crude oils contain compounds which properly belong under each of the three basic headings and the name given a particular crude oil is usually indicative only of its predominating constituents. Pennsylvania oil is generally accepted as being the nearest to a pure paraffin crude oil obtainable on a large scale, while the mid-continent oils and products of the Illinois fields are usually spoken of as semi-asphaltic or semi-paraffin crude oils. In these latter oils there are asphaltic-forming hydrocarbon compounds present in quantities sufficient to necessitate modifying the refining methods appreciably and in addition there is contained a very large proportion of the paraffin series. Many of the Texas crude oils are composed of highly unsaturated hydrocarbons, are heavy in gravity, difficult to refine, contain little or no wax but large proportions of asphalt, and yield products with poor flash and low boiling points.

The two principal sources of the naphthenic or cyclo-paraffin base crudes are the Russian and the Californian. The products are distinguished by their high specific gravity, and viscosity, and they are quite stable.

Refining

The refining of crude oil, reduced to its simplest terms, may be said to consist of separating the oil into its constituent products and removing the impurities. Due consideration must be given to the characteristics of the raw material and the products which it is desirable and profitable to make.

The principal operations of an oil refinery may be divided into two general classes; those for separating the products in the original crude oil, and those for removing the impurities. There are two operations in the first class; distillation, and crystallization by freezing. Distillation is the more important and is applied in the preliminary separation and final selection of most of the products; while crystallization is resorted to in separating the solid paraffin waxes from the oils in which they are originally held in solution. The two operations in the second class consist of (*a*) the sulphuric acid-treating method, which is usually employed for purifying gasolene, illuminating oils, and the cheaper grades of lubricating oils; and, (*b*) filtering through Fuller's earth, the method generally used for decolorizing and purifying insulating oils, light spindle lubricating oils, automobile lubricants, and steam cylinder lubricating stocks.

The distillations are usually carried on in horizontal cylindrical tanks, which range in capacity from 180 barrels (of 50 gallons) to more than 1,000 barrels, or 50,000 gallons. In refining, generally three methods of distillation are followed: *First*, the "Dry" or "Cracking," *Second*, the "Wet" or "Steam," and *Third*, the "Vacuum."

Jeoffry Ornad in the French army transport service

General Vehicle Company truck in commercial service

Same vehicle as above equipped as an armored car

Motor transport train in the French army

Important Users of Gasolene and Oil, the Primary Products of the Petroleum Industry

First: Cracking distillation is so called because, under the influence of the high temperature necessary to distill the oil in the ordinary way, the more unstable of the heavier hydrocarbons break up or "crack" into lighter compounds. At the same time a small quantity of fixed gas, that is, hydrocarbon vapor not condensable under ordinary conditions, is evolved with the attendant formation of some coke.

The principle of subjecting an oil to a temperature higher than its natural boiling point, in order to crack it, has long been applied to increasing the production of illuminating oils from heavy gravity, lower priced products. Of late years this method has been very extensively used in making gasolene from these same products, and even from the illuminating oil itself.

Another very important function of dry distillation is the crystalizing of the wax present in the crude oil. As found in crude oil, paraffin wax has very little crystalline form, being in an amorphous state, and only after it has been subjected to thermolizing, or heat treatment of dry distillation, does it attain the crystalline form of the paraffin wax of commerce. The difference in the structure between the regular paraffin wax and that in the amorphous form is made apparent by comparing the former with vasoline or "petroleum jelly." This latter is really paraffin wax in its original amorphous state, but decolorized by filtering through Fuller's earth.

Second: The object of introducing live steam into the still during the steam distillation of products is diametrically opposite to that underlying dry or "cracking" distillation. The comparatively low vapor pressure of superheated steam has the effect of reducing the pressure on the surface of the oil in the still. This enables the refiner to carry on distillation at materially lower temperatures than the natural boiling points of the oil. It tends to eliminate the destructive distillation, or cracking, of the dry method, preserving the quality and uniformity of the hydrocarbons.

Third: The vacuum distillation method is that of distilling under a partial vacuum by exhausting the vapors from the still with a pump. The object is the same as in the steam method; viz., to prevent destructive distillation by carrying out the distillation at lower temperatures. It involves more expensive apparatus and is costlier to operate. It is being used but little now, as the results secured by the steam distillation method are considered to be equal to those of the vacuum method by most refiners.

Selective Condensation

While full advantage has been taken by refiners of the possibilities of separation by distillation, it was not until about eight or ten years ago that any practical attempt was made to utilize the fractionating possibilities of selective condensation of the vapors of distillation. It was a well known fact that while the hydrocarbons comprising the distillate obtained at any particular part of the distillation consisted of a much narrower range of boiling points than the product being distilled, there was still a wide difference between the light and heavy fractions of any such distillate. About 1908 an aerial condensing tower was perfected, based on the principle of the dephlegmator, which succeeded in separating the stream of distillate into from two to four parts.

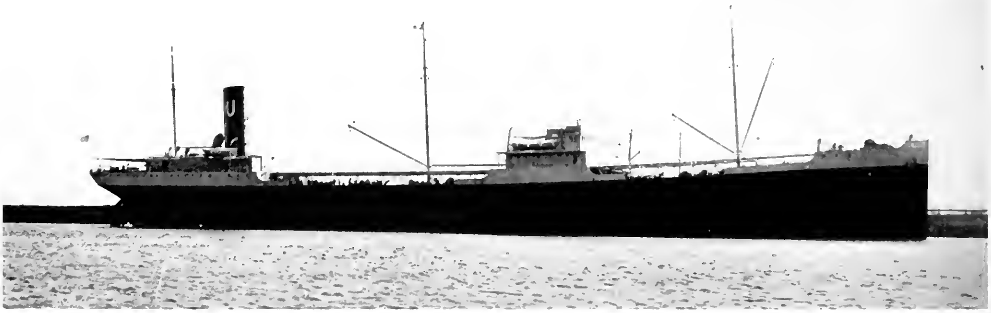
This separation is accomplished by passing the vapors through tubes around the outside of which air is allowed to circulate. The principle has since been extended to a much further degree and the aerial condensing towers with which the more modern crude stills are equipped enable refiners to separate the distillate at any point into as many as ten fractions. By means of this apparatus it is possible to extend the separation and obtain uniformity of products to a degree impossible under the older methods.

In addition to the three methods of distillation that have been mentioned, distilling under pressure in special apparatus is now largely resorted to in order to increase the production of gasolene. This procedure will be referred to later in connection with other gasolene-making processes.

Separating the Wax

Crystallization or freezing is resorted to for separating the wax from the oil. As the boiling points of the waxes are the same as many of the lubricating oil series, it is obvious that separation by distillation is impossible. The method generally employed is to cool the wax-bearing distillates to a temperature at which wax crystals will solidify, and then to force the cooled mixture through filter presses. In this operation from 75 to 80 per cent of the mixture passes through the canvas plates of the filter press while the remainder is retained in solid form. This soft wax, or "slack wax" as it is called, consists of a mixture of approximately 40 per cent paraffin wax and 60 per cent heavy oils. It is necessary in this first crystallizing operation to have the temperature low enough to remove all of the available wax from the distillate being pressed.

The next step is a further separation of the slack wax. This is done by dumping it, after melting, to what are known as sweaters, an apparatus consisting of long shallow pans equipped with hot and cold water coils for alternately cooling and heating the wax. The slack wax is first cooled to the point of solidification, and after this has been reached the cooling water is withdrawn and the cake slowly heated. An effect similar to distillation, but on a lower plane of physical processing, is obtained. A selective melting of the slack wax takes place, the lighter oils and lower melting point waxes being allowed to run off into suitable receiving tanks until the wax of commercial standards is left. The principal purpose of this process, as distinguished from that of the pressing operation, is to insure all of the oil being eliminated from the wax. The intermediate fractions of both methods are simply returned to the raw material tanks and reprocessed, until final separation has been accomplished.



Oil Burning Tanker "La Brae." Driven by 2600-h.p. Curtis Turbine through Alquist Reduction Gear

Purifying Operations

The purifying operations are less complicated than the separating processes. The sulphuric acid treatment consists in mixing sulphuric acid with the oil to be treated, and at the same time agitating the oil either with air or by mechanical means to insure intimate and uniform contact of the acid and oil. The apparatus consists of an upright cylindrical tank with a cone bottom to facilitate the drawing off of the acid and impurities. The acid attacks and throws down in the form of sludge some of the unstable hydrocarbons, impurities, and coloring matter. This sludge is later put through a separating and concentrating process, and about fifty per cent of the original acid is recovered. The oils are then washed, first with water and then with a solution of caustic soda to neutralize any acid particles which might have remained.

Filtration processing is also carried on in upright cylindrical tanks, somewhat similar in appearance to the agitators as the acid treating tanks are called. These filters, which are about fourteen feet in height and ten feet in diameter, are filled with comparatively coarse Fuller's earth to within six inches of the top. The oil is forced through the Fuller's earth under a slight pressure and the decolorizing and purifying action continues until the earth has become satuated with impurities. It is interesting to know that even after the tank is filled practically to the top with Fuller's earth it is still possible to get over five thousand gallons of oil into a filter before all of the spaces between the grains of the earth have been filled. When the clay, as the filtering medium is sometimes called, becomes saturated with impurities the oil remaining in it is washed out with naphtha and the clay is revivified by gradual heating in a rotary kiln to about 1000 deg. F.

"Cracking" Processes for the Manufacture of Gasolene

The fact that heavy hydrocarbons could be broken up or "cracked" into lighter constituents by heating above the normal boiling point of the oil has been known and used in a practical way since 1861, for increasing the yield of illuminating oils at the expense of the heavier and less valuable fractions. It was not until comparatively recently that the growing requirements for gasolene have made such a process desirable for increasing the

the output of hydrocarbons suitable for use in internal combustion engines. Previous to 1910, the aim of the refiner was to pass as much as possible of the light distillates from the crude oil into the kerosene fractions. There was usually a good export and domestic market for kerosene, while gasolene and naphtha were a "drug." Four and five cents a gallon was considered a good price for gasolene and hundreds of thousands of barrels were burned as fuel under stills and boilers. Over practically all the world laws were passed requiring the burning-oil products to conform to certain flash specifications, in this way restricting the quantity of naphtha which the refiner could mix off with his burning oil fractions. The closer the refiner could approximate the legal limit of flash-point and still pass inspection, the less gasolene he would have to dispose of at a loss. Today, the situation is so different that every particle of illuminating oil is squeezed for the last drop of gasolene or naphtha which can be extracted from it. Instead of shipping burning oils with a flash-point as near as possible to the limit, practically all such products are being turned out now with flash-points from 15 to 30 degrees higher than legally required.

With gasolene selling at from 20 to 30 cents per gallon. however, the incentive to increase the production quickly stimulated the inventive minds of oil men and scientists; and processes and apparatuses almost without number, comparatively few of which ever passed the laboratory stage, have been worked out and patented. These processes can be divided into three general classes:

First: Those employing the principle of pressure distillation in stills of the cylindrical type. These are known as two-phase processes, because of the fact that both liquids and vapors are present at all times. This makes the pressure and temperature interdependent. It is practically impossible to develop a higher temperature than that due to the boiling point of the oil at the pressure employed.

Second: Those treating the oil in tubes at high temperatures, the entire product being vaporized. These are known as single-phase processes. Any temperature can be used regardless of the pressure and vice versa. Some of these employ steam.

Third: Those termed "catalyzer processes," in which the oils to be treated are heated in the presence of metals having a catalyzing effect. Cracking is accomplished without pressure and at comparatively low temperatures.

The most successful example of the first method is the process invented by Dr. W. M. Burton of the Standard Oil Company of Indiana. That company has now in operation about 400 stills of the Burton type and other refiners have in operation, and in course of construction, between 300 and 400 more. During 1917, the gasolene produced by this process, over and above the normal yield from crude oil, will probably amount to 400,000,000 or 500,000,000 gallons.

None of the second method processes has been operated on anything like the scale of the Burton. The Hall process, which employs a continuous one-inch tube 350 feet long, operates at from 950 to 1000 deg. F. and at pressures up to 70 pounds; the Rittman process, which involves the use of about an 8-inch tube 12 to 16 feet high, operates at temperatures ranging from 1000 to 1400 deg. F. and at pressures from 70 to several hundred pounds; and the Greenstreet process, carried on in a continuous 2-inch pipe about 200 feet long, with superheated steam at pressures and temperatures similar to the Hall process, are all being worked on a comparatively small scale.

The only system of the third class which appears to have reached a practical stage is the process employing aluminum chloride as a catalyzing agent, patented by Dr. A. M. McAfee of the Gulf Refining Company. This company has a large plant in course of construction for carrying on this process. Dr. McAfee's method is also noted for the improved quality of the by-products of distillation. The principal problem is the recovery of the catalyzing agent, on a commercial scale, which presents considerable difficulty.

Manufacture of Gasolene from Natural Gas

There is one more large source of gasolene of comparatively recent origin and that is the extraction of the product from natural gas. It is obtained from the gas from oil wells and natural gas wells. The growth of this industry since it first became a commercial factor about 1910, has been phenomenal; stimulated as it was by the constantly increasing demand and higher prices, which also played such a large part in the growth of the cracking process. By one method, the gas issuing from the wells is compressed to pressures ranging from 75 to 300 pounds, and cooled while under pressure, to temperatures at which the heavier hydrocarbons condense. The yield obtained varies from one-half gallon to five gallons per 1000 cubic feet. The gas issuing from oil wells naturally contains the larger yields. This casing-head gasolene, which is very high in gravity and extremely volatile, is blended with the comparatively heavy naphtha fractions derived from crude oil, and is put on the market in that form. Another method largely used is known as the absorption process, in which the gases issuing from the well are allowed to bubble through the blending stock, as the heavy naphtha is termed, at pressures ranging from 30 pounds upwards, and at temperatures low enough to cool the heavier hydrocarbons and retain them in the blending stock. The estimated production from this source was 43,000,000 gallons in 1914, close to 75,000,000 gallons in 1915, and the rate of increase will be even more rapid for three or four years to come.

Successive Steps in Refining

In order to illustrate the oil refining process we can follow the progress of Pennsylvania crude oil through a modern refinery. The first step is to divide the crude oil into its various constituents, this being accomplished by distillation in a still heated by fire as distinguished from stills heated by steam.

By separating the liquefied fractions as they come from the condenser coils, an initial yield of the various products is obtained in about the following proportions:

Crude Gasolene	about 15 per cent
Crude Illuminating Oil and Naphtha Mixture	about 10 per cent
Crude Illuminating Oil	about 15 per cent
Crude Illuminating Oil and Light Gas Oil Mixture	about 20 per cent
Lubricating Distillate (mixture of Gas Oil, Wax, and Lubricating Oils)	about 23 per cent
Steam Cylinder Lubricating Oil (Cylinder Stock)	about 16 per cent
Loss	about 1 per cent

The next step in the process is a further distillation of the mixed products in order to get a sharper separation than was possible in the original operation. The crude illuminating oil and naphtha mixture is redistilled. Because of the comparatively low boiling point of this fraction, it is possible to get the requisite heat from steam. The mixture is thus divided into crude naphtha and crude illuminating oil in about equal proportions. Fire-heated stills are necessary to further separate the crude illuminating oil and light gas oil mixture. This product breaks up into about 20 per cent crude gasolene, 50 per cent crude illuminating oil, and 20 per cent light gas oil. The lubricating distillate, sometimes called wax distillate, is a more complex mixture than either of the preceding, in that it contains three constituents instead of two; viz., gas oil, wax, and lubricating oil, in addition to impurities which are present to a greater or lesser extent in all the fractions. The first step is to eliminate the wax from the mixture. For this purpose, artificial refrigeration is resorted to, the entire distillate being cooled to about 20 deg. F, at which point all wax particles solid at ordinary temperatures will have assumed crystalline form. This cooled distillate is then forced at high pressure through the filter presses. About 75 per cent of the mixture passes through the plates while the remainder is retained. This "slack wax" contains all of the 9 per cent of wax in the original distillate, mixed with some of the heavy lubricants. The selective melting of the sweating process removes the heavy lubricants and very soft waxes, and leaves commerical scale wax ready for purifying and decolorizing.

The lubricating distillate, called "pressed lubricating distillate," from which the wax has been removed, now undergoes a combined steam and fire distillation which vaporizes the gas oil, the more volatile constituent, and leaves the lubricating oil content in the still as a residue. This treatment completes the first phase of the refining operations, that of the separation of the crude oil into its constituent products, and the results at this point are, roughly, as follows:

Crude Gasolene and Naphtha	about 24 per cent
Crude Illuminating Oil	about 30 per cent
Gas Oil	about 20 per cent
Lubricating Oils	about 7 per cent
Wax	about 2 per cent
Steam Cylinder Lubricating Oil	about 16 per cent
Loss	about 1 per cent

There are of course by-products ("tailings" and "intermediate cuts") which require incidental working and reprocessing

In the second phase of refining, that of removing impurities, the crude gasolene, naphtha, and illuminating oils are all treated with 66 deg. gravity sulphuric acid. The agitator is filled to within four to six feet of its top with the product to be treated. The acid is introduced at the top of the tank while the entire contents are violently agitated. The water wash, neutralization with caustic soda, and in some refineries filtration through Fuller's earth, practically complete the process during which one or two per cent of the product treated is lost.

Gas oil is not usually refined, as the uses to which it is put do not require any particular standard of purity. It is used for enriching illuminating gas.

The better grades of lubricating oils are usually purified by filtration through Fuller's earth until the requisite standards are attained, the loss on this occasion amounting to about 4 per cent. With the sulphuric acid method the operation is similar to that for gasolenes and refined oils, but from two to five times as much chemical is used and the losses are from 5 to 25 per cent, depending on the quality of the raw material and quantity of acid used.

The wax is purified by filtration, either through Fuller's earth or bone black. The loss involved is approximately 1 per cent.

Steam cylinder lubricating oil or "cylinder stock" is suitable for most of its uses without further processing, but it is sometimes filtered and the wax content settled out cold as vaseline to make the finer grades of oil known as cold test cylinder stocks.

The yields of finished products obtained from Pennsylvania crude oil, when worked out as described, are approximately as follows:

Gasolene and Naphtha	about 23.7 per cent
Illuminating Oil	about 29.5 per cent
Gas Oil	about 20.0 per cent
Lubricating Oil	about 6.7 per cent
Wax	about 2.0 per cent
Cylinder Stock	about 16.0 per cent
Loss	about 2.1 per cent

Insulating Oils

Insulating oils are not an everyday product of a refinery. In the sequence of the products yielded by crude oil, they fall between the gas oil and the lubricating oil fractions. They are actually very light lubricating oils, doubly distilled, with a lower content of the low melting point waxes than average lubricating oil, and are very carefully refined.

Insulating oils are usually distilled from lubricating distillate which has undergone a minimum of destructive distillation; and filtration through Fuller's earth plays a very important part in their purification. Finally, before shipping, the all-important complete dehydration must be effected. The special processes employed in producing this class of products not only involves special equipment, but also requires more elaborate testing equipment and chemical and processing skill than is available in all refineries.

Operation of Series Incandescent Lighting Circuits with Series Transformers

By E. D. Treanor

Transformer Engineering Department, General Electric Company

The series street-lighting transformer was developed for the purpose of furnishing a local low-voltage series lighting circuit where a standard high-voltage series circuit might be dangerous. The type of transformer described in the following article is the latest and most highly developed form of series incandescent lighting transformer for the above purpose. Mr. Treanor clearly describes the open-circuit and short-circuit characteristics of the series transformer and shows how these have been brought into agreement with the necessary and the desirable characteristics of the series incandescent circuit. He then analyzes the combined subject of grounding, operation, and protection.—Editor.

The rapid growth of street lighting with high candle-power incandescent lamps has greatly increased the use of small series transformers which are connected in existing high-voltage constant-current circuits to facilitate the operation of street lighting units. These transformers are used primarily to utilize existing circuits and to retain the advantages of the series system while limiting the voltage on the circuits actually connected to the lamps. Therefore, they are largely employed in areas where the maximum voltage is fixed by consideration of safety. It frequently happens that the voltage which may be used in streets or parks is fixed by ordinance.

Some aspects of the operation and characteristics of series transformers are not so well understood as those of constant-potential apparatus; and, as a result, the series installations are not always arranged so that the best service will be obtained. A brief description of the more important features may therefore be of interest.

The system as usually operated consists of one or more series transformers connected in a constant-current series circuit, which is supplied by a constant-current transformer or constant-current regulator. The transformer may be in series with high candle-power lamps, or the entire load on the constant-current transformer may be made up of small circuits each isolated by a series transformer. These series transformers may each feed the lighting circuit for a park area, one or more city blocks, a bridge, a "safety isle," etc. As the usual consideration is to limit the voltage on the lamps and their fixtures, the size of the series transformer is fixed by the voltage which is considered safe. As the current is known, the working voltage may be obtained by dividing the load in watts, plus the line loss in watts, by the current.

Open-circuit Voltage

One of the features of a series system is that if an open circuit occurs at any point the entire open-circuit voltage of the system is available at that point to maintain the current or to operate the cut-out. The equivalent of this feature is needed in the series transformer, since its maximum working voltage is usually not sufficient to operate the film cut-outs. It is, therefore, important that the open-circuit voltage of a transformer, operated as just described, be very much higher than its working voltage, since the automatic operation of the film cut-outs at each lamp depends upon this.

This open-circuit voltage lasts only momentarily under normal conditions, as the film immediately breaks and restores the transformer to the normal voltage for its load. When, however, the circuit is broken accidentally, so that the film will not close it, adequate protective devices are necessary for the open-circuit voltage may be of dangerous value. These protective devices must function without interfering with the normal operation of the films across the lamps.

The actual value of the open-circuit voltage cannot readily be measured and, on account of the fact that its wave shape is much distorted, a statement of its value in effective volts may be misleading, for the danger to operators or to the public depends upon the peak voltage, the value of which is not indicated by a measurement or a statement of the effective value of the open-circuit voltage. It is quite possible that the peak voltage may be three or more times as high as the peak of a sine wave of the same effective value. As a concrete example, a two-kilowatt series transformer having a working voltage of 256 volts at 7½ amperes may have an effective open-circuit voltage of 925 volts, which on a sine wave would mean a peak of $925 \times 1.41 = 1300$ volts.

However, the actual peak of the distorted wave may be 4000 volts, corresponding to the peak of a 2820-volt sine wave.

Protection against this condition is therefore absolutely necessary. The usual method of supplying this is by means of film cut-outs of the proper strength connected directly across the transformer. These cut-outs are of such strength that they will permit the failure of a lamp and the operation of its individual film without .puncture of the main film; but when the circuit is broken and cannot be closed by the individual films, this protective device short circuits the transformer and reduces the voltage to zero. Open-circuit operation of a series transformer is somewhat analagous to short-circuit operation of a constant-potential transformer. In the short circuit of a constant-potential transformer, the current increases to a value limited by the transformer impedance. In the open-circuit operation of a series transformer, the voltage rises to values limited practically by the saturation of the core and other factors discussed more in detail elsewhere. Either condition is abnormal and will usually result in damage to the transformer by burning out the winding of a constant-potential transformer and by overheating the core of a series transformer. The overload relay is a protective device for the constant-potential transformer, and the film cut-out for the series transformer. The smaller series transformers, due to their large radiating surface, can operate on open circuit indefinitely without overheating; and, as their open-circuit voltages are not dangerous, no protective devices are needed. When the transformer is so large that its open-circuit voltage is dangerous the protective device must be used in any case, and consequently there is no longer any object in making the transformer capable of thermally withstanding open-circuit conditions. A short circuit on a series transformer (externally) merely results in zero load, so that the transformer is not damaged by continous operation short circuited.

Assuming a peak voltage of 1000 volts (corresponding to an effective value on a sine wave of 710 volts) as the maximum value which is safe on apparatus which operators handle, although they do not touch current carrying parts, protective devices should be used with all transformers having higher peak voltages. This means that transformers of one kilowatt or above are provided with protective devices consisting of two pairs of clips, one pair adapted to hold the film cut-out and to be inserted in in the second pair which is connected across the transformer. The latter pair of clips short circuits the transformer when the pair containing the cut-out is removed for examination or replacement of the film.

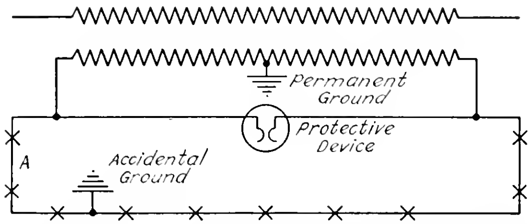


Fig. 1. Diagram of Series Lighting Circuit Employing Single Series Transformer with Middle Point of Secondary Grounded

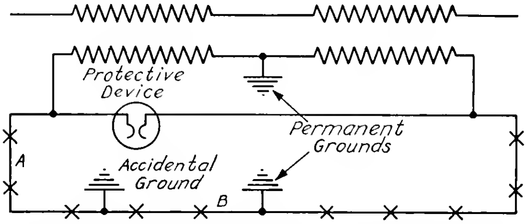


Fig. 2. Diagram of Series Lighting Circuit Employing Two Similar Series Transformers with Intermediate Point Between Secondaries and Middle Point of Lamp System Grounded

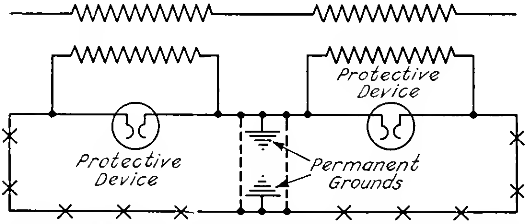


Fig. 3. Diagram of Series Circuit Employing Two Similar Series Transformers with Intermediate Point Between Secondaries and Middle Points of Lamp Circuit Grounded and with Two Protective Devices in Circuit

It must be understood that the high open-circuit voltage is necessary to maintain the operation of a series system (i.e., to supply the high voltage required to break the film and close the circuit after a lamp fails) but it is dangerous under accidental conditions and safe-guards must be provided against these dangerous conditions.

Grounding of Secondary Circuits

The secondary circuit is frequently grounded to reduce, to a value equal to half the open-circuit voltage of the transformer, the voltage above earth which may occur in case of an accident. Without this ground the breaking of a pole might open the transformer secondary and ground one side, so that full open-circuit voltage would exist between line and ground on the other side of the transformer. The permanent grounding is accomplished by connecting the middle point of the secondary to earth, or by using two independent transformers (at least having two independent magnetic circuits and secondaries) connected in series, with the point between them grounded. The advantages and disadvantages of these two arrangements are as follows:

Referring to the single transformer having its neutral point grounded, the disadvantage is that if the secondary circuit becomes grounded at any point away from the center of the secondary system, the lamps between the transformer and the accidental ground will be subjected to excessive current amounting perhaps to nearly 100 per cent over the normal current. These lamps, shown at *A* in Fig. 1, will be burned out.

The advantages are that there is only normal strain on the winding, and that the single unit costs less.

With two equal transformers connected in series the disadvantages are as follows: *First*, if the transformers have not been specially designed for this system of operation, (i.e., if two standard transformers of half capacity are used) there will be an extra strain on the ends of the secondary winding due to the fact that one end is grounded permanently. Ordinarily, however, this is not important. *Second*, the two transformers will cost more than a single unit. *Third*, a ground on one side of the system may subject the other transformer to severe overload, in spite of the protective device. Fig. 2 shows this is due to the fact that a ground occurring on one side of the middle of the system causes the other transformer to add to its load the lamps included between the middle point and the accidental ground, whereas the load on the other transformer is decreased. This condition can be satisfactorily avoided only by grounding the middle point of the lamp system, as well as the point between the transformers. This connection will prevent any overload on either transformer, but will have the disadvantage that the lamps at *B* in Fig. 2 will be cut out, although they will not be damaged in case of an accidental ground.

The advantage in this system is that, if the point between the two transformers is prop-

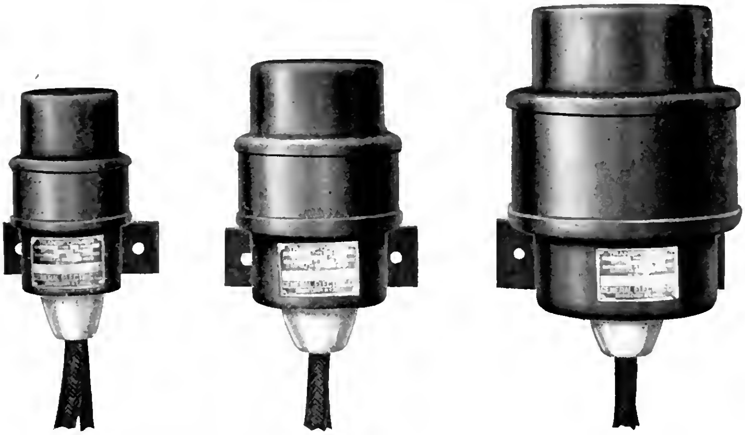


Fig. 4. Series Lighting Transformers of Various Sizes for Mounting on Poles

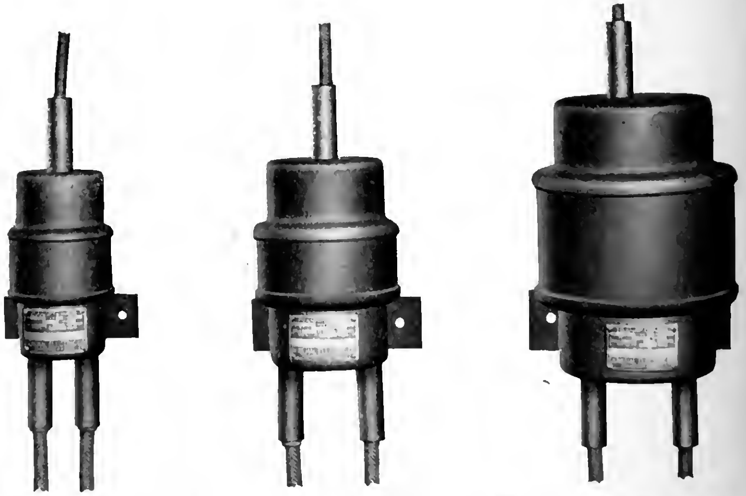
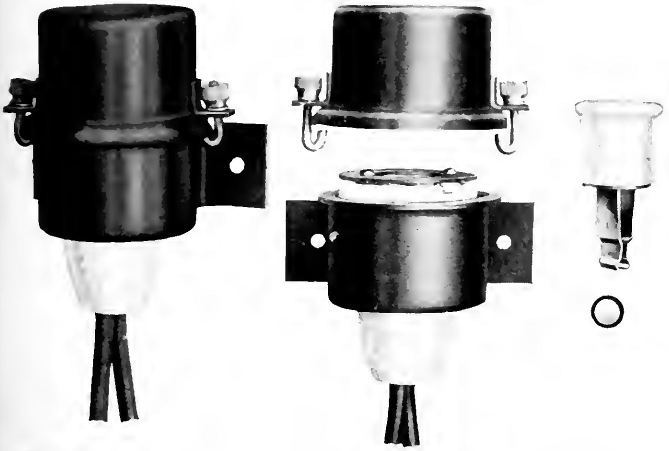


Fig. 5. Series Lighting Transformers for Installation in Manholes or at Base of Poles.

erly grounded, a ground on the secondary circuit does not damage the lamps at *A* in Fig. 2. Even if only one or two lamps are included between the ground and the transformer, these lamps will not be subjected to excessive current, as the short-circuit current of each transformer under this system is only three to five per cent in excess of normal current.

In general, then, if protection of the lamp is the primary object, the system having two transformers in series is superior; but in order to prevent the possibility of overloading one transformer, it is necessary to securely ground the middle point of the secondary circuit. This arrangement entails the use of a separate protective device on both transformers, which slightly increases the cost of installation. This system is really the equivalent of two distinct series loops with a common return wire for which the earth is used, as shown in Fig. 3.



Figs. 6 and 7. Views of Protective Device, Assembled and Disassembled

For transformers less than 1 kilowatt capacity, grounding is not usually considered necessary. For transformers from 1 to 3 kilowatts capacity inclusive, the grounding of the neutral really accomplishes very little, as the full normal voltage is not dangerous, and even half of the open-circuit voltage *is* dangerous, so that the protective device must be relied upon to render the system safe, irrespective of whether the neutral is grounded. If the ground is made to keep the voltage above earth within a specified or ordinance limit, the object of the latter is defeated unless the peak voltage is considered instead of the effective voltage. The only real value of grounding the secondary of such a transformer is to prevent high static potentials from accumulating on the ungrounded secondary, due to a ground on the primary or even to the normal potential of the primary above earth. For this purpose a ground at one end of the secondary serves as well and avoids the possibility of burning out lamps as referred to in the case of Fig. 1 where the middle point of the transformer secondary is grounded.

Regulation

The regulation may be seriously changed by running the secondary cable in iron armor which adds an inductive component to the load and greatly increases the line losses and decreases the available output of the transformer. It is difficult to calculate and provide for this effect, so it is generally better to avoid such operation wherever possible.

Apparatus

The transformers are built in capacities ranging from 40 watts to 10 kilowatts, and in all standard series currents from 4 amperes to 7½ amperes. They may be mounted either on the poles, in manholes, or, in case of the smaller sizes, in the base of ornamental poles, or buried at the foot of the poles. When mounted on poles they are provided with suitable porcelain outlet bushings and weather-proof cable for connection in the primary and secondary circuits, (see Fig. 4). When they are to be used in manholes or at the base of poles, a water-tight construction is used with wiping sleeves for connection to the lead cable of the circuit (see Fig. 5).

The smaller transformers, namely, the 2-kilowatt sizes and less, are of the air-cooled type with a shell-type core and circular steel casings. The larger transformers are oil-cooled and use standard lighting transformer parts with special porcelains or subway bushings. The insulation throughout is so proportioned as to be adequate for the strains to which the transformers may be subjected on series systems of approximately 10,000 volts, and for the internal strain due to open-circuit voltage

The protective devices are usually mounted across the secondary terminals of the transformer. They are contained in small steel cases similar to the transformer cases. The films consist of disks of easily fusible metal, cemented to the two sides of insulating washers. Under the open-circuit voltage of the transformer, the gap between the two disks breaks down and the soft metal melts and bridges the gap, thus short circuiting the transformer.

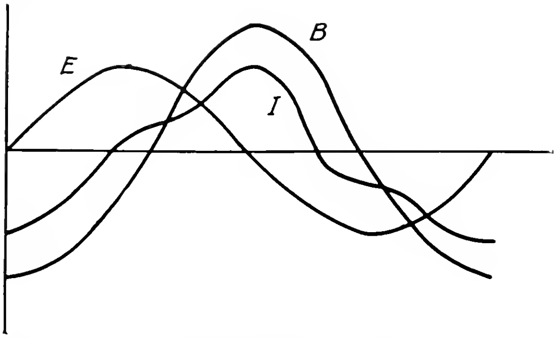


Fig. 8. Curves Illustrating Normal Conditions with Series Transformer Secondary Closed

I. "Saw tooth" exciting current in transformer.
B. Sinusoidal flux wave.
E. Sinusoidal voltage across loaded transformer.

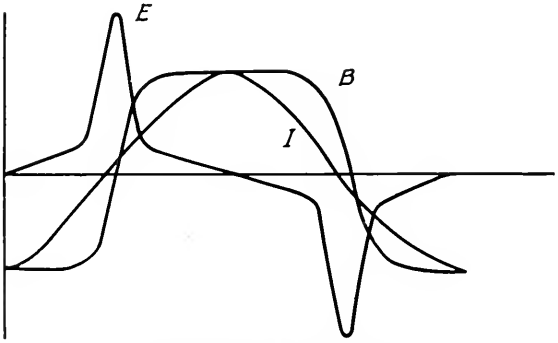


Fig. 9. Curves Illustrating the Condition with Series Transformer Secondary Opened

I. Forced sinusoidal exciting current.
B. Flux wave distorted to a flat-topped wave by saturation of core.
E. Distorted voltage wave with very high peak caused by the distorted flux wave.

It is not within the scope of this article to give a detailed discussion of the cause of the voltage distortion, but a very brief explanation and reference to some of the factors which determine the value may be included.

When the secondary of a series transformer is open circuited, the current flowing in the primary is practically unchanged, as the series transformer forms only a small part of the total load on the supply transformer, and the latter is designed to prevent change of the current value with change of load. Not only is the value of the series current unaffected by the open circuit on the secondary of the series transformer, but its wave shape remains unchanged, and as the remainder of the load is, under the conditions considered, noninductive and the supplying voltage sinusoidal, the current will be sinusoidal.

In a loaded series transformer the primary current may be considered as made up of two components, one balancing the secondary load current, and the other, amounting to perhaps 10 per cent of the total, is the exciting current. The exciting component is of the usual "saw tooth" wave shape taken by a closed magnetic circuit under sinusoidal voltage. When the secondary circuit opens, the entire primary current is forced through the transformer as exciting current of quite different wave shape from that which is required to produce sine voltage. The core is subjected to far greater magnetizing force than normal and the iron is saturated. Under these conditions the voltage is distorted into a single narrow peak, whose effective value is far higher than that which would be produced by an exciting current of the same root-mean-square value but of the usual wave shape of the exciting current taken by a closed magnetic circuit, and whose peak may be very much higher still.

Thus the voltage across a series transformer under these conditions may appear to be safe and yet contain a peak actually dangerous to the apparatus or to life. The ratio of peak to effective value in a sine wave is 1.41, while the ratio in the distorted wave may rise to 10 or more. Ordinary voltmeters reading the effective value of the wave give no indication of the peak value. This effect is illustrated graphically by Figs. 8 and 9.

The demand for very close regulation tends to increase the value of the peak, for when very accurate ratio is required over a wide load range, i.e., the transformer has good regulation, the normal exciting current is small, and the ratio of increase on open circuit is great, so that the peak value is relatively higher. The ratio of peak on open circuit to peak on closed circuit is roughly equal to the ratio of full series current to the percentage of exciting current of the transformer under load. The peak can never be higher than the peak of the primary system, and may be reduced by magnetic leakage.*

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* A very full and interesting treatise on this subject is given under the chapter headed "Shaping of Waves by Magnetic Saturation" in "Theory and Calculation of Magnetic Circuits" by Dr. Steinmetz.

Street Lighting with Modern Electric Illuminants

By S. L. E. Rose and H. E. Butler

Illuminating Engineering Laboratory, General Electric Company

This article amounts practically to a handbook on street illumination, covering both incandescent and arc lamps from the illumination standpoint, and enables anyone having to do with street lighting to compare different units on the basis of illumination. It discusses the various factors entering into street lighting contracts which should be thoroughly understood by all parties concerned in order to avoid controversies later on. It is a well known fact that street lighting appropriations are usually much too small and are apt to remain so until the advantages of well lighted streets are better recognized.—Editor.

The earliest form of street lighting consisted of lamps placed in the windows of houses for certain specified hours each night, and probably the first street lighting company on record was organized by an Italian abbott, Landati Caraffa, in Paris, about the sixteenth century, whereby torch bearers were furnished to guide people through the streets at night, for which a fixed charge per hour was made. The next development was street lanterns, and as early as 1745, it is said, reflectors were used on these lanterns.

In 1879, Thomas A. Edison perfected the electric incandescent lamp and shortly after lighted the roads and paths at Menlo Park, which was probably the first incandescent electric street lighting system in this country. It was not until about 1900, however, that incandescent electric lamps were extensively used in street lighting.

About 1880, Thomson brought out the open arc which gave a great impetus to street lighting by electricity. This was followed by the enclosed arcs which were placed on the market about 1895, and marked a step forward in electric lamps for street lighting.

In 1905, the luminous or magnetite arc lamp was developed, and marked a distinct advance both in efficiency and light distribution. The development since that time has been mostly in the improvement of electrodes and minor changes in the lamp itself.

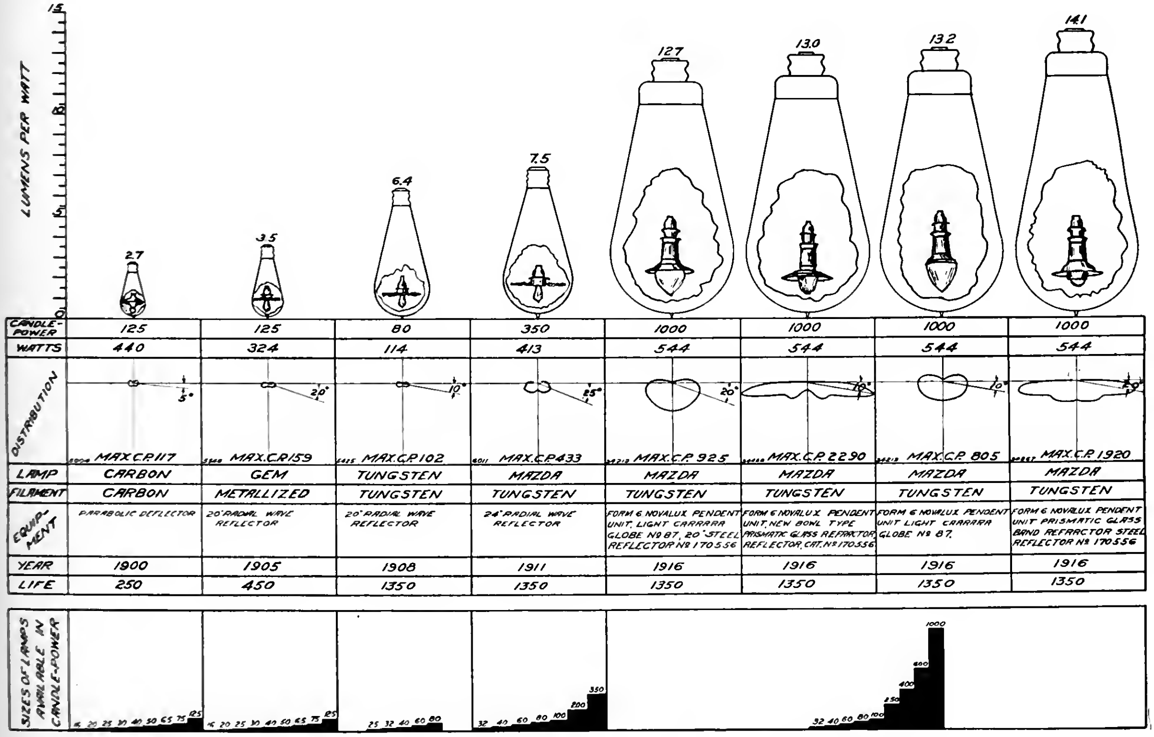


Fig. 1. Advances in Efficiency of Series Incandescent Lamps, 1900-1916

It was about 1908 that tungsten filament lamps were first used for street lighting, and the growth since that time has been rapid. In 1911, the tungsten filament or Mazda lamps as they are now called were available in sizes up to 350 c.p., while in 1916 lamps of 1000 c.p. were in common use, and today 1500 c.p. lamps are being used in some places. The advances in efficiency made both in incandescent lamps and arc lamps are shown on Figs. 1 and 2. It will be noted in Fig. 2, which shows the advances in series arc lamp efficiencies, that the enclosed flame arc is slightly higher in overall efficiency than the luminous arc. For this reason some may wonder why data are not included on the flame arc lamp. In street lighting, overall efficiency is not always the deciding factor. Other factors such as maintenance, operation, candle-power distribution, available accessories, such as the prismatic refractor, etc., enter into the problem with the advantages all in favor of the luminous arc or Mazda lamp. Very few systems of street lighting with flame arc lamps were ever installed in this country and this lamp is now practically obsolete as a street lighting unit. Furthermore, the flame arc was only available in one size and, therefore, only adapted for one class of lighting where large units could be used. For the foregoing reasons the authors did not consider the flame arc lamp for street lighting and did not think it worth while to furnish data on this obsolete unit.

So long as incandescent lamps were not available in large candle-power sizes, the arc lamp had no serious competitor for street lighting. With the advent of the large Mazda series lamps, however, conditions were changed, and today units suitable for all classes of street lighting are available in both arc and incandescent lamps. The selection is usually governed by local conditions.

Probably the greatest advance in street lighting accessories was the development of the Holophane prismatic refractor which gives a control of light distribution hitherto unattainable. It can be used on either arc or Mazda lamps, its use being made possible by the fact that with the magnetite arc lamp the arc does not travel down as it does on the open and enclosed carbon arcs, and with

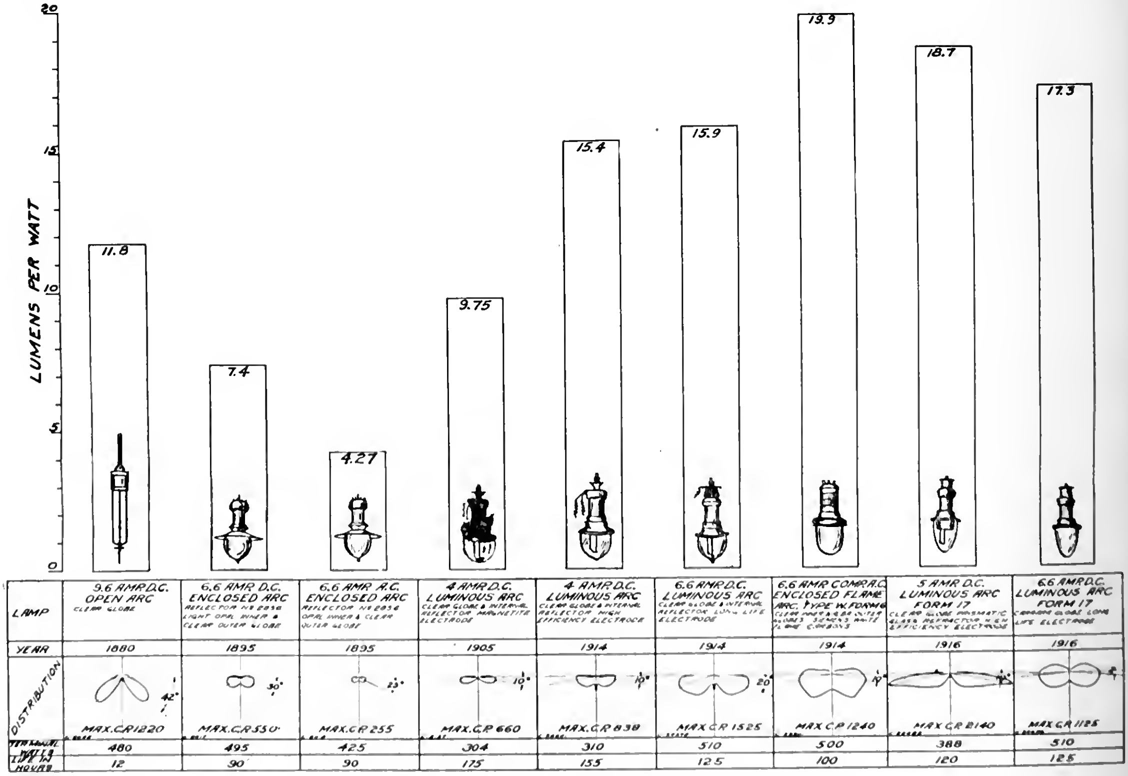


Fig. 2. Advances in Efficiency of Series Arc Lamps, 1880-1916

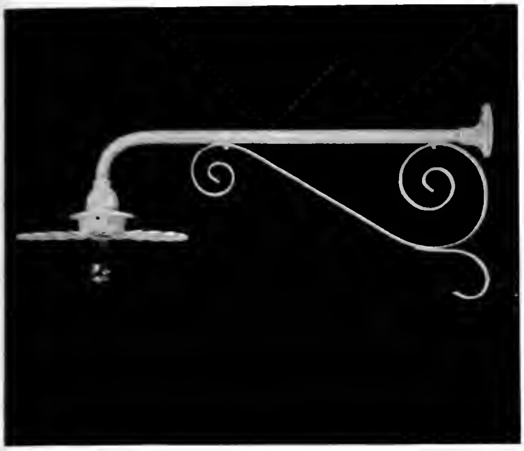


Fig. 3-a. Flat Radial Wave Reflector Unit used with 40-, 60-, 80- or 100-c-p. Mazda Series Lamp

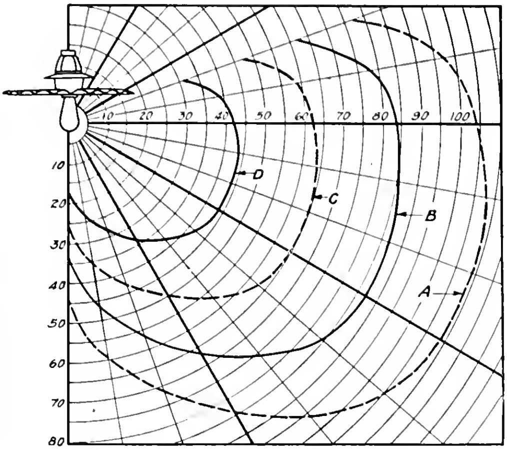


Fig. 3-b. Initial Distribution of Candle-power in a Vertical Plane of the Unit shown in Fig. 3-a

Curves *A* *B*, *C* and *D* correspond to the lamps named in Fig. 3-c.

Mazda lamps the filaments have been concentrated into a much smaller space than on the older incandescent lamps.

Utilitarian lighting usually is accomplished by means of pendant units mounted on bracket arms along one side of the street, while for ornamental lighting the units are mounted on top of poles and placed on both sides of the street, arranged either parallel or staggered. As the name implies, an ornamental system uses diffusing or other ornamental glassware and the aesthetic effect is

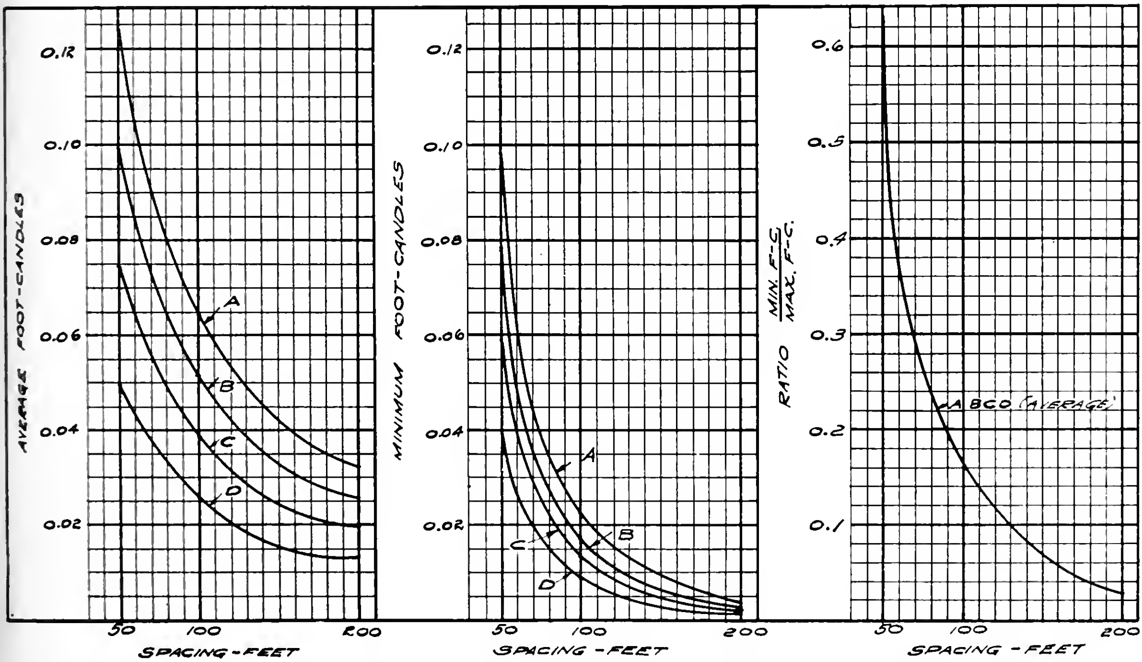


Fig. 3-c. Calculated Illumination Values on Street Surface along Center Line of Street

Lamps one side of street only, on 4-ft. bracket arm. Height, 18 ft. Width of street, 40 ft.

A:	100-c-p. Mazda Series Lamp, S-24½ bulb	*C:*	60-c-p. Mazda Series Lamp, S-24½ bulb
B:	80-c-p. Mazda Series Lamp, S-24½ bulb	*D:*	40-c-p. Mazda Series Lamp, S-24½ bulb

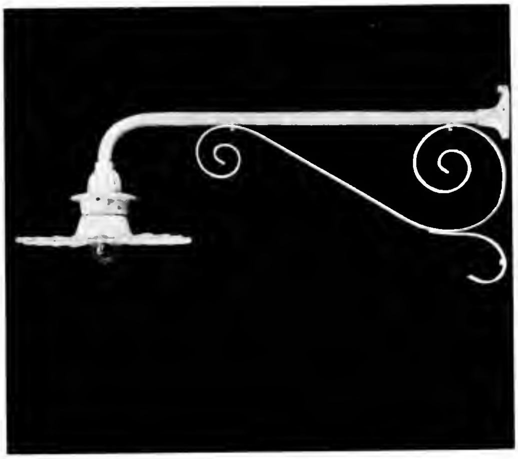


Fig. 4-a. Dome Radial Wave Reflector Unit used with 40-, 60-, 80-, 100- or 250-c-p. Mazda Series Lamp

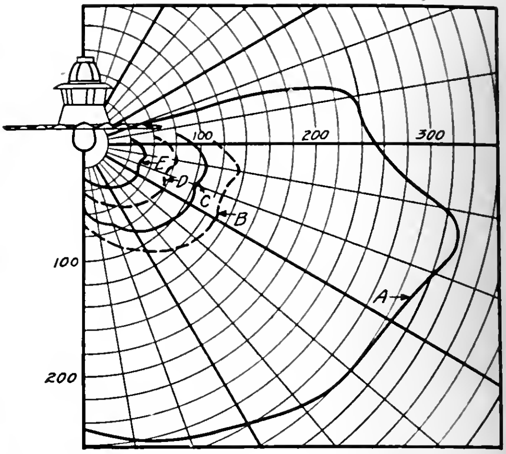


Fig. 4-b. Initial Distribution of Candle-power in a Vertical Plane of the Unit shown in Fig. 4-a

Curves *A*, *B*, *C* and *D* correspond to the lamps named in Fig. 4-c.

obtained by some sacrifice in the efficiency of the unit. In a system of this kind, the upper stories of the buildings receive light from the unit and the street receives back some of the upward light by reflection and diffusion from the building fronts.

Obviously, intensities will vary with the class of service; i.e., outlying districts will not require as high an intensity as important residence streets, and the residential districts will not need the intensity of the business districts. In the various districts, the im-

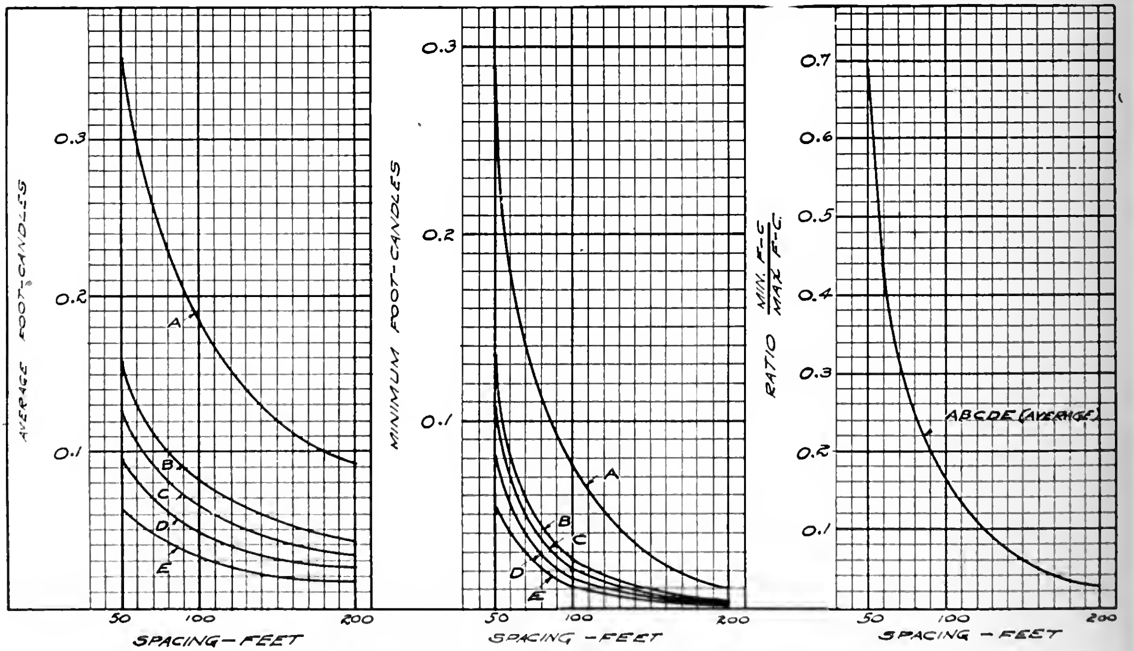


Fig. 4-c. Calculated Illumination Values on Street Surface along Center Line of Street

Lamps on one side of street only, on 4-ft. bracket arm. Height, 18 ft. Width of street, 40 ft.

A: 250-c-p. Mazda Series Lamp, PS-35 bulb
B: 100-c-p. Mazda Series Lamp, S-24½ bulb
C: 80-c-p. Mazda Series Lamp, S-24½ bulb
D: 60-c-p. Mazda Series Lamp, S-24½ bulb
E: 40-c-p. Mazda Series Lamp, S-24½ bulb

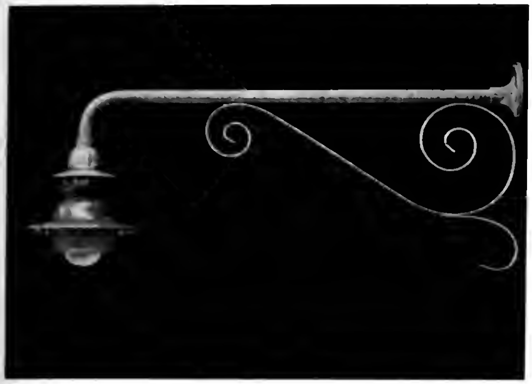


Fig. 5-a. Prismatic Refractor Unit used with 40-, 60-, 80-, 100- or 250-c-p. Mazda Series Lamp

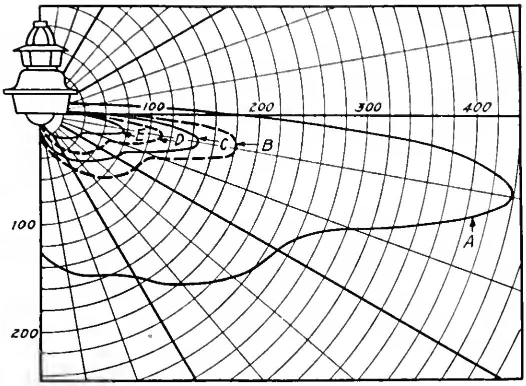


Fig. 5-b. Initial Distribution of Candle-power in a Vertical Plane of the Unit shown in Fig. 5-a

Curves *A*, *B*, *C*, *D* and *E* correspond to the lamps shown in Fig. 5-c.

portant streets are usually given preference over the side streets as regards intensity of illumination.

Table I gives an indication of the illumination intensities required for various classes of service but local conditions may necessitate a variation from these values, and a further development of the art may see them materially increased, as evidenced by some recent western installations.

TABLE I

	Average Hor. Illum. Foot-candles
Principal streets in cities . . .	0.25 to 1.0
Important side streets	0.10 to 0.25
Residence streets	.01 to .05
Suburban roads	.005 to .01

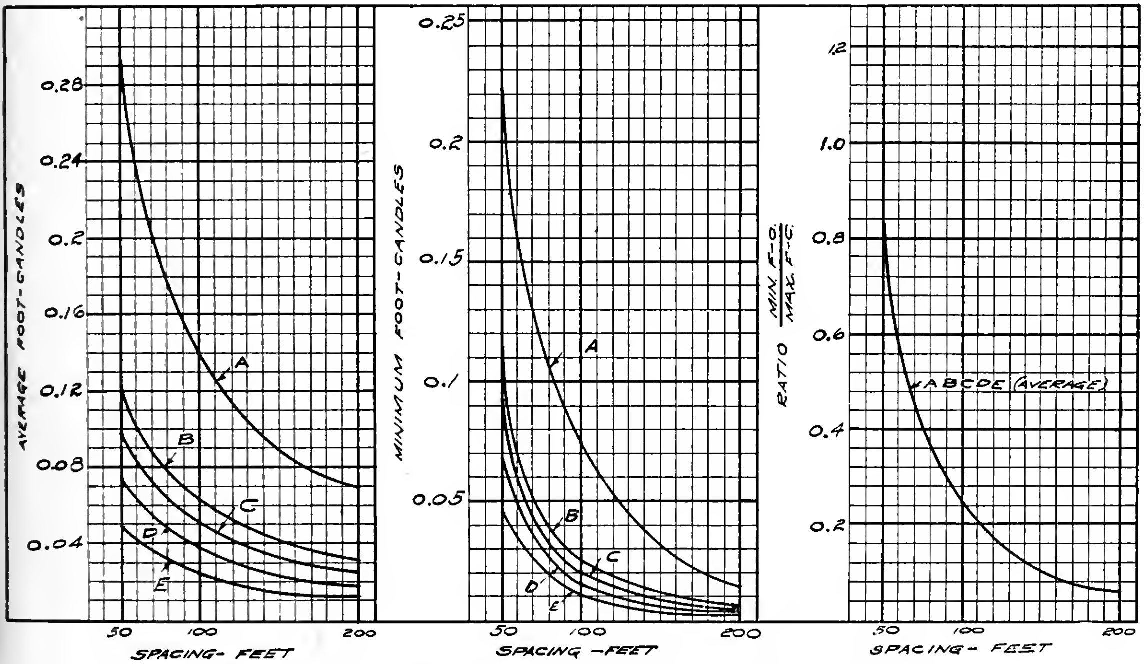


Fig. 5-c. Calculated Illumination Values on Street Surface along Center Line of Street

Lamps on one side of street only, on 4-ft. bracket arm. Height, 18 ft. Width of street, 40 ft.

A: 250-c-p. Mazda Series Lamp, PS-35 bulb
B: 100-c-p. Mazda Series Lamp, S-24½ bulb
C: 80-c-p. Mazda Series Lamp, S-24½ bulb
D: 60-c-p. Mazda Series Lamp, S-24½ bulb
E: 40-c-p. Mazda Series Lamp, S-24½ bulb

Fig. 6-a. Novalux Pendant Unit with Diffusing Glass Globe and Reflector used with 250-, 400-, 600- or 1000-c-p. Mazda Series Lamp

Fig. 6-c. Novalux Pendant Unit with Prismatic Refractor and Reflector used with 250-, 400-, 600- or 1000-c-p. Mazda Series Lamp

In using Table I it should be borne in mind that the color or reflecting power of the pavements and buildings have a marked effect on the illumination of a street. Buildings or pavements having dark-colored or dirty surfaces require a higher intensity of illumination than those having light-colored surfaces in order to appear equally well lighted.

The data are presented mostly in the form of curves which are practically self-explanatory, and need no lengthy description in order to indicate their usefulness in solving the street lighting problems that come within their range. However, there frequently are cases where special conditions have to be met, or where individual and distinctive treatment is required, which will make necessary the services of an illuminating engineer. The assumptions upon which the calculations are based, and the range of the calculated values, were made to conform as nearly as possible to what was considered good average practice. In case other values are met, it will usually be possible to interpolate sufficiently close for all practical purposes. The curves show initial values of illumination and, where necessary, some allowance should be made for depreciation in service. The various

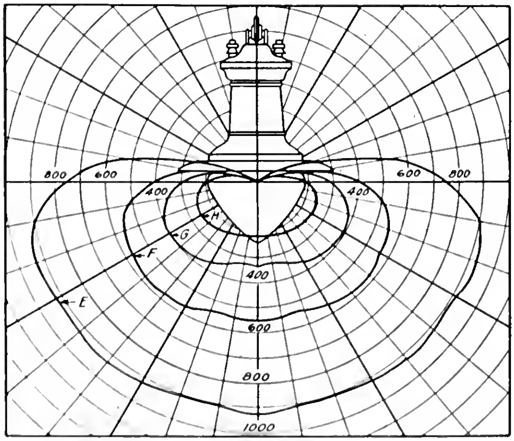


Fig. 6-b. Initial Distribution of Candle-power in a Vertical Plane of the Unit shown in Fig. 6-a

Curves *E*, *F*, *G* and *H* correspond to the lamps named in Fig. 6-e.

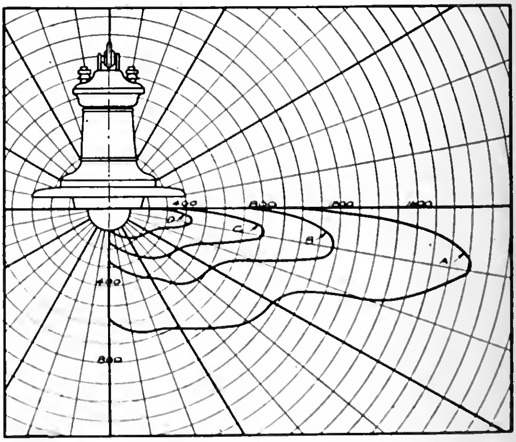


Fig. 6-d. Initial Distribution of Candle-power in a Vertical Plane of the Unit shown in Fig. 6-c

Curves *A*, *B*, *C* and *D* correspond to the lamps named in Fig. 6-e illustrations are made up of three distinct parts: photograph of the unit; characteristic distribution curves of its candle-power; and curves showing its average foot-candles, minimum foot-candles, and uniformity of illumination for various spacings. The uniformity factor is the ratio of minimum to maximum foot-candles.

The following are a few of the many questions that can readily be answered by reference to the curves:

What average or minimum intensity of illumination will result from a specified spacing and arrangement of units?

Taking equal average or minimum intensity of illumination as a basis, what will be the spacing required for the various units with their different equipments?

From this and the wattage, what is the power consumption per linear foot?

Taking equal uniformity of illumination as a basis, what will be the spacing required?

With a specified spacing and equipment, what will be the average and minimum illumination and the uniformity?

For ornamental systems, how do the parallel and staggered arrangement of units compare?

Where more than one unit per pole is employed, these curves can be used by simply increasing the illumination values and the wattage two or more times according to the number of units per pole. Other uses will suggest themselves, and the illustrations should be a valuable aid in designing and laying out street lighting systems.

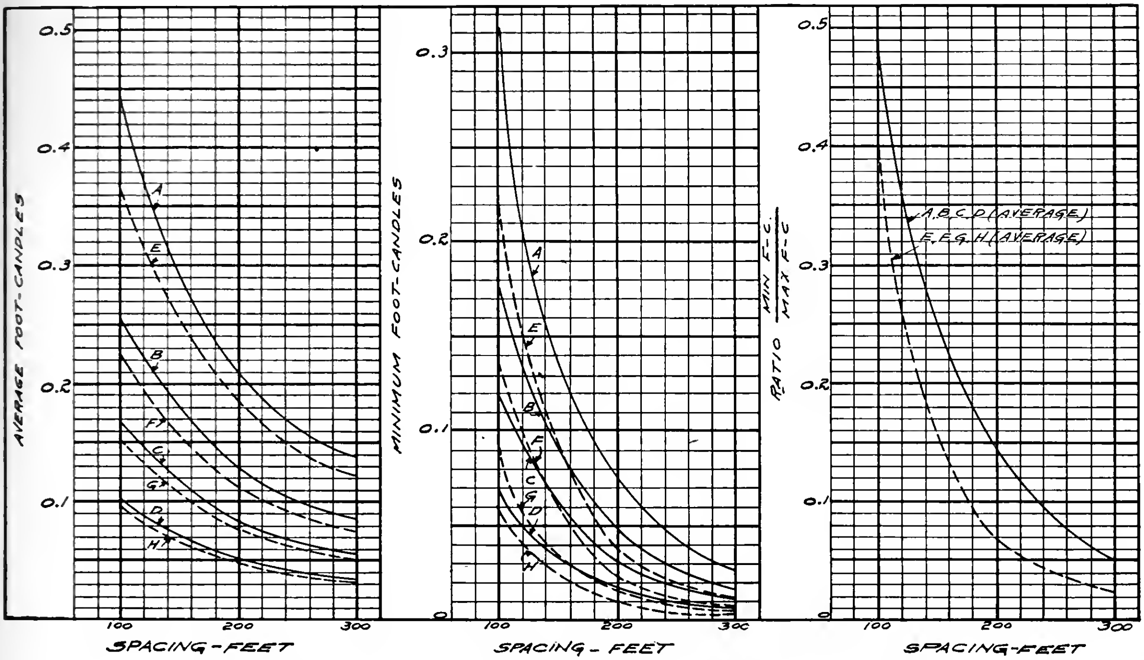


Fig. 6-e. Calculated Illumination Values on Street Surface along Center Line of Street

Lamps on one side of street only, on 4-ft. bracket arm. Height, 25 ft. Width of street, 60 ft.

A, B, C, D: Prismatic Glass Band Refractor and Steel Reflector
E, F, A, H: Diffusing Glass Globe and Steel Reflector
A and *E:* 1000-c-p., 20-amp. Mazda Series Lamp, PS-40 bulb
B and *G:* 600-c-p., 20-amp. Mazda Series Lamp, PS-40 bulb
C and *G:* 400-c-p., 15-amp. Mazda Series Lamp, PS-40 bulb
D and *H:* 250-c-p., 6.6-amp. Mazda Series Lamp, PS-35 bulb

Clear glass globes are seldom seen today on large candle-power units, due to the high intrinsic brilliancy of the light sources, but if clear glass globes are used the units should be suspended as high as local conditions will permit. Diffusing glass globes or similar glassware will reduce the glare, and though lowering the efficiency of the unit as a whole, they may increase the ability to see.

Ornamental or "white-way" installations are becoming more and more popular as an advertising feature for a city. Business men realize the advantages of an ornamental lighting system in attracting crowds to their street and are usually willing to help financially in the installation. Civic Improvement Leagues and Associations also realize the advantage to their city in such a system and are usually found giving the movement their vigorous support.

Street Lighting with Mazda Series Lamps

The most efficient incandescent lamp for street lighting today is the Mazda series lamp. It can be equipped with a variety of accessories suitable for all types of outdoor lighting from the rural highway to the so-called "white-way" or ornamental systems in business districts. Various equipments of glassware and reflectors together with a wide range of candle-power sizes (see Tables II and III), give a flexibility which adapts this lamp to almost every condition to be met in street lighting service. Never before has there been so large a number of units to select from, which will meet both small and large appropriations and give satisfactory results.

TABLE II

DATA ON MAZDA SERIES LAMPS

Nominal Rated C.P.	Total Lumens	Watts	
		6.6 Amps.	7.5 Amps.
40	400	35	36
60	600	46.8	48
80	800	60	60
100	1000	72	72
250	2500	155	147
400	4000	244	228
600	6000	368	344

For outlying and residence districts, especially where shade trees line the streets, small units, Figs. 3a, 4a, and 5a, which can be hung low and spaced at frequent intervals will give better results than large units, Figs. 7a and 7c, spaced at relatively long intervals. Figs. 3, 4, and 5 give data on small units available for this class of service. For relatively wide spacings, the refractor is particularly well adapted.

Where large pendent units may be used, the data in Fig. 6 will apply and for ornamental installations the data are given in Figs. 7 and 8.

Fig. 7-a. Novalux Ornamental Unit with Diffusing Glass Globe used with 400-, 600- or 1000-c-p. Mazda Series Lamp

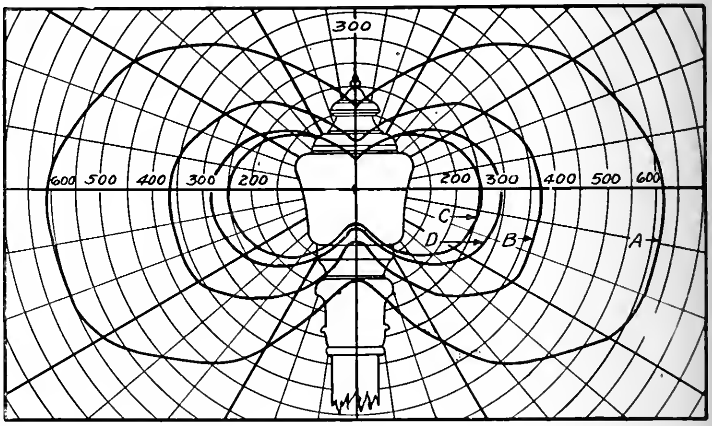


Fig. 7-b. Initial Distribution of Candle-power in a Vertical Plane of the Unit shown in Fig. 7-a

Curves *A*, *B*, *C* and *D* correspond to the lamps named in Figs. 7-c and 7-d.

Table III lists high-current Mazda lamps with which auto-transformers are used having 6.6 amperes or 7.5 amperes primary and 15 or 20 amperes secondary.

TABLE III

Nominal Rated C. P.	Total Lumens	Lamp Amperes	Watts at Auto Transformer
400	4000	15	245
600	6000	20	330
1000	10000	20	544

Street Lighting with Arc Lamps

The most efficient and useful arc lamp for street lighting today is the direct-current, series, luminous or magnetite arc lamp. It is economical to maintain and reliable in operation. It is made in two types, one for pendant lighting and one for ornamental or "white-way" lighting. It can be equipped

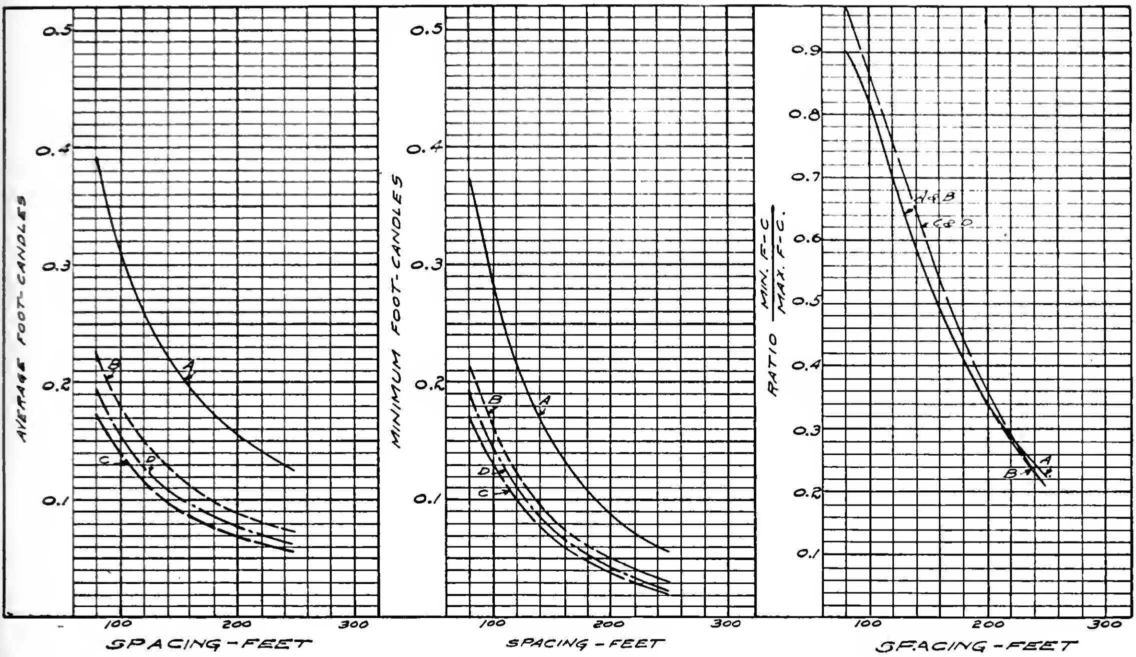


Fig. 7-c. **Calculated Illumination Values on Street Surface along Center Line of Street**

Lamps on both sides of street, staggered. Height, 15 ft. Width of street, 60 ft.

A: 1000-c-p., 20-amp. Mazda Series Lamp, PS-40 bulb, and Medium Density Diffusing Globe
B: 600-c-p., 20-amp. Mazda Series Lamp, PS-40 bulb, and Medium Density Diffusing Globe
C: 400-c-p., 15-amp. Mazda Series Lamp, PS-40 bulb, and Medium Density Diffusing Globe
D: 400-c-p., 15-amp. Mazda Series Lamp, PS-40 bulb, and Light Density Diffusing Globe

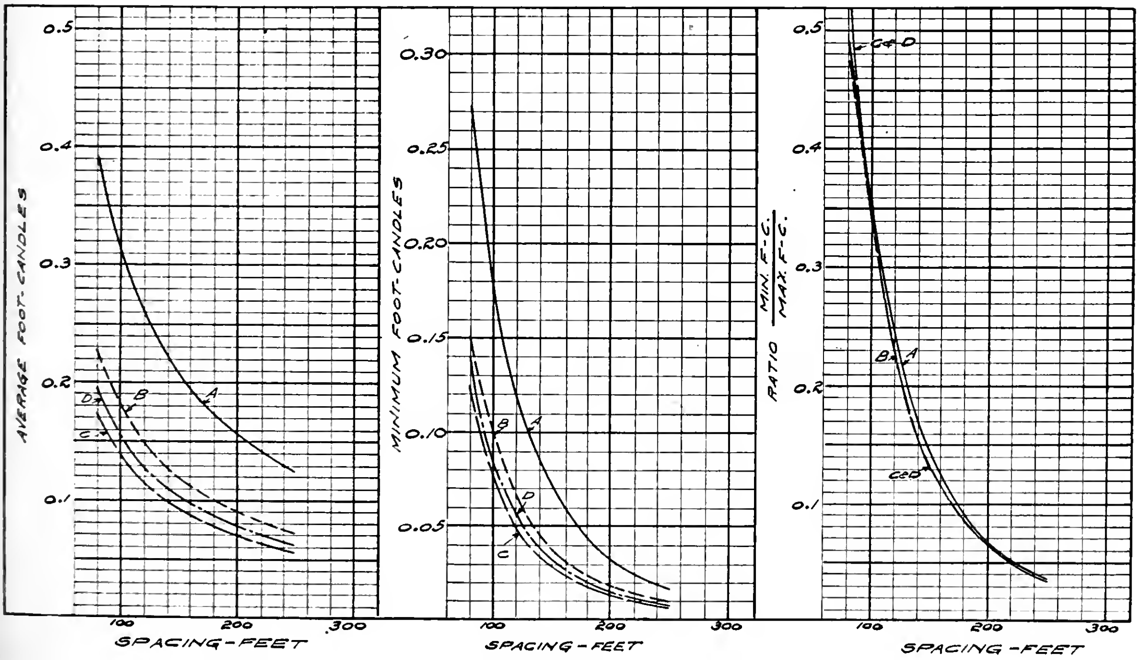


Fig. 7-d. Same as Fig. 7-c, except lamps are arranged parallel instead of staggered

with clear or diffusing glassware, or with a prismatic refractor. Long life and high efficiency electrodes are available which, when operated at various currents (see Table IV), give a wide range of candle-power to this unit. For data on the pendent type luminous arc see Figs. 9, 10, and 11; and for data on the ornamental type see Figs. 13 and 14.

There are still a great many enclosed carbon arc lamps in use for street lighting in this country which should be replaced by modern illuminants. In order that a comparison may be made between these obsolete lamps and the modern street lighting units, similar data have been prepared for the carbon arcs and are shown in Fig. 12.

Fig. 8-a. Novalux Ornamental Unit with 8-panel Diffusing Glass Globe used with 400-, 600- or 1000-c-p. Mazda Lamp

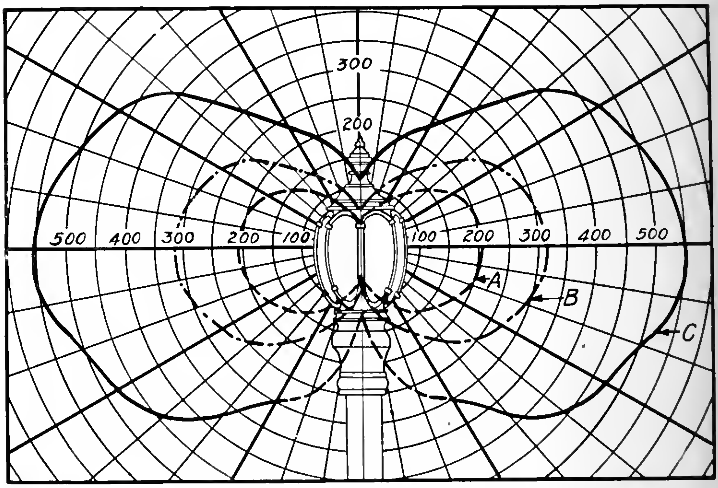


Fig. 8-b. Initial Distribution of Candle-power in a Vertical Plane of the Unit shown in Fig. 8-a

Curves *A*, *B* and *C* correspond to the lamps named in Figs. 8-c and 8-d.

Street Lighting Contracts

A great deal of trouble and misunderstanding between central station and city officials has been caused in the past by street lighting contracts not being specific enough. This matter has been receiving more and more attention by the National engineering societies and various states.

TABLE IV

DATA ON D-C. SERIES LUMINOUS ARC LAMPS

Pendant Type		Ornamental Type	
Amps.	Watts	Amps.	Watts
4	310	4	330
5	388	5	403
6.6	510	6.6	532

Committees have endeavored to draft model contracts that would serve as a guide, but the work is not so easy of accomplishment as it might seem, owing to the different conditions prevailing in various localities.

A great many factors which enter into this problem make it extremely difficult to draft a satisfactory street lighting contract. This condition results from the wide diversity of opinion as to what constitutes good street lighting and as to what is the best basis upon which different systems may be fairly and equitably compared. Some favor uniform over non-uniform lighting; some favor staggered over parallel arrangement of units; and some favor hanging the units over the center of the street instead of along the curb line. As to what are the relative advantages of each of these it is difficult to state, due to lack of sufficient data, and what is best in one case may be entirely unsuitable in another due to a change in conditions.

Interior lighting practice is standardized to a great extent. There is a fairly close agreement as to the intensities required for various classes of interior lighting, but street lighting practice is not so well standardized nor is it likely to be until the problems mentioned previously, and many others, have been

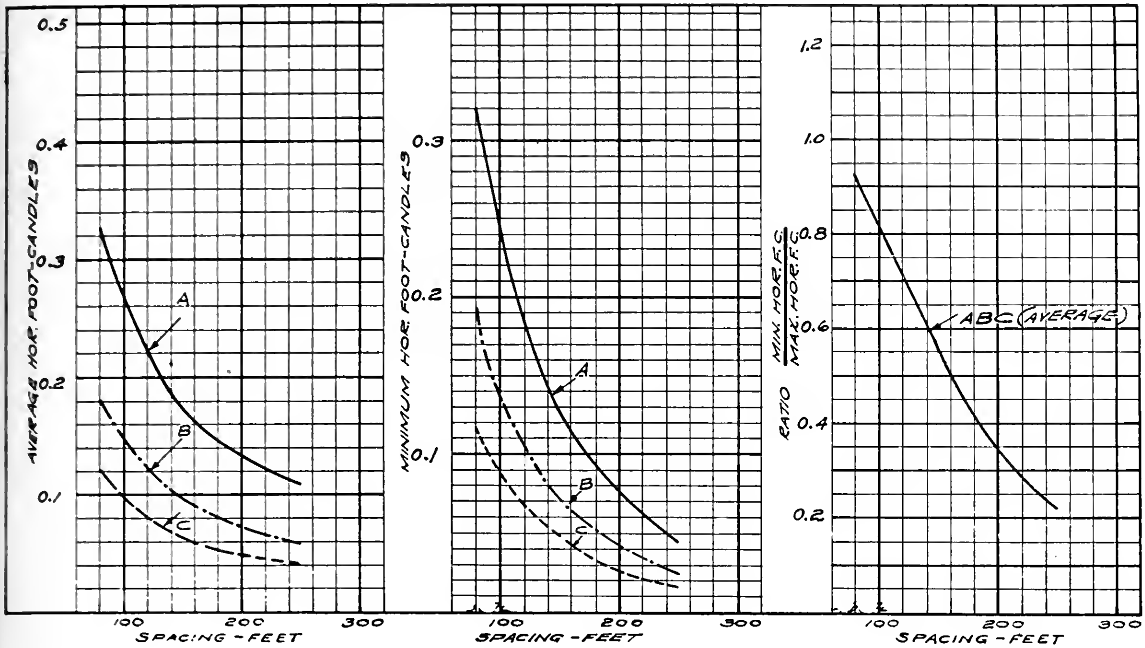


Fig. 8-c. Calculated Illumination Values on Street Surface along Center Line of Street

Lamps on both sides of street, staggered. Height, 15 ft. Width of street, 60 ft.

A: 1000-c-p., 20-amp. Mazda Series Lamp, PS-40 bulb
B: 600-c-p., 20-amp. Mazda Series Lamp, PS-40 bulb
C: 400-c-p., 15-amp. Mazda Series Lamp, PS-40 bulb

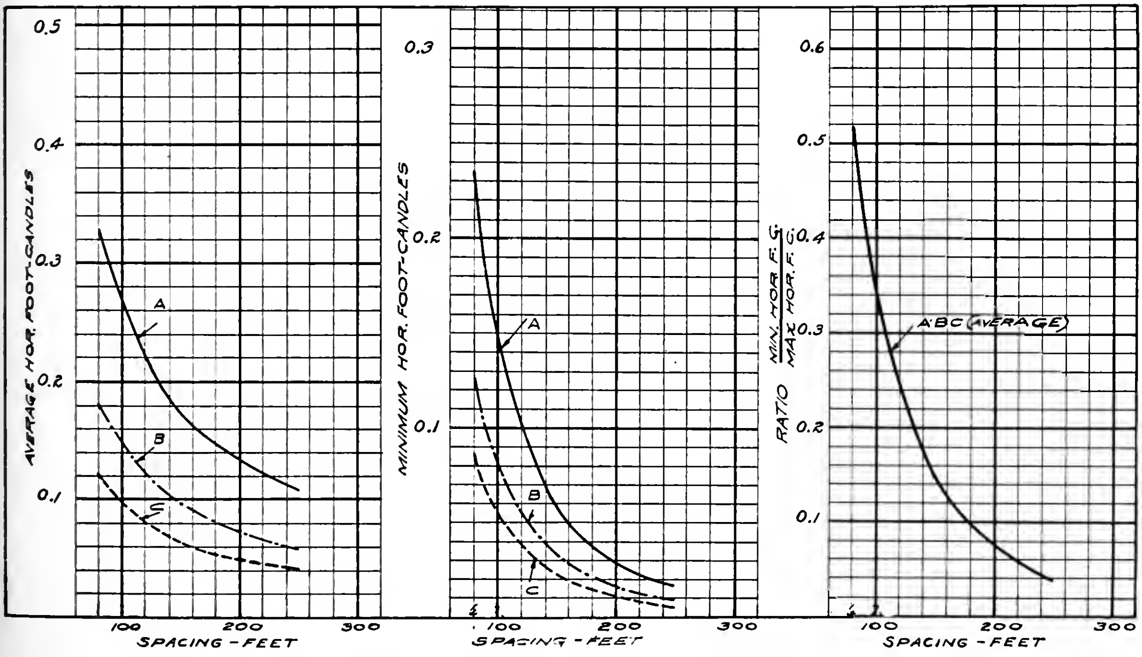


Fig. 8-d. Same as Fig. 8-c, except lamps are arranged parallel instead of staggered

Fig. 9-a. Pendant Type Luminous Arc Lamp with Clear Glass Globe

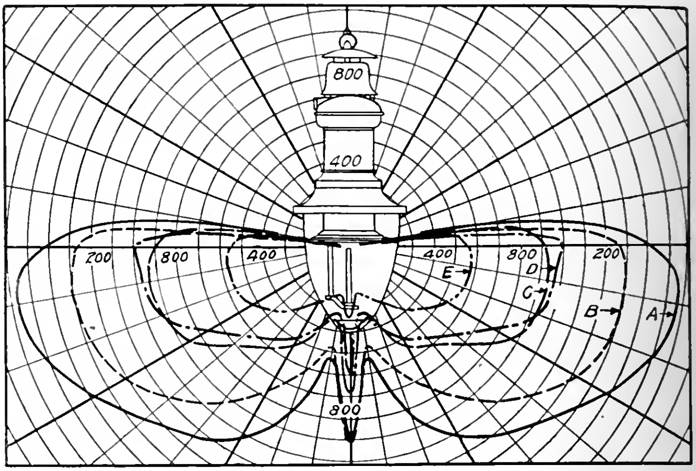


Fig. 9-b. Initial Distribution of Candle-power in a Vertical Plane of the Unit shown in Fig. 9-a

Curves *A*, *B*, *C*, *D* and *E* correspond to currents and electrodes named in Fig. 9-c.

solved. It is usually not a question of how much light should be given this street or that, but of what will be the irreducible minimum, or of accommodating the street lighting system to an appropriation which is usually much too small.

It is quite generally agreed that the best method of comparing lamps or lighting units, as regards their efficiency as light generators, is on the basis of total lumens per watt. (Spherical candle-power × 4 π). The total lumens will be a maximum when the lamps

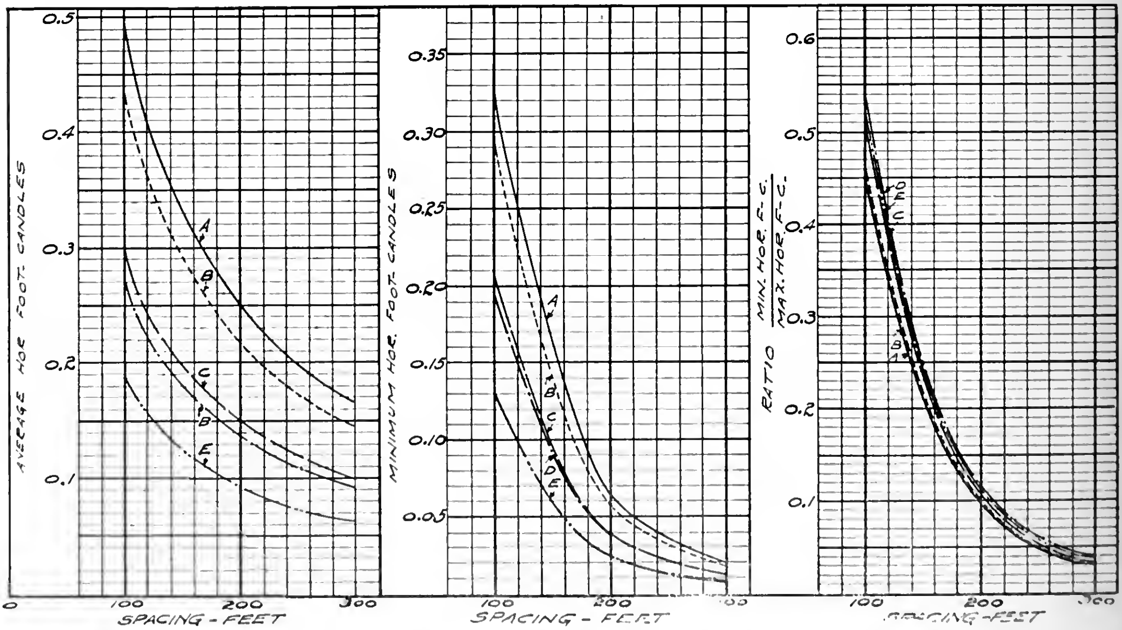


Fig. 9-c. Calculated Illumination Values on Street Surface along Center Line of Street

Lamps on one side of street only, on 4-ft. bracket arm. Height, 25 ft. Width of street, 60 ft.

A: 6.6-amp. long life electrode
C: 5-amp. long life electrode
B: 5-amp. high efficiency electrode
D: 4-amp. high efficiency electrode
E: 4-amp. long life electrode

Fig. 10-a. Pendant Type Luminous Arc Lamp with Diffusing Glass Globe

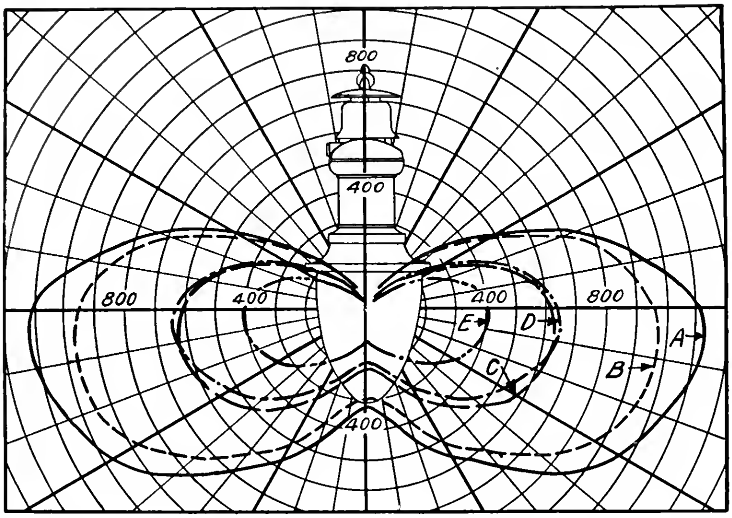


Fig. 10-b. Initial Distribution of Candle-power in a Vertical Plane of the Unit shown in Fig. 10-a

Curves *A*, *B*, *C*, *D* and *E* correspond to the currents and electrodes named in Fig. 10-c.

have the least possible equipment; they will be greater with a clear globe than with a diffusing globe, and will gradually decrease as equipment is added. It can, therefore, be readily understood that it would be unfair to compare two units for efficiency, one having a clear globe and the other a diffusing globe. Obviously, the total lumens will vary with

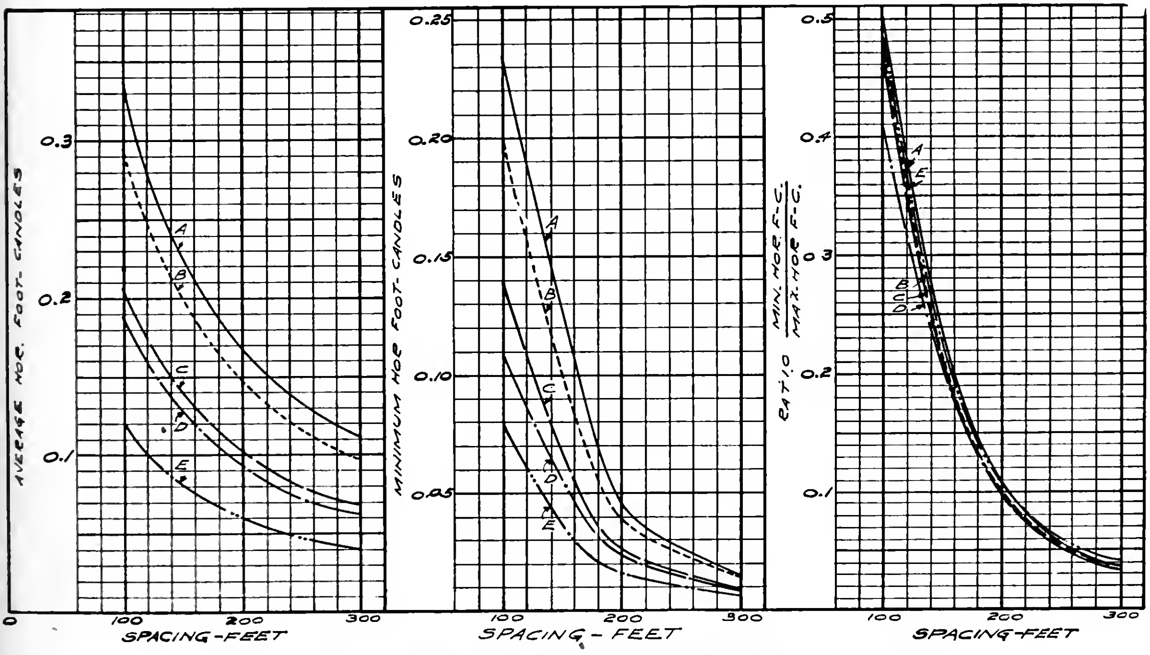


Fig. 10-c. Calculated Illumination Values on Street Surface along Center Line of Street

Lamps on one side of street only, on 4-ft. bracket arm. Height, 25 ft. Width of street, 60 ft.

A: 6.6-amp. long life electrode
C: 5-amp. long life electrode
B: 5-amp. high efficiency electrode
D: 4-amp. high efficiency electrode
E: 4-amp. long life electrode

Fig. 11-a. Pendant Type Luminous Arc Lamps with Prismatic Band Refractor

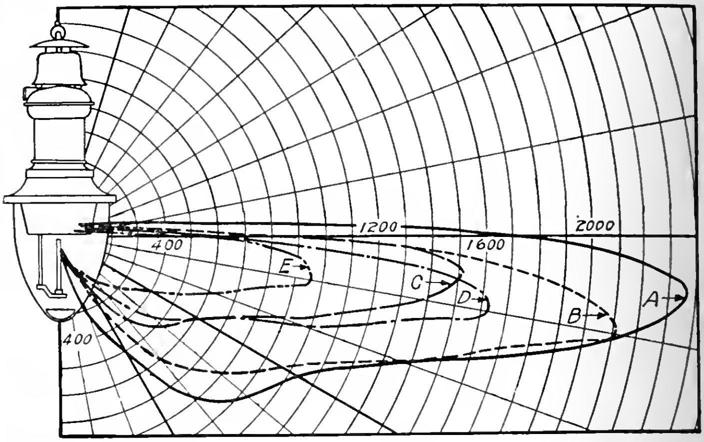


Fig. 11-b. Initial Distribution of Candle-power in a Vertical Plane of the Unit shown in Fig. 11-a

Curves *A*, *B*, *C*, *D* and *E* correspond to the currents and electrodes named in Fig. 11-c.

different densities of diffusing globes. Before writing contracts, therefore, it is advisable to know the energy consumed and the characteristic candle-power distribution of the equipment it is proposed to use. These can best be obtained in a properly equipped laboratory. The contract should specify the lamp equipment, operating conditions, etc., and if the specifications are complied with the city will get its full measure of illumination. It is a

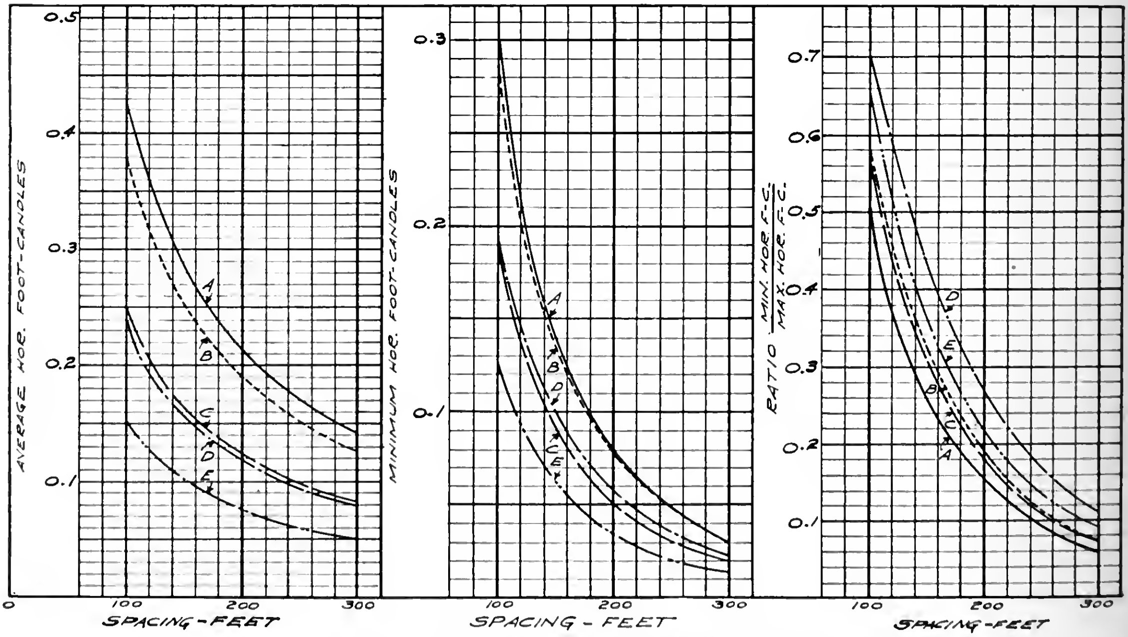


Fig. 11-c. Calculated Illumination Values on Street Surface along Center Line of Street

Lamps on one side of street only, on 4-ft. bracket arm. Height, 25 ft. Width of street, 60 ft.

A: 6.6-amp. long life electrode
B: 5-amp. high efficiency electrode
C: 5-amp. long life electrode
D: 4-amp. high efficiency electrode
E: 4-amp. long life electrode

Fig. 12 a. **Enclosed Carbon Arc Lamp with Light Opal Glass Inner Globe, Clear Glass Outer Globe, and Street Reflector**

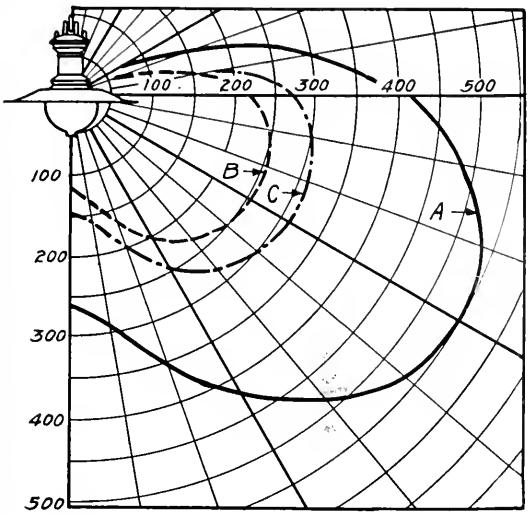


Fig. 12-b. **Initial Distribution of Candle-power in a Vertical Plane of the Unit shown in Fig. 12-a**

Curves *A*, *B* and *C* correspond to the lamps named in Fig. 12-c.

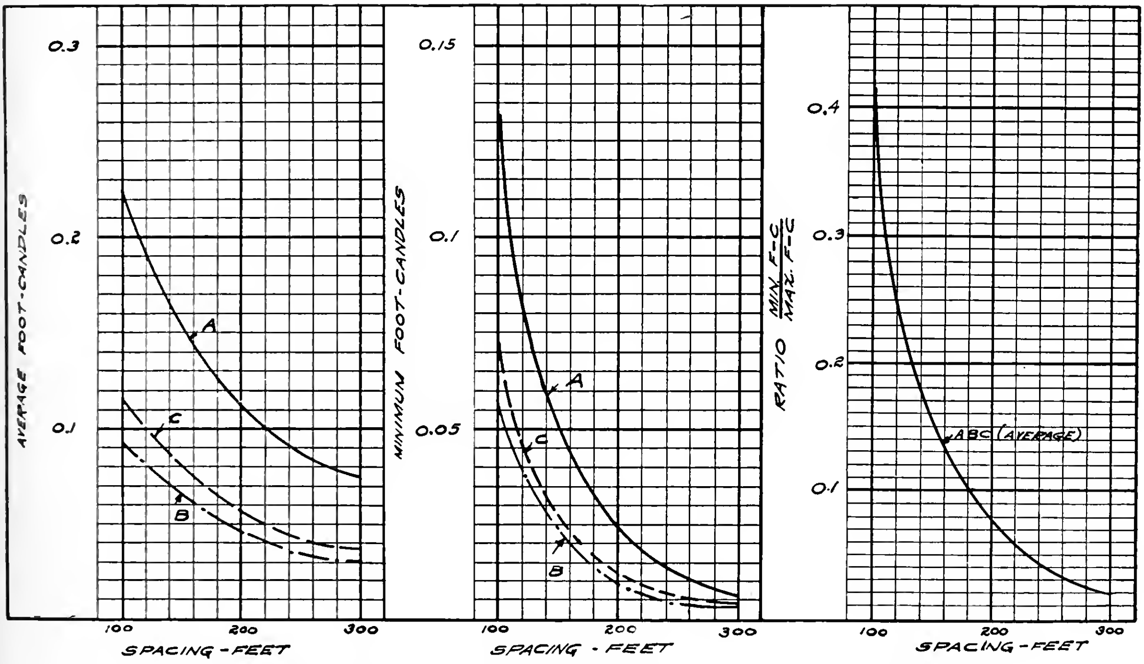


Fig. 12 c. **Calculated Illumination Values on Street Surface along Center Line of Street**

Lamps on one side of street only, on 4-ft. bracket arm. Height, 25 ft. Width of street, 60 ft.

A: 6.6-amp. d-c. series enclosed carbon arc lamp
B: 6.6-amp. a-c. series enclosed carbon arc lamp
C: 7.5-amp. a-c. series enclosed carbon arc lamp

Fig. 13-a. Ornamental Type Luminous Arc Lamp with Diffusing Glass Globe

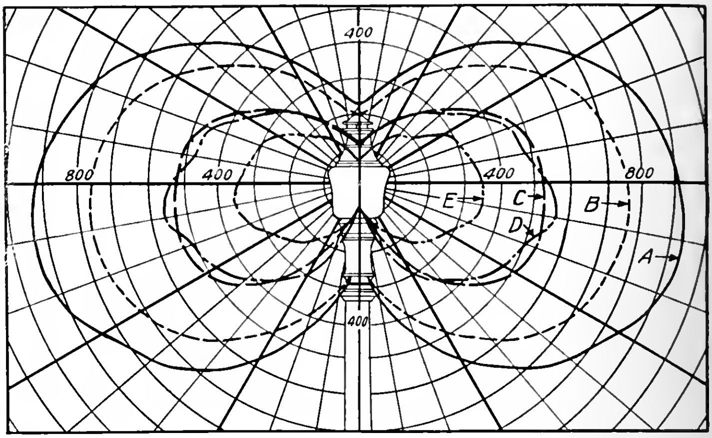


Fig. 13-b. Initial Distribution of Candle-power in a Vertical Plane of the Unit shown in Fig. 13-a

Curves *A*, *B*, *C*, *D* and *E* correspond to the currents and electrodes named in Figs. 13-c and 13-d.

ILLUMINATION CONSTANTS

HEIGHT OF LAMP	15 FT.		18 FT.		25 FT.	
Angle Degrees	Distance from Lamp	Horizontal Constant	Distance from Lamp	Horizontal Constant	Distance from Lamp	Horizontal Constant
0	0.000	0.004444	0.000	0.003086	0.000	0.001600
5	1.312	0.004394	1.575	0.003051	2.187	0.001582
10	2.645	0.004245	3.174	0.002948	4.408	0.001528
15	4.019	0.004005	4.823	0.002782	6.699	0.001442
20	5.460	0.003688	6.551	0.002561	9.099	0.001328
25	6.995	0.003309	8.394	0.002298	11.66	0.001191
30	8.660	0.002887	10.39	0.002005	14.43	0.001039
35	10.50	0.002443	12.60	0.001697	17.51	0.0008795
40	12.59	0.001998	15.10	0.001388	20.98	0.0007193
45	15.00	0.001571	18.00	0.001091	25.00	0.0005657
50	17.88	0.001180	21.45	0.0008197	29.79	0.0004249
55	21.42	0.0008387	25.71	0.0005824	35.70	0.0003019
60	25.98	0.0005556	31.18	0.0003858	43.30	0.0002000
65	32.17	0.0003355	38.60	0.0002330	53.61	0.0001208
70	41.21	0.0001778	49.45	0.0001235	68.69	0.00006401
72.5	47.57	0.0001208	57.09	0.00008392	79.29	0.00004351
75	55.98	0.00007706	67.18	0.00005351	93.30	0.00002774
77.5	67.66	0.00004506	81.19	0.00003129	112.8	0.00001622
80	85.07	0.00002327	102.1	0.00001616	141.8	0.000008378
81	94.71	0.00001801	113.6	0.00001182	157.8	0.000006125
82	106.7	0.00001198	128.1	0.000008320	177.9	0.000004313
83	122.2	0.000008044	146.6	0.000005586	203.6	0.000002896
84	142.7	0.000005076	171.3	0.000003525	237.9	0.000001827
85	171.5	0.000002942	205.7	0.000002043	285.8	0.000001059
86	214.5	0.000001509	257.4	0.000001048	357.5	0.0000005431
87	286.2	0.0000006371	343.5	0.0000004424	477.0	0.0000002294
88	429.5	0.0000001889	515.5	0.0000001312	715.9	0.00000006801

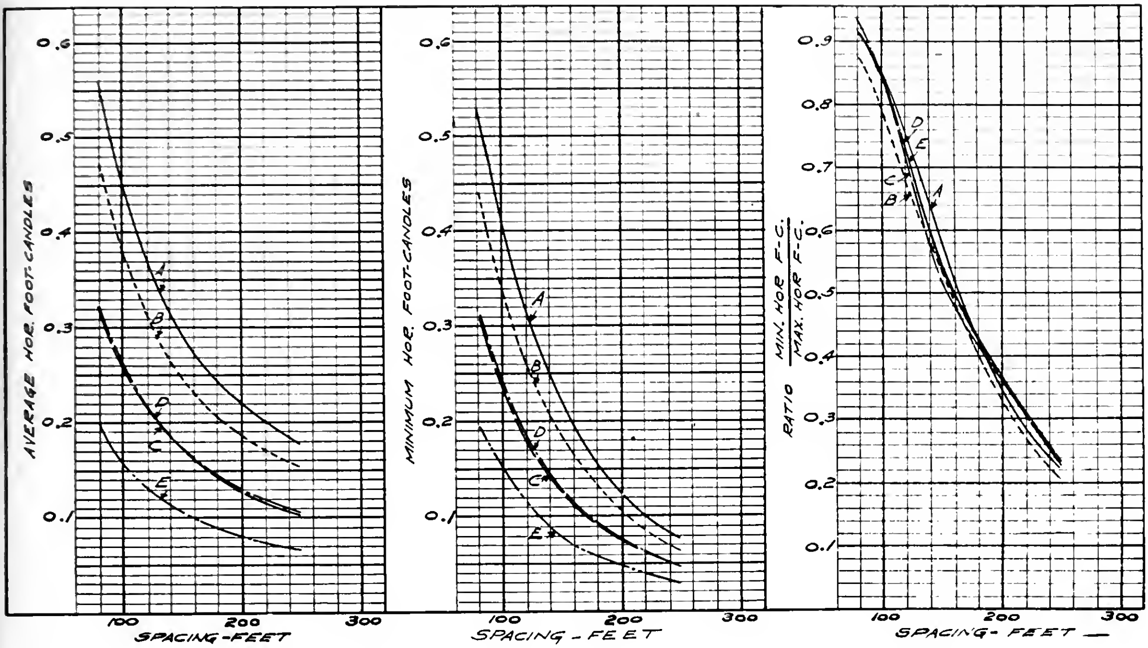


Fig. 13-c. Calculated Illumination Values on Street Surface along Center Line of Street

Lamps on both sides of street, staggered. Height, 15 ft. Width of street, 60 ft.

A:	6.6-amp. long life electrode with medium density diffusing globe
B:	5-amp. high efficiency electrode with medium density diffusing globe
C:	5-amp. long life electrode with light density diffusing globe
D:	4-amp. high efficiency electrode with light density diffusing globe
E:	4-amp. long life electrode with light density diffusing globe

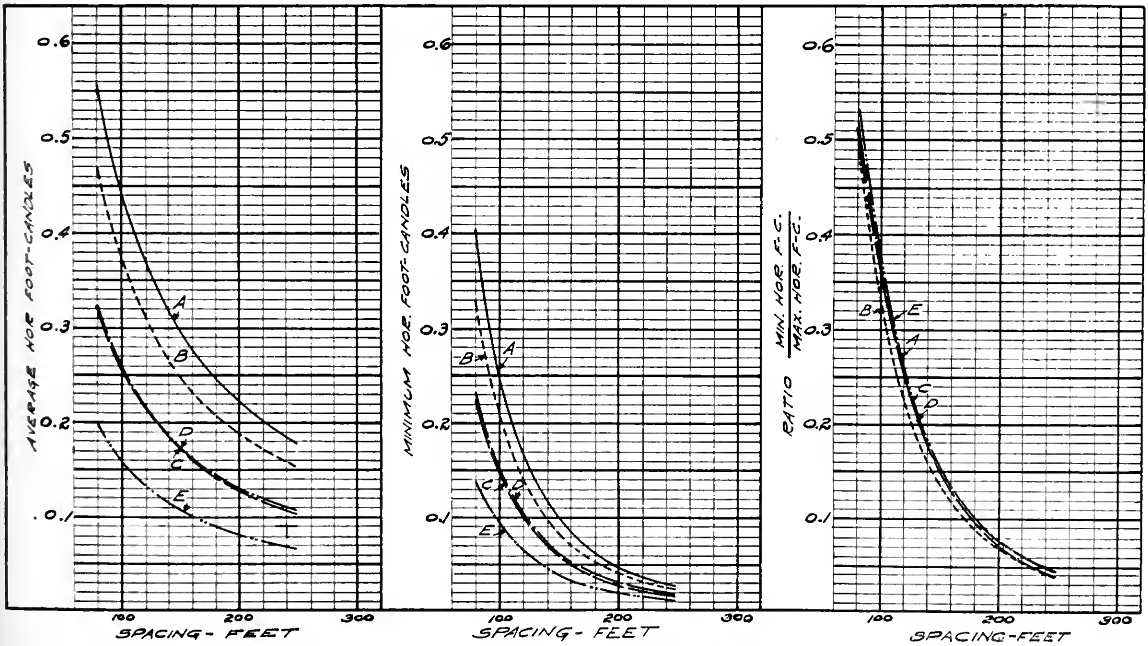


Fig. 13-d. Same as Fig. 13-c, except lamps are arranged parallel instead of staggered

comparatively simple matter to check up the energy consumed, but the making of satisfactory candle-power or illumination tests in the street is both difficult and expensive, especially during the winter months and that is when the lights are used most. There are some variations in individual lamps and equipment from the ideal aimed at in manufacture, and the contract should not be too rigid and should not impose unnecessary restrictions on the central station, or the increased cost of the service will be more than the supposed advantages are worth.

Advances in the art may make a change desirable and some means of doing this should be provided for on a fair and equitable basis to both parties. It would seem as if the best service and lowest rates can only be obtained by a close co-operation between all the parties concerned before the contract is written and signed.

Fig. 14-a. Ornamental Type Luminous Arc Lamp with Eight-panel Diffusing Glass Globe

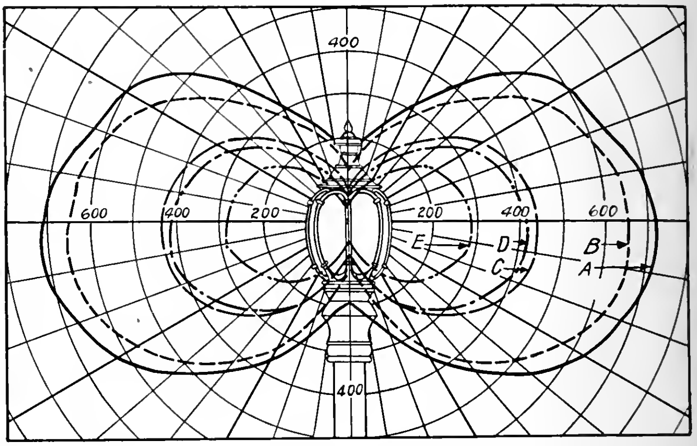


Fig. 14-b. Initial Distribution of Candle-power in a Vertical Plane of the Unit shown in Fig. 13-a

Curves *A*, *B*, *C*, *D* and *E* correspond to the currents and electrodes named in Figs. 14-c and 14-d.

INDEX

The units described, together with their wattage, are indexed in the following by figure number in order that the photometric characteristics and the calculated data on any unit may be more readily located.

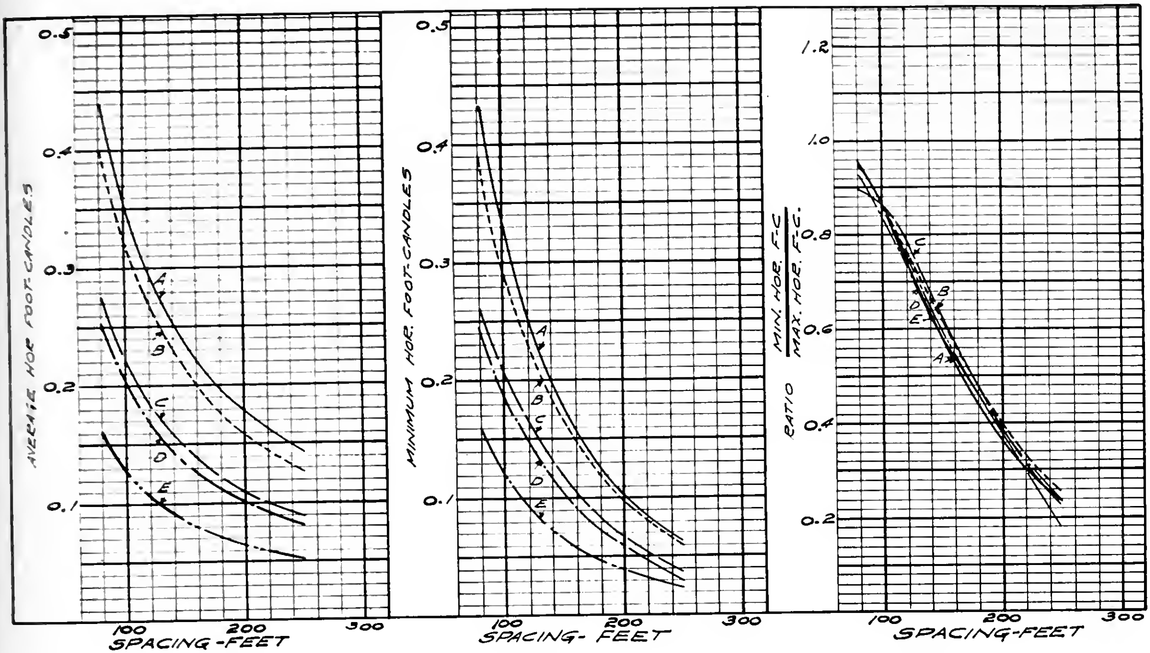


Fig. 14-c. **Calculated Illumination Values on Street Surface along Center Line of Street**

Lamps on both sides of street, staggered. Height, 15 ft. Width of street, 60 ft.

- *A:* 6.6-amp. long life electrode, and medium diffusing glass
- *B:* 5-amp. high efficiency electrode, and medium diffusing glass
- *C:* 5-amp. long life electrode, and medium diffusing glass
- *D:* 4-amp. high efficiency electrode, and medium diffusing glass
- *E:* 4-amp. long life electrode, and medium diffusing glass

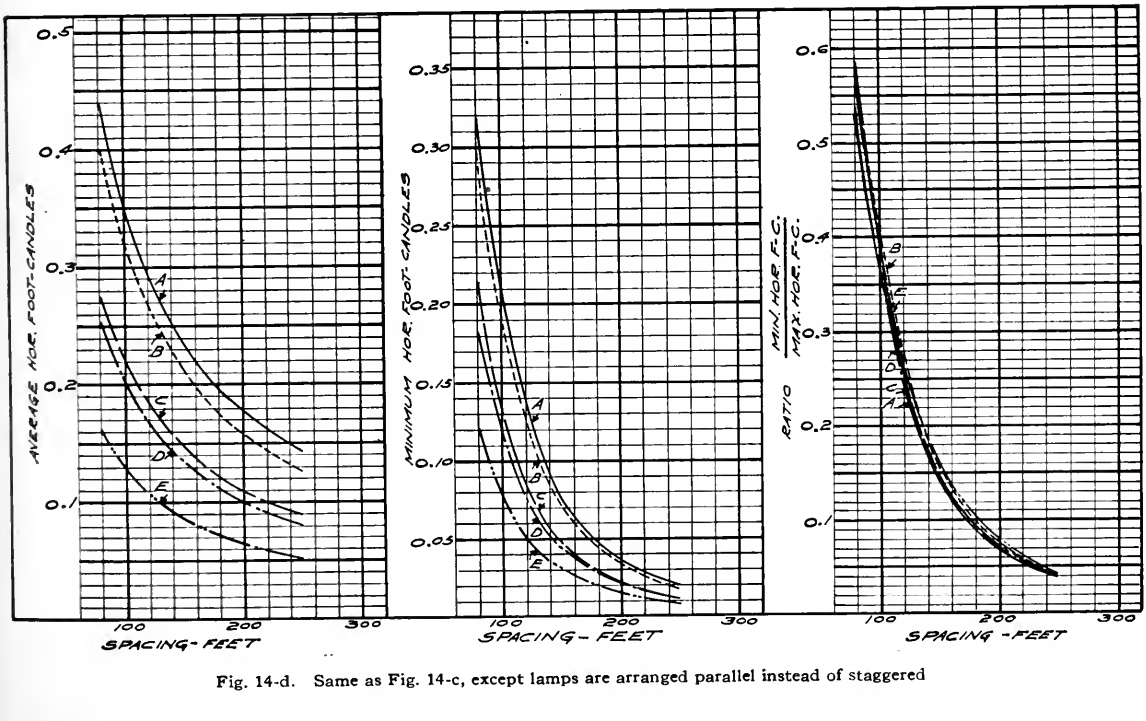


Fig. 14-d. **Same as Fig. 14-c, except lamps are arranged parallel instead of staggered**

The Lighting of New York City's New $3,000,000 Garbage Disposal Plant

By A. L. Powell

Edison Lamp Works, Harrison, N. J.

A description is given of the process employed for reducing 2000 tons of garbage daily, the final products consisting of grease and dry tankage. The tankage is ground up and makes an excellent fertilizer. The great amount of piping and belting made a satisfactory lighting system, providing adequate illumination for reading steam gauges and records, and for operating valves, belt shifters, etc., a problem requiring special attention. The installation successfully fulfilling these requirements is shown by diagram and photographs. A special arrangement for illuminating the interior of each reducer was required for observing the process of "cooking." The boiler room, outlying buildings, and yards are lighted by 100- and 200-watt Mazda C lamps, and flood-lighting projectors are employed in the yard to assist in construction work, and in loading and unloading barges.—Editor.

The Metropolitan By-Products Company have recently placed this modern plant in operation at Green Ridge, Staten Island. It is said to be the largest in the world, and when operated at full capacity can handle 2000 tons per day, which will take care of the refuse from Manhattan, Bronx, and Brooklyn.

The artificial lighting, as well as every other detail of the plant, was the subject of careful design, and therefore warrants description.

Description of Process

Modern chemical engineering has done great things in the line of hygienic disposal of refuse. It is no longer necessary to carry it out to sea to be dumped overboard, and then by the action of the waves gradually brought back to shore. By the careful application of scientific processes this cast-off material can be partially reclaimed, and more important, rendered inoffensive and harmless.

This gigantic, well constructed plant is evidence that sufficient by-products can be produced to make it a profitable venture. These are grease, dried tankage (which when ground forms an excellent fertilizer), and a certain amount of metal.

The method of disposal is one of straight dehydration. There is no digestion carried on to give odors, and no chance for unpleasant smells if there are no leaks in the piping system. The product, as it comes from the reducer house, is dry and sterile.

Every precaution is taken to avoid the system becoming a nuisance. The raw garbage is delivered in huge barges so constructed as to prevent the discharge of any of the water drained from the garbage, and carefully covered with a special canvas apron to prevent any falling off.

The garbage is unloaded by steam hoist grab buckets, and delivered to closed conveyors of the steel scraper type which carry it to the main building where the reducers are located. A brief description of the general method of reclaiming the by-products from the garbage is given in a paper presented by Gustave R. Tieska before the American Society of Municipal Improvements, November 11, 1916.

In this plant the Cobwell process is used. Conveyors distribute the raw garbage to the reducers, which are then sealed air-tight. A solvent is next pumped in and steam admitted to the jacketed walls. Gasolene is ordinarily used as a solvent, but in this instance a special kerosene distillate etc., is employed.

An agitating device is constantly turning, and the charge is "cooked" until the solvent and water evaporate. These vapors are drawn off to a condenser, and there again assume a liquid state. This liquid is pumped to a closed tank where the solvent and water separate by gravity. The solvent is drawn to a storage tank, and the water discharged into the adjacent stream.

When the garbage has been dried by this method, fresh solvent is pumped into the reducer to dissolve the grease. After picking up the grease the mixture is drawn to an evaporator of the vacuum type. Vaporization separates the solvent from the grease. The former, after being liquefied in a condenser, is ready to be used again.

After the grease has all been extracted from the garbage the jacketed walls are again filled with steam, and after being thoroughly dried the tankage is removed from the reducer and conveyed from the building by belted conveyors, ground in pan mills, and screened by rotary screens. This tankage or fertilizer is then stored, and finally automatically conveyed to the loading vessel through swivel spouts.

Reducer House

The main building is a one-story structure 30 feet high, 200 feet wide, and 330 feet long. When completed this will contain 250 reducers 8 feet in diameter and 4 feet high.

Each unit has a capacity of from 8 to 10 tons per 24 hours, depending on the steam pressure used.

The reducers are arranged in rows facing each other, as shown roughly on the plan and elevation of a small portion of the plant (Fig. 1). Between the rows a walk is provided for the operators. From here the valves and other mechanisms are controlled. There is also a higher runway at the rear for the workmen who fill the tanks from the overhead conveyors.

The night view of the reducer house (Fig. 2) shows one of the conveyors for raw garbage at the extreme right. It is also seen that there is a veritable maze of piping for steam and solvent, and transmission machinery or belting. This multiplicity of overhead structures complicated the lighting problem and made a careful analysis necessary. Lighting units had to be so placed that dense shadows were avoided. The requirements for lighting were as follows:

1. Sufficient general lighting for safety. The workmen must be able to move about the plant without the liability of stumbling over piping, falling off the runway, or being caught in the moving parts.
2. Adequate illumination for the operation of valves, belt shifters, reading of steam gauges, etc.
3. Suitable spread of the light so that the conveyors can be inspected, and the reducers loaded and emptied.
4. The operators are required to keep a log or record of each charge. This is done on a tabulated sheet attached to a board at each reducer. These data must be readily discernible at all times. Needless to say, if this requirement was met by general lighting, there would be adequate illumination for the first two items.
5. Some special arrangement was required to light the inside of the tanks so that the charge could be inspected while being "cooked."

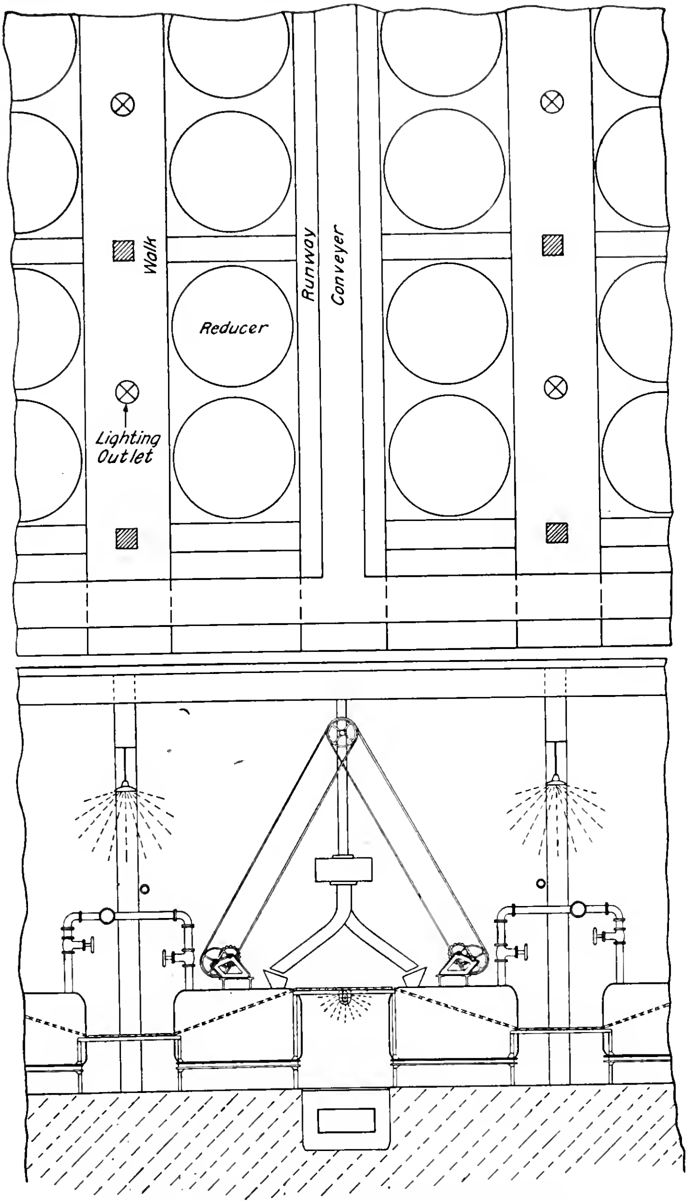


Fig. 1. Plan and Elevation of Portion of Reducer Plant Showing Arrangement of Reducers and Lighting Units

Method of Lighting

As shown in the plan, a row of outlets was located on the beam above the walk along the front of the reducers, for here a minimum of obstructions existed. One outlet was placed in each bay giving a spacing of approximately 20 feet by 30 feet. 200-watt Edison Mazda C lamps with dome shape (distributing) porcelain enamel steel reflectors were used, giving a specific power consumption of ⅓ watt per square foot of floor area. The average illumination intensity is in the neighborhood of 2 foot candles.

This equipment and arrangement fulfill conditions 1, 2, and 4. There is sufficient spread of light to illuminate the conveyors and charge the reducers. The night view (Fig. 2) is taken from the runway under the conveyors and gives a very good idea of the illumination.

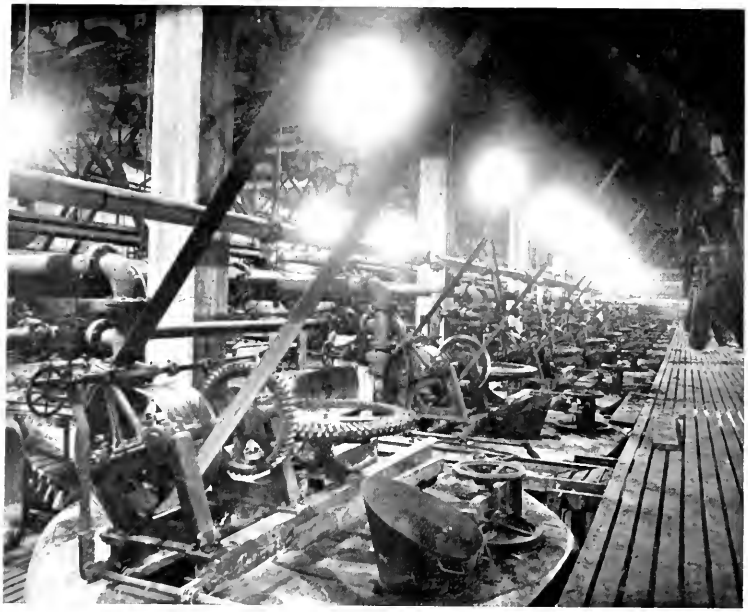


Fig. 2. Night View of Reducers showing Maze of Steam Piping and Belting, and in spite of these, the Excellent Illumination that has been Obtained

The reducers are emptied through doors at the rear. The dried tankage is raked out and falls on a belted conveyor beneath the floor proper. The night view (Fig. 3) shows this arrangement. Special lighting was required here as the runway obstructed the rays from the overhead units. The lower conveyor is normally covered with loose planking, and if this space is not fairly well lighted there is great danger of stumbling over misplaced boards or stepping into openings. For example, in the foreground of this picture can be seen a board in an almost up-right position.

A central row of outlets is provided, and 40-watt Edison Mazda lamps with wire guards are placed on 20-foot centers. These are close to the walk, about 7 feet above the floor. Advantage is taken of this line of wiring to provide a means of attaching portable lamps for use when repairing or inspecting the interior of the reducers.

The line of conduit passes through a circular receptacle box having a porcelain socket. From the side of this box a line of pipe, after being bent downward, terminates in the female portion of a plug attachment. This is shown diagrammatically in Fig. 4, one of the plugs being indicated by an arrow in Fig. 3. This permits any of the tanks being reached with a portable lamp.

The close-up day view of a reducer (Fig. 5) gives an idea of the scheme employed to light the interior when in operation. Two openings with suitable projections are cast in the top of the tanks at A and B. These are placed at such an angle that the light entering one is specularly reflected from the surface of the charge to the second opening. These are kept steam tight by means of re-enforced glass plates and suitable gaskets.

In A is placed a parabolic shaped polished aluminum reflector with an opening the size of the glass plate mentioned above. A bayonet candelabra socket is protected by a wooden cover, an extension on which serves as a handle. A 6-volt 12-candle power Mazda C automobile headlight lamp was found to furnish enough light.

A flexible conduit extends from the lamp to a push switch near opening B. When the operator wishes to observe the condition of the charge he peers in at this opening and presses the switch. Such an arrangement is desirable on account of the intermittent requirements.

Boiler House

Adjoining the main building is the boiler house with water tube boilers of 7500 horse power capacity: 200-watt units are placed about 18 feet above the floor on the wall opposite the firing doors. These are installed at an angle so that the maximum light is directed toward the boilers, yet there is sufficient downward light to illuminate the coal heaps and tracks.

Outlying Buildings

General illumination of a suitable intensity is provided by 100- and 200-watt Mazda C lamps in dome type reflectors in the machinery building where are located the pumps and the blacksmith, machine, and pattern shops.

In addition to the main building, which has been described in detail, there are a number of storage buildings, condensers, evaporators, and storage tanks. These latter have a capacity of 400,000 gallons of solvent, and 14,000 barrels of grease. Their lighting requirements are not at all exacting.

Yards

For lighting the yard, units have been so located that practically all the outdoor spaces are illuminated, and no shadows cast by the buildings. Some of these lamps are held by brackets attached to the buildings, and in outlying portions poles are erected. Medium size Mazda C lamps are used with weatherproof equipment, giving a wide spread of light.

At regular intervals along the conveyor structures iron pipes are erected with curved tops which support 100-watt Mazda C lamps in distributing reflectors.

Fig. 3. Runway between Reducers. Under the Loose Flooring shown is a belt conveyor which carries off the dry tankage raked out through the doors. Good illumination is required here on account of the uneven surface of the flooring

Several floodlighting equipments are advantageously placed with the beams so directed that construction work and the loading of barges is facilitated.

The fact that the plant operates continuously, with three shifts of eight hours each, makes artificial lighting of much importance, and it is fitting that the matter should have received such careful attention, for very frequently plants which operate under similar conditions are erected where the lighting is apparently an afterthought, and more or less of a makeshift system is in use. In many chemical plants, for example, every attention is given to the arrangement of machinery, and all details of the chemical processes very carefully planned in advance. The designing engineer is prone to look at his technical side of the question as of importance, and neglects to provide means by which the human factor can operate at maximum efficiency. Proper artificial lighting has been proved to be a most important element in plant construction. No matter how perfectly a system may be worked out from a mechanical point of view, this advantage will be offset if the men who operate the plant cannot work effectively. Such a condition does not exist in this instance.

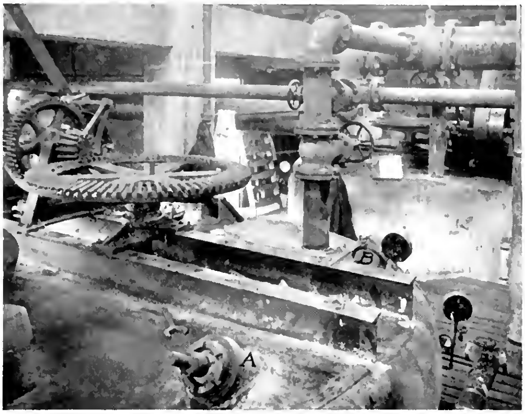


Fig. 5. View of Top of one of the Reducers showing Peakholes *A* and *B* and Light Source for Examining Contents

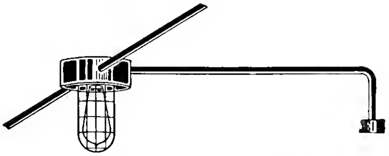


Fig. 4. Plug Attachment for Portable Light for Cleaning and Repairing Reducers. These outlets are located on either side of the Lighting Units shown in Fig. 5

Life in a Large Manufacturing Plant

PART V. MUTUAL BENEFIT ASSOCIATION

By Chas. M. Ripley

Publication Bureau, General Electric Company

The Mutual Benefit Association of the General Electric Company provides its members with a combined health, accident, and life insurance policy at a cost far below that at which the same protection could be obtained from a commercial insurance company. It is wholly mutual, without the expenses of high salaried officials and heavy rentals for office space, and through its existence thousands of employees are afforded protection against the contingencies of accident who otherwise could not afford the cost of this insurance, and much privation and suffering is thus saved them and their families.—Editor.

An employees' organization largely under their own management, with financial transactions totaling close to $200,000 per year and with 23,000 voluntary members in six different cities—this is the General Electric Mutual Benefit Association.

The purpose of this chapter is to describe this Association, telling what it costs and what it affords the members, and how and when it was organized; to explain its scheme of operation and management and its various sources of income; and lastly, briefly to review the main essential points of its constitution and by-laws.

An enthusiastic member made the following comment on the protection afforded by the Mutual Benefit Association:

"The great health and accident insurance companies of this country have several different policies compensating for accidents and several different policies compensating for sickness; but the 'accident' policies do not recompense for sickness and the 'health' policies which protect against sickness do not recompense for accidents.

"An exception to this is a combined health and sickness policy which costs considerably more than either of the above. Many of these policies, however, which do protect against both accident and sickness, do not pay any death benefit.

"The General Electric Mutual Benefit Association, however, protects against both accident and sickness and, in addition to this, pays a death benefit to the members.

"Therefore, it may be seen that the protection and benefits of the General Electric Mutual Benefit Association are more comprehensive and liberal than those of the companies who conduct their business for a profit. This would naturally be expected, since the General Electric Mutual Benefit Association is not conducted for profit, and has no rent nor salaries to pay; even its stationery and printed forms are provided free of expense."

Protection

Briefly stated, the protection consists of a death benefit and a weekly indemnity while sick or disabled. The death benefit paid out of the treasury of the Mutual Benefit Association is $100, but the General Electric Company supplements this by another payment of $100; thus, in effect, making the death benefit $200. This is payable at once in cash to the beneficiary of the deceased member.

The weekly disability payment in case of sickness is $6.00 per week for men and $5.00 per week for women. Payment is continued for fourteen weeks during any twelve consecutive months. In all periods of disability members are excused from paying dues. A visiting committee is formed in each case to call upon the sick member and in many cases the Company's nurse likewise calls upon the patient.

The liberality of the arrangement is shown by the fact that even though a member leave the employ of the General Electric Company while disabled through sickness or accident, his right to receive payment of the benefits to the full amount is not annulled for a period of two years from the beginning of the disability, provided that he has not in the meantime recovered from the disability or secured remunerative employment. Or putting it differently, the weekly benefits are limited to fourteen weeks in twelve months, and the right to receive them is extended over a period of two years from date of such disability without regard to service in the General Electric Company. Similarly, if the disability should result in death, the death benefit would be paid any time during a two-year period, even though the member had left the employ of the General Electric Company. The Association follows the wisely established practice of most fraternal organizations by omitting the benefit for the first week of disability.

Members are Steady Workers

An interesting fact in connection with the Mutual Benefit Association is that during hard times, when business is slack, the percentage of employees who are members of the Association increases rather sharply.

This is shown in Fig. 1. In other words, it appears from the record that the members of the Association are more steadily employed than those who are not members. This does not indicate that when work is slack, members of the Association are carried through the hard times because they are members of the Association; but it does indicate that the steadiest and most far-sighted employees who are interested in their work are those who have already joined the Mutual Benefit Association; and these are retained on the pay roll because of their ability, and not because they are members of the Mutual Benefit Association.

Field Day, Pittsfield Works Section, General Electric Company Mutual Benefit Association

Over Four Millions Life Insurance

Last year the Schenectady, Lynn and Pittsfield Mutual Benefit Associations paid benefits to members amounting to approximately $80,000. The total of death and sick benefits in the various factories of the General Electric Company approximate $100,000 per year. The amount of life insurance carried by all these Associations is over $4,500,000.

Financing the Association

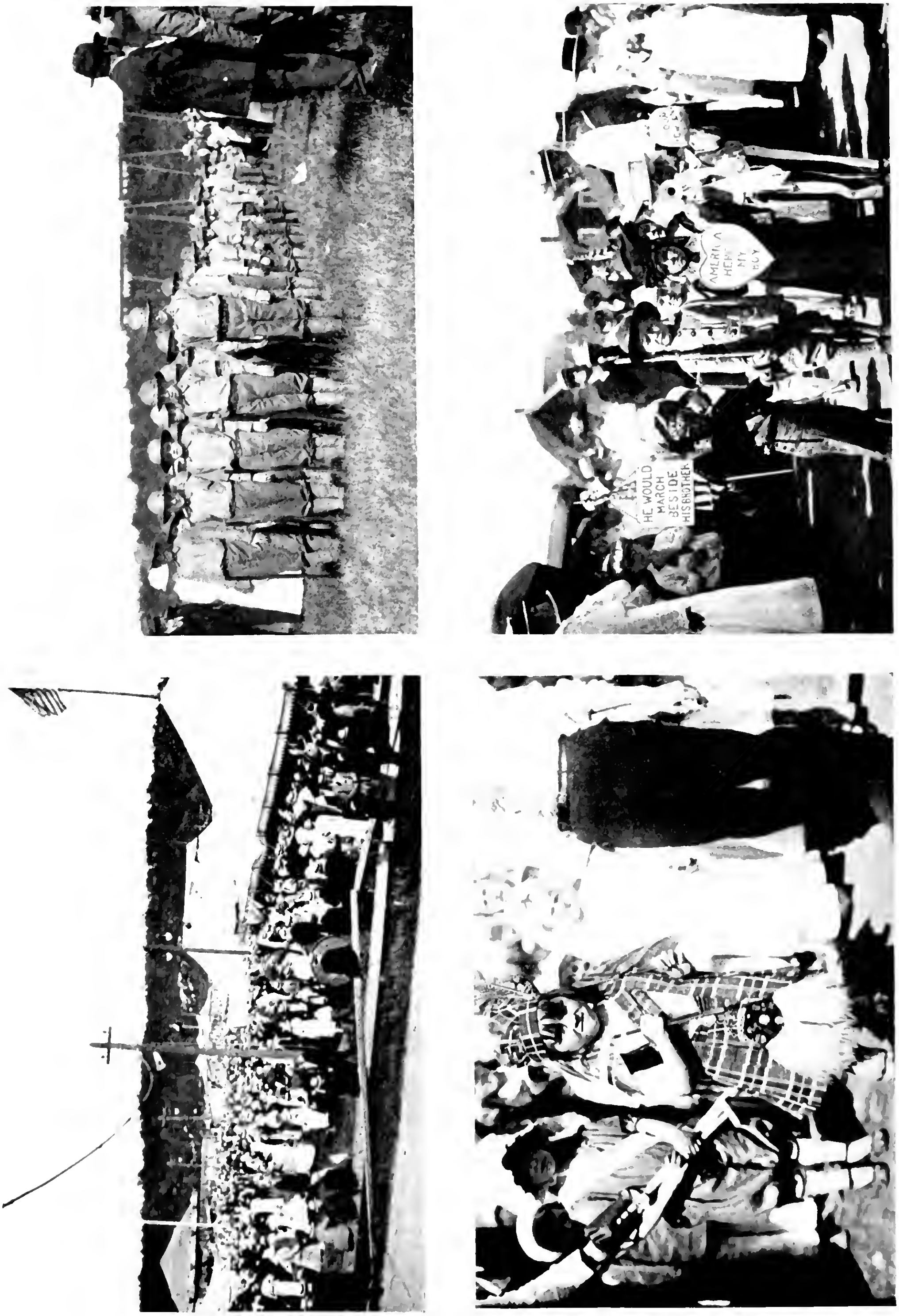
The cost of this triple protection against death, sickness, and accident varies from nothing a year in some sections, up to a maximum of $5.20 per year. The cost per member averaged $4.07 at Lynn in 1916; and the average at Schenectady was but $3.97 in 1917.

It would not be fair to health and accident insurance companies to compare their cost and the protection offered with the cost and protection offered by the General Electric Mutual Benefit Association, as the latter, it might be said, is literally "in business for its health." The fundamental idea of the Mutual Benefit Association is to help one another and not to make a profit. The administration expenses, including stationery and blank forms, are paid by the General Electric Company, and these with the auxiliary $100 benefit, amount to approximately $18,000 for the year 1916.

The combination of health, accident, and life insurance purchased from corporations engaged in this enterprise is expensive. Factory workers are not inclined to invest a large sum of money in advance for such purposes; therefore, the method pursued by this Association in collecting its dues of 10 cents every week has been largely responsible for its phenomenal growth. However, for industrial managers who care to go into this question, it would be interesting to obtain data on death, accident, and life insurance and see if any protection could be purchased for $4.00 per year! And when it is further considered that the premiums of the Mutual Benefit Association are payable weekly to a collector, it will be obvious that an internal organization can perform a service among fellow employees which it would be practically impossible for an outside corporation to carry on at a profit, or even at cost under existing conditions. In other words, there are thousands of employees who would not have any protection against the contingencies of accident, were it not for this Association, formed and conducted by fellow employees. This recalls the fact, shown in the October issue of the GENERAL ELECTRIC REVIEW, in the chapter dealing with fire protection in the General Electric Company, that a decided advantage results from adopting the plan of mutual fire insurance; and just so the mutual life, health and accident insurance has proved a wonderful success.

Other Sources of Income

The total receipts of the various Mutual Benefit Associations are approximately



Scenes at 1917 Annual Field Day and Parade of Lynn Works Section, G. E. Mutual Benefit Association

Field Day, Schenectady Works Section, G. E. Mutual Benefit Association

$100,000 per year. In addition to the dues from members, the Association has other small sources of income, principally the annual field days held at Lynn, Schenectady, and Pittsfield. The receipts from these field days are turned into the treasury of the Mutual Benefit Association. Dances are held from time to time; and other entertainments, more or less impromptu in their nature, assist in swelling the treasury fund and in reducing the dues paid by the members. These events meet with hearty response from the members, for the money paid for admission to the various entertainments and amusements is practically refunded to them by a lessening of their dues. This results in a large attendance at such events, an illustration of which is seen in the 1917 Schenectady field day, for which over 13,000 tickets were sold.

The slogan adopted for this fourth annual field day which appeared on posters displayed throughout the plant, was: "Suspend assessments to the death benefit fund. Twenty thousand tickets to be sold—two tickets per member. Buy now and cancel later payments."

Good natured rivalry was shown in the ticket-selling contests between sections, and $75.00 was divided as first and second prizes for the two sections selling the greatest number of tickets. In preparing for this field day, a special committee was appointed and

View from Grand Stand in Illustration Above. Office Buildings of General Electric Company in Background one of the indirect benefits which resulted was a wider acquaintanceship between those sharing in the management of the event.

The receipts for the last field day were $1400. After expenses were deducted for the prizes, etc., a net balance of $1125 was added to the death benefit fund.

It might be well to mention that these field days are under the direct auspices of the Mutual Benefit Association and are separate and distinct from the General Electric Athletic Association.

The attendance at the Mutual Benefit Association field day at Lynn was over 30,000, and the total proceeds of last year's entertainments were $2836.

At Pittsfield special stress is laid upon the social features of the Mutual Benefit Association and the fraternal spirit developed by the various entertainments.

"The Mikado" was reproduced by members of the Association at the Colonial Theater and the attendance was 1418 and included about 100 outsiders. All of the performers were members and the rehearsals and various negotiations connected with the management of the affair contributed in developing executive ability among the employees.

An electrical fair was participated in by the members of the Association, and the dance, attended by 1200 young people, netted a profit of nearly $200.

Financial Statistics

The financial operations of the Mutual Benefit Association in Schenectady over the period of four years and a half which it has been in existence, may be summarized in round numbers:

Total receipts	$86,800
Total disbursements	68,700
Balance on hand	$18,100
Number of sickness claims	2,494
Total sickness benefits	$49,630
Death benefits:	
(Mutual Benefit Association)	$10,500
(General Electric Company)	7,800
Total	$18,300

SUMMARY OF AUDITS, GENERAL ELECTRIC MUTUAL BENEFIT ASSOCIATION, LYNN, MASS.

	YEAR ENDING						
	9-25-11	9-30-12	9-30-13	9-30-14	9-30-15	9-30-16	9-29-17
Number of sections	35	45	45	45	45	46	53
Members	5040	5911	5963	5857	6143	7093	7408
Receipts							
From dues	$19844.10	$25799.45	$27236.38	$27083.45	$24573.80	$28866.00	$34577.68
From entertainments			354.20	57.25	111.55	18.99	
From interest			181.33	121.64	177.25	156.08	163.13
Expenditures							
Disability benefits	17809.99	20636.82	24682.28	22873.59	20098.79	25095.56	30785.60
Stationery, car fares, etc.			194.46	228.92	148.92	88.79	133.54
Average dues per member	4.62	4.36	4.57	4.62	4.00	4.07	4.67
Disabilities	711	863	989	869	756	987	1155
Average amount paid each disabled member	25.05	23.91	24.91	26.32	26.58	25.43	26.67
No. of disabilities per 1000 members	141	146	166	148	123	139	156
Disabilities, per cent of total membership	14.1	14.6	16.6	14.8	12.3	13.9	15.6
Amount in sections' treasuries	5543.16	8153.78	6691.28	8915.48	10263.01	9516.58	12190.88

EMERGENCY AND DEATH BENEFIT FUND

Receipts							
Proceeds of entertainments and field days	$21.50	$318.74	$332.14	$1456.49	$15920.20	$1560.09	$2836.54
Interest on deposits	20.50	31.97	35.03	44.55	44.70	31.68	52.05
Total amount in treasury	2043.69	1467.60	1687.92	1718.59	2867.24	2793.06	2363.55
Expenditures							
Death benefits	2800.00	3500.00	4280.00	3350.00	3600.00	6200.00	6300.00
Emergency benefits		264.00	230.00	57.50	154.50	69.00	65.00
Total amounts expended for all benefits	20609.99	24400.82	29192.28	26281.09	23853.29	31364.66	37150.60
No. of deaths	28	36	43	34	36	62	65
Death rate per 1000 members	5.5	6.1	7.2	5.6	5.8	8.7	8.8

Table I shows a summary of audits of the Lynn Mutual Benefit Association for a period of years up to October, 1917. Attention is directed to the thoroughness with which these audits were made and the fact that the General Electric auditors donate their time in making these audits without charge to the Association.

History

The plan of organization and management of the six Mutual Benefit Associations of the General Electric Company is practically identical with the original plan conceived in the Lynn Works in 1902. It is fitting to record that these great activities sprung from one man's idea, whose faith in the success of the plan was so great that he personally loaned a sum of money to form the nucleus of the Lynn Association. It is impossible to estimate the amount of distress which has been alleviated by this altruistic deed and the idea which time has proved so successful.

Scheme of Operation

If the Schenectady death benefit fund is equal to $3000 or more, no assessments are levied against the section treasuries; but when the death benefit fund, owing to payment to families of deceased members, falls to $1500 or less, monthly assessments are made on each section equivalent to 10 cents for each member of the section. This minimum and maximum of the death benefit fund varies in the different associations, according to their size. In some associations $1000 is the maximum and others $2000, etc. Similarly, when the treasury of each section shows a balance of $300 or more, the payment of dues by members is suspended until such time as the balance is reduced by the payment of sick benefits to $200, when the maximum assessment of 10 cents per week is levied upon each member.

From this it will be seen how a payment of over $2800 into the death benefit fund, resulting from the annual field day and other entertainments at Lynn last year resulted in a direct suspension of dues from the members. Each section of the Association collects its own dues and compensates its own members for disability.

The advantage of the sub-division into sections not only makes the work of collection easier, but groups together, for mutual aid, the employees in a department. It establishes, therefore, a community of active interest in each small group. New employees of the department, when approached with a request to join, will usually be attracted to an organization composed of fellow workers in the same department, while they might hesitate to join a large organization of the whole Works. On account of the acquaintanceship among the members, the genuineness of the disability claims can readily be established, and fraudulent practices are, therefore, easily prevented. Finally, by a sub-division of the Association into groups, the Company is given a better opportunity of coming into touch with individual members than would otherwise be the case.

Membership

Membership begins with the payment of an initiation fee of 50 cents and the first week's dues of 10 cents. Thereafter, 10 cents is payable and collected every week in advance and no member can be obliged to make any further contribution. As previously stated this payment is suspended altogether for shorter or longer periods when the section treasury shows a balance of $300 or more. This provision stimulates economical administration of the funds in each section, and establishes a wholesome rivalry among the various sections. It arouses the interest of the members themselves, who have it largely in their power to secure inexpensive insurance for themselves by maintaining a full quota of membership in their section, and by carefully but sympathetically scrutinizing all claims for disability payments, to the end that only just claims shall be allowed. Finally, it prevents the accumulation of unnecessarily large funds in the treasuries.

Many sections have thus been enabled to suspend payment of dues for a part of the year; some have even afforded their members full insurance for the whole year at no cost whatsoever!

Size and Growth

With a membership of 22,675 in the summer of 1917, the Mutual Benefit Association stands in an enviable position among co-operative employees' associations. Some large corporations have benefit associations whose membership is compulsory; so the success of this Association is all the more gratifying because membership is voluntary. It will be recalled that the idea was first conceived in Lynn, Mass. Fifteen years ago there were but 656 members and, as seen in the curves of membership shown in Fig. 1, the growth was quite gradual during the first ten years. However, the membership in the past two years has increased very rapidly —81 per cent as shown in Fig. 1.

Only in the year 1917 did the Schenectady Association, organized four years and a half ago, in March 1913, exceed in size the Association at the Lynn Works. The Lynn Association, however, can boast of a larger percentage of membership, 58.7 per cent of its employees being members in 1917, against 42 per cent in the Schenectady Association during this its greatest year.

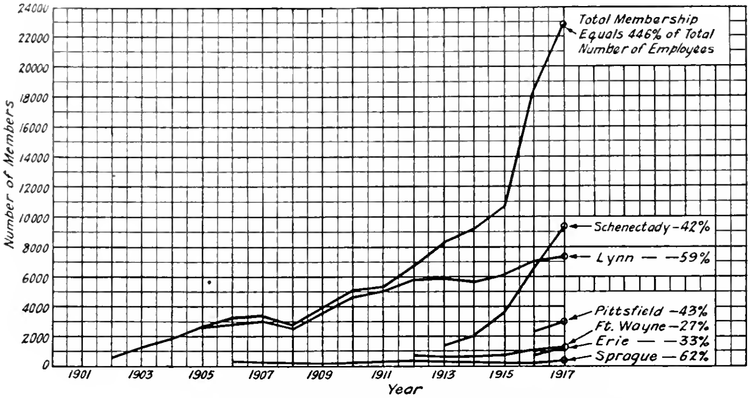


Fig. 1. Curves showing Growth of Membership of General Electric Mutual Benefit Association

The Association at the Sprague Works has the largest percentage of employees as members, and the Pittsfield Association shows a greater proportionate development in point of time than others, it being but two years old and having 43 per cent of the employees as members.

Fig. 2 permits a careful study of the fluctuation in the total number of employees and members at the Lynn Works. As mentioned earlier in this chapter, when periods of depression occur, such as in 1908 and 1915, a sharp increase is noted in the percentage of employees who are members of the Mutual Benefit Association. In 1915, 72 per cent of the total number of employees were members of the Association.

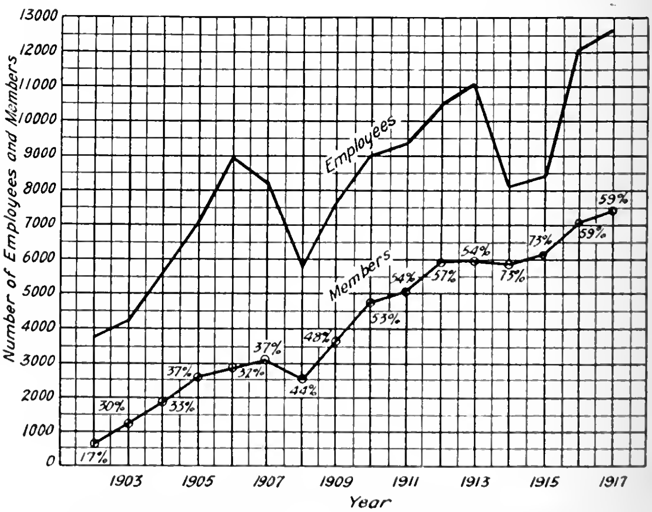


Fig. 2. Number of Employees and Membership of Mutual Benefit Association, Lynn Works

A study of Fig. 7, which gives the same information for the Sprague Works, reveals the same situation to an even more pronounced degree, for here it is clearly shown that during the 1908 depression the membership was 79 per cent, and during the 1915 slump it rose to 82 per cent of the total number of employees in the works. Very few of those who were laid off were members of the Association.

Fig. 3 shows the phenomenal growth of the Association's percentage at the Schenectady Works during its comparatively recent existence—four and a half years.

Similarly, Figs. 4, 5, and 6 show respectively the situation at the Erie, Pittsfield and Fort Wayne Works, and it will be noted that the progress of the Association clearly proves that the idea upon which it was founded has finally met with a most enthusiastic reception on the part of General Electric employees as a whole.

Doubly Mutual

The mutual features in connection with the Association are of two kinds, viz., mutual advantages to the employees themselves, and mutual advantages in the relations between the employees and the Company. The mutuality among the employees has already been discussed in connection with protection, acquaintanceship, and entertainments. The relation between the Company and the employees is almost entirely indirect and psychological, but none the less important. The fact that few of the members of the Association are laid off during the slack times is one indication that the members of the Association are able and trustworthy employees. And, since the Company encourages the Mutual Benefit Association it may be inferred that the executives in charge of its affairs consider such activities on the part of the employees as really mutual with respect to the Company's welfare.

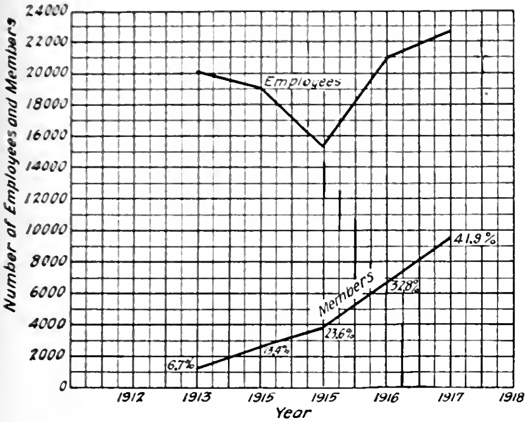


Fig. 3. Employees and Membership, Schenectady Works

Extensions

At the Lynn Works the Mutual Benefit Association activities are extended to include additional features as follows:

1. Additional emergency benefits payable to disabled members in such amounts and manner as the Committee in charge of the emergency fund may allow.

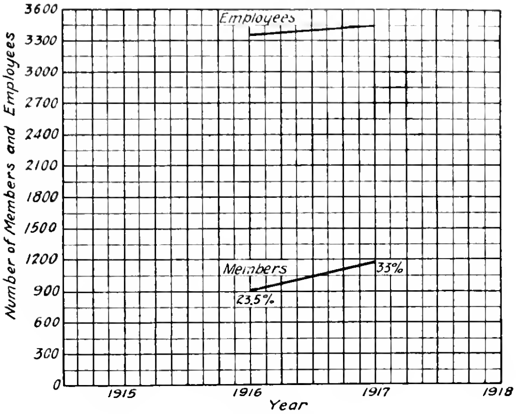


Fig. 4. Employees and Membership, Erie Works

2. Temporary loans at no interest charge or other extra cost which the loan fund committee may decide to grant to any

TABLE OF MEMBERSHIP

Year	Schenectady	Lynn	Sprague	Ft. Wayne	Pittsfield	Erie	Total No. Members
1902		656					656
1903		1285					1285
1904		1856					1856
1905		2591					2591
1906		2874	300				3174
1907		3076	305				3381
1908		2524	200				2724
1909		3684	200				3884
1910		4785	250				5035
1911		5040	275				5315
1912		5911	310	492			6713
1913	1346	5963	315	601			8225
1914	2256	5857	300	751			9164
1915	3620	6143	250	777			10790
1916	6875	7093	325	994	2410	900	18597
1917	9460	7408	400	1205	3052	1150	22675
Total No. of employees in 1917.......	22600	12644	650	4372	7050	3500	

Grand total number of employees in General Electric factories above..................50,816
Grand total number of members in Mutual Benefit Association.....................22,675
Percentage of employees who are members of Mutual Benefit Association............44.6 per cent

member of more that one year's standing.

3. Banquets attended by officers, committees, and members of sections. These are held in the large new restaurant, which is admirably adapted to such events.

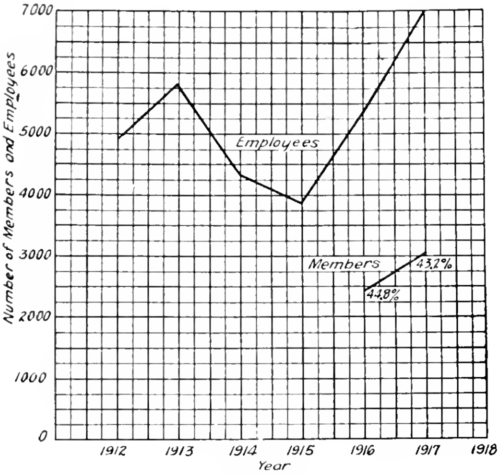


Fig. 5. Employees and Membership, Pittsfield Works

At Pittsfield the presentation of theatrical entertainments, such as the "Mikado," are a step in advance in fostering the social and fraternal spirit.

Essential Points of Organization

A study of the structural organization suggests clearly five features as important factors in the achievement of success. They are:

1. Sub-division of the Association into small, self-acting and self-administering though closely connected bodies—the Sections.

2. Management of these sub-divisions by the members themselves, with only a general supervision of all by a representative of the Company.

3. Limitation of the trust funds in the treasuries to such amounts as, under ordinary circumstances, would seem sufficient for the payment of all guaranteed benefits.

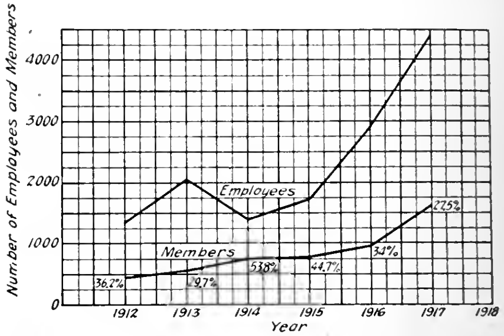


Fig. 6. Employees and Membership, Fort Wayne Works

4. Utilization of practically all contributed moneys for the purpose for which they are contributed—sickness, accident, and life insurance.

5. Simplicity of administration.

These principles and the method of their application have proved efficacious and afford the employees the cheapest insurance against disability and death, consistent with safe and sane management; and at the same time develop contentment among the members, and relations of mutual loyalty between the employees and the Works' management.

A brief outline of the Constitution and By-Laws and their significance may be in order at this point.

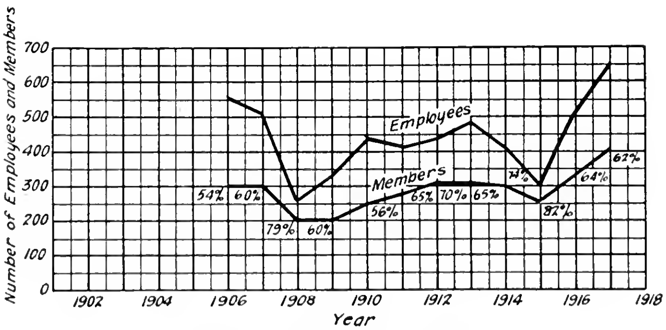
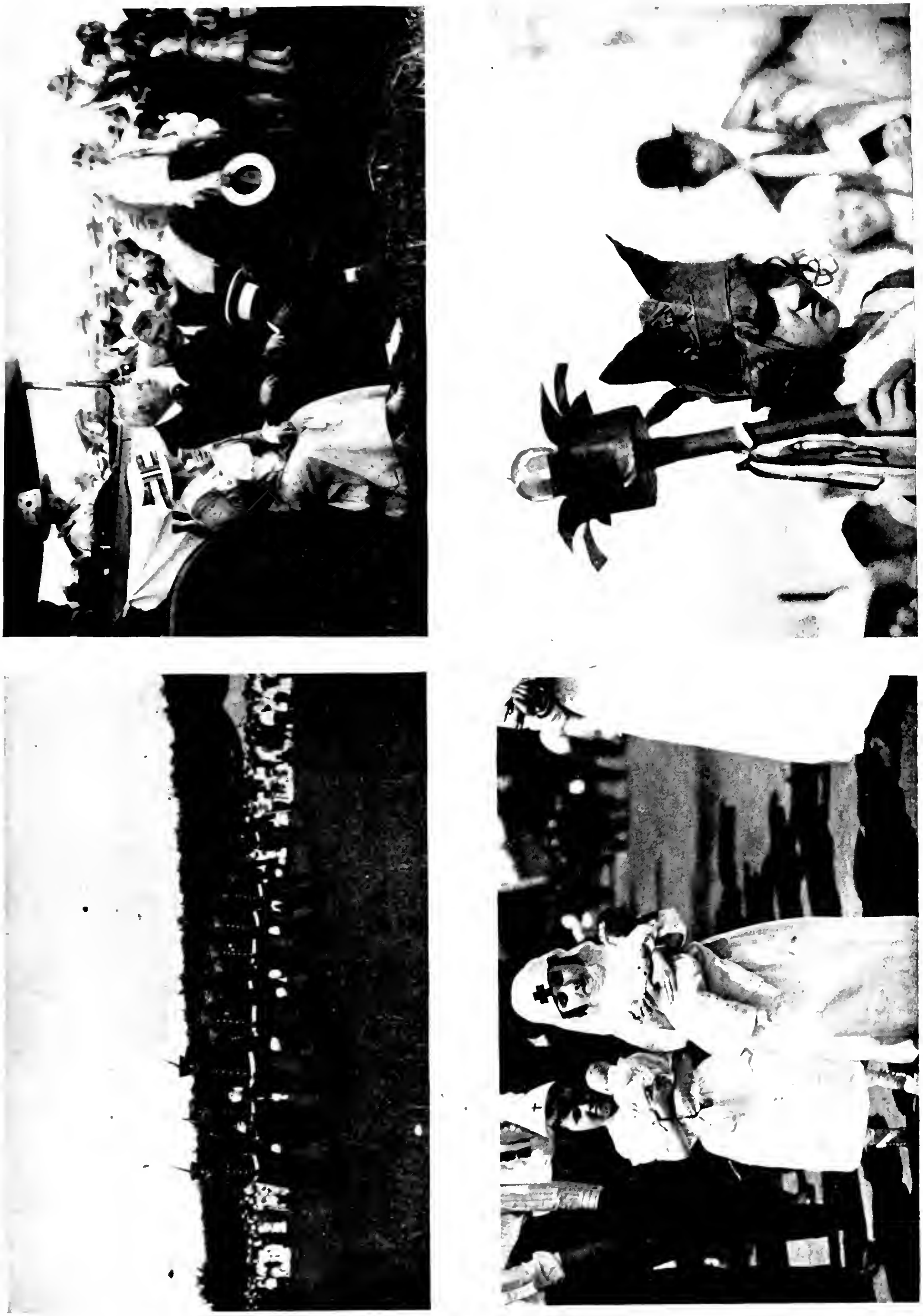


Fig. 7. Employees and Membership, Sprague Works



Scenes at Recent G-E Mutual Benefit Association Field Day, Lynn Section

The Constitution and By-Laws provide that the Mutual Benefit Association shall be divided into individual sections, the membership of which shall not exceed 150. Membership in a section is, as far as practicable, recruited from one department of the Works, and transfers from one section to another are made possible and easy whenever members are transferred from one department to another. When necessary, two or more sections are formed in the same factory department. Each section has its own administrative body and treasury, and operates independently of, and yet interdependently with, all other sections; but its procedure of business is controlled by the governing rules of the whole Association.

A chairman, vice-chairman, secretary-treasurer, and six directors constitute the governing body, and their decisions in regard to payment of claims and all other matters of procedure are final and conclusive as long as they do not conflict with the provisions of the Constitution and By-Laws. While each section, therefore, remains a separate unit, all are brought together and placed on the same basis of operation by the common Constitution and By-Laws, and a close correlation is established through the emergency fund, the loan fund, through social activities involving the whole Association, and through the work of the general chairman. The latter is the only official of the whole Association, and the only appointee of the General Electric Company, with whose selection, however, the statutory influence of the Company ceases. It is the function of the general chairman to guard the interests of the whole Association, to stimulate the various officers and committees, to keep all sections within bounds of constitutional limitations, and to act as the connecting link between the Association and the Company. Though he is not vested with any executive authority in any section, save that of preventing unconstitutional procedure, he must draw his real power from the personal influence which he may be able to exert; and this influence will be strengthened and enlarged to the degree to which he will offer wise and definite counsel, and at the same time keep it clearly before all members that his opinion and suggestions are only of an advisory nature and do not need to be followed by the sections unless their contrary actions conflict with the accepted Constitution and By-Laws. Because they realize, therefore, their own power in the premises, the members naturally proceed with care and are consequently willing to seek and take council. As presiding officer of the emergency committee, the general chairman is afforded an excellent opportunity of discussing with the section chairman the welfare of the Association as a whole and of the individual sections. Holding his finger on the pulse of the membership and having the confidence of the Company, the general chairman can work to the advantage and benefit of both interests; and he will fill this dual position so much the better the more fairly and impartially he deals with both and the more strictly he keeps the Association to those activities which promote the objects for which the Association was founded, viz.: to foster a fraternal spirit among its members, to afford relief to its members for disability through sickness or accident, and to provide benefits in case of death.

An Industrial Democracy

Summing up the whole situation then, it may be said that the General Electric Mutual Benefit Association represents truly an industrial democracy—a government of the members, by the members, and for the members. Not unlike the greatest political democracy, the United States of America, the Association is composed of individual self-governing sections, all of which, however, operate under a common Constitution, the interpretation and enforcement of which is lodged in a central department, that of the general chairman. Like each State of the Union, each section of the Association bears the cost of its own administration and supports itself for that purpose by taxation of its own members, to whom in return it affords protection and certain privileges. As the States of the Union, however, have delegated to the Federal Government certain functions, such as the conduct of the postal system, whose benefits must be shared by all the people alike, so the sections of the Association have transferred to the central department the payment of death benefits, and such other matters as can best be undertaken by the Association as a whole.

Mazda Lamps for Motion-Picture Projectors

By L. C. Porter

Edison Lamp Works, Harrison, N. J

The excellent qualities of the incandescent lamp promoted an investigation into the possibilities of using this type of lamp in motion-picture projectors. In the beginning of the following article is given an analysis of the difficulties encountered in successfully developing an incandescent lighting system to replace the arc-lighting system which has been commonly used. The description of the manner in which these difficulties have been surmounted, by the development of a special incandescent lamp and condenser and the addition of a spherical mirror, is very interesting. The article is concluded by a table comparing the detailed operating cost of the new incandescent lamp with that of the arc lamp and showing that the former type of lamp projector is more economical to operate than the latter.—Editor.

The inherent advantages of the incandescent lamp such as simplicity, steadiness of light, cleanliness, good color value, and lower fire risk, as well as ease of control, have made this type of lamp a most desirable light source. These advantages are obtained where Mazda lamps are used for projection purposes as well as for general lighting service.

For a long time it was thought impractical to apply Mazda lamps to large motion-picture projectors. There were three reasons for this belief:

1. The crater of the arc in common use as a light source for motion-picture projectors operates at about 130 candle-power per square millimeter; whereas the tungsten filament of a Mazda lamp at the melting point emits only 79 candle-power per square millimeter and at practical operating temperatures about 34 candle-power per square millimeter.
2. The condensers in common use utilized a solid angle of light of about 32 degrees. This angle picked up a high percentage of the light flux from an arc due to the light distribution characteristic of the arc (Fig. 1A), whereas with the nearly spherical light distribution of the Mazda lamp this became a very small proportion of the available light flux (Fig. 1B).
3. The crater of the arc is a relatively solid homogeneous light source and an image thereof projected onto the screen resulted in fairly even illumination; whereas with the filament of the Mazda lamp in back of the plano-condensers an enlarged image thereof was projected, resulting in a very streaked screen.

Great though these obstacles seemed to be, they have been overcome. The enormous difference in brilliancy of the two sources was

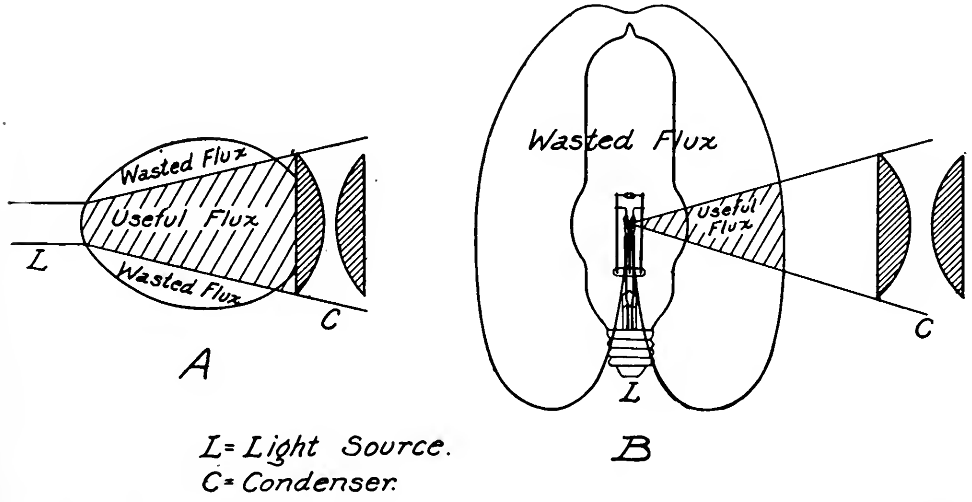


Fig. 1. Diagram showing Distribution of Light from (A) 90-deg. Carbon Arc, and (B) Projection-Type Mazda and Proportion of Total Flux Utilized

lessened by developing a new type of Mazda lamp and a new lens system. Probably the condenser plays the greatest part in solving the problem, therefore it will be described first.

Obviously, it was highly desirable to utilize a much greater solid angle of light than was intercepted by the plano-condensers commonly used. It was found impractical to make a plano-condenser of sufficiently short focus as the thickness of the glass would be great and the curvature excessive, resulting in much spherical abberation. The difficulty was overcome by the design of a condenser somewhat similar to a semaphore lens, i.e, it was a one-piece condenser made in steps, or corrugations (Fig. 2). With this condenser a solid angle of 75 degrees was intercepted which immediately resulted in a very large increase in the amount of light flux available.

Fig. 2. Special Condenser

The condenser is $4\frac{7}{16}$ in. diameter and is of $2\frac{1}{2}$–$6\frac{1}{2}$ in. conjugate foci, meaning that the light source should be located $2\frac{1}{2}$ in. back of the edge of the convex face of the condenser and the film $6\frac{1}{2}$ in. ahead of the corrugated side. The former distance must be closely adhered to for best results, but the latter may be increased an inch or so without materially affecting the resultant illumination.

Fig. 3. Spherical Mirror

A further gain in illumination was obtained by the use of a spherical mirror (Fig. 3) placed in back of the light source. This arrangement practically doubled the available useful angle, making a net increase of from 32 degrees with the old plano-condensers to 150 degrees by use of the new condenser and mirror. The corrugations on the condenser also performed the further function of breaking up the filament image, resulting in a smooth and even screen illumination. The great increase in light flux thus obtained went a long way toward offsetting the difference in operating efficiencies of the arc and the Mazda lamp. To further decrease this difference the

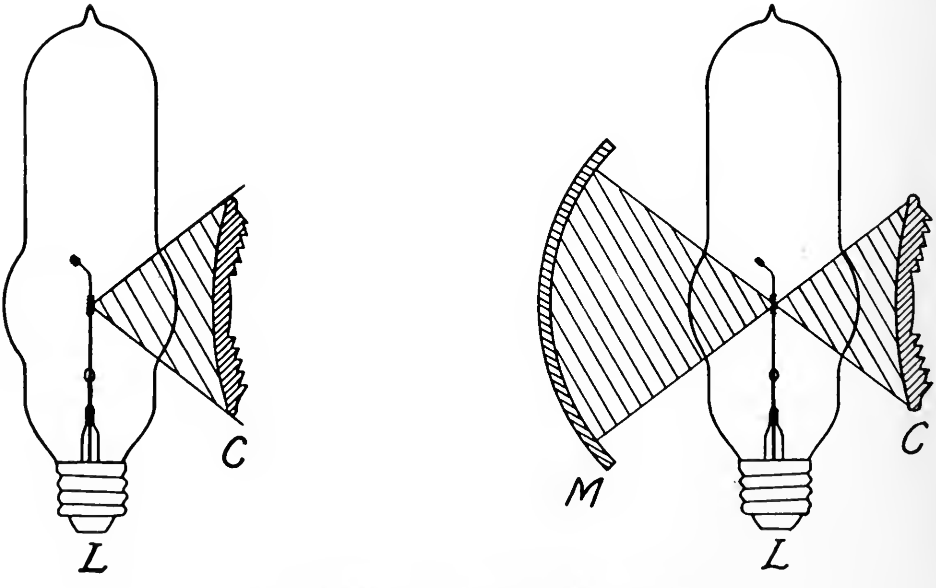


Fig. 4. Arrangement of Lamp, Mirror, and Condenser

lamps were operated very close to the melting point, resulting in high brilliancy and an average life of approximately 100 hours.

Many types of lamps were tried and the one finally chosen has a filament arrangement somewhat different from those in common use. The filament consists of four helices of tungsten arranged in one plane (Fig. 5). This construction has a double advantage. First, it brings more of the filament close to the focus of the condensor; and, second, it enables the spherical mirror, when properly adjusted, to throw images of these filament coils back between the coils themselves, thus resulting in an effectually solid light source. It can be seen that careful setting of the lamp, mirror, and condenser are necessary to obtain maximum results. Fig. 6 shows these elements in their proper relative positions.

The capacity of the lamp finally chosen was 750 watts operating at 30 amperes. The determining factor was that the condenser would pick up light from a 0.4-in. square, hence the filament was designed which would place the greatest possible amount of light in that area. Low voltage (25) and high amperage are used because these call for heavier wire, and the greater the diameter of the wire the higher the temperature, hence the greater the candle-power (within certain limits) that can be obtained therefrom.

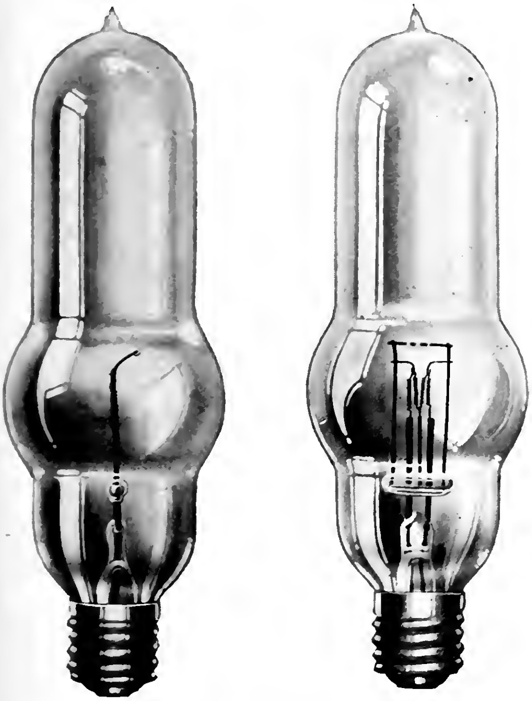


Fig. 5. A Front and a Side View of the Motion-Picture Mazda Lamp

Using a 25-volt lamp some economical means of reducing the line voltage of 110 or 120 to that of the lamp became desirable. For this purpose special compensators have been designed for use on alternating-current circuits* (Fig. 7). These control equipments consist of a compensator with either a rheostat, or a reactance control in the primary, by means of which the secondary current can be regulated very closely and exactly 30 amperes delivered to the lamp regardless of whether the primary voltage happens to be 105, 125, or any value between. An accurate ammeter on which to read the secondary current forms part of the equipment. This *accurate control* is of *great importance*. With the lamp operating at so high an efficiency as to give an average of but 100 hours life, a very small amount of over current will reduce this life materially. As the lamps are fairly expensive, it is evident that the saving in lamp renewals will soon more than offset the additional cost of accurate control equipment.

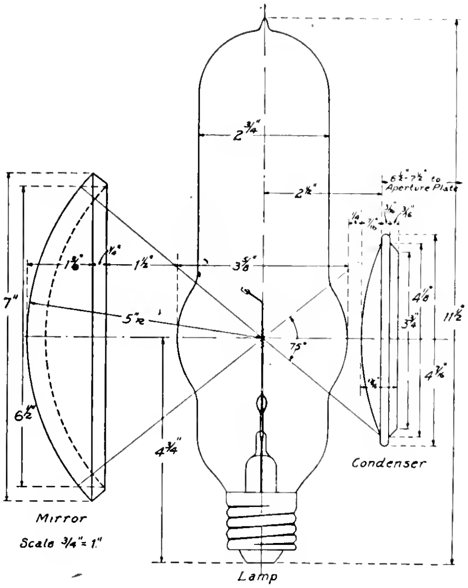


Fig. 6. 30-Ampere Motion-Picture Lamp, Corrugated Condenser, and Spherical Mirror in Correct Operating Positions

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* Motor-generators are used for direct-current service.

A 600-watt lamp operating at 30 volts and 20 amperes has also been developed and may be used with gasolene generator sets which are being marketed throughout the country for motion-picture work. This lamp is made in a somewhat smaller bulb than the 30-ampere lamp, thus allowing the use of a smaller condenser and a smaller mirror. This is of advantage in machines for home use, portable machines, etc., where compactness and light weight is of value. As the lamp does not exceed the Underwriters' limit of 660 watts, it may also be used on house lighting circuits, in schools, churches, etc., without special wiring. The "Compensarc" will control either the 750- or the 600-watt lamp.

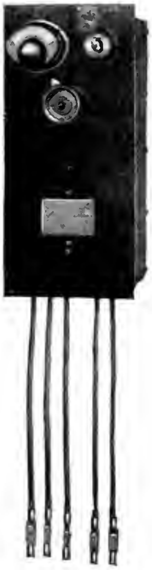


Fig. 7. Compensator for Alternating-current Circuits

After the application of Mazda lamps to motion-picture projectors had become possible, the various manufacturers of motion-picture machines developed new housings containing the new lamp, condenser, and mirror with proper means for adjustment. One of these furnishes two lamps in the housing. Each is carefully focused before the picture is started and then in case one burns out the other can be quickly substituted with practically no interruption to the picture. These housings (Fig. 8) are interchangeable with the old arc-lamp housings previously used. Another type of housing is being built which fastens onto the front of the arc-lamp housing.

TABLE I

LUMENS

Objective Focal Length in Inches	4½	5	5½	6	6½	7	7½	8
Objective Aperture								
1½	325	261	216					
1¾	440	355	294	247				
2	577	464	384	323	275			
2¼	727	588	487	409	349	300	262	
2½	900	727	600	505	430	370	323	284
2¾		880	727	611	521	448	392	345
3			863	727	620	532	466	410
3¼				855	727	625	550	480
3½					845	727	635	557
3¾						833	727	640
4							830	727

Not satisfied with the good projection obtained by the means which has been described, investigation was carried further. It was found that by increasing the diameter of the objective lens a still greater increase in illumination resulted, approximately as given in Table I which is based on an arbitrary standard of 600 lumens for the 5½-in. objective of 2½-in. aperture.

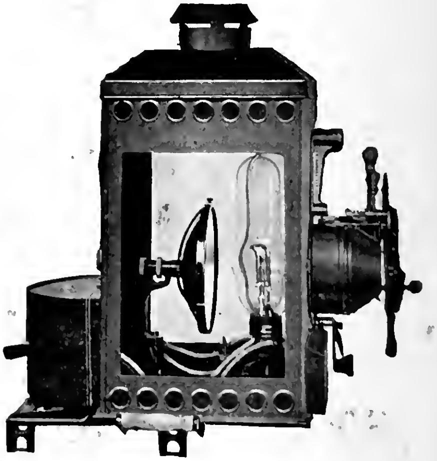


Fig. 8. Lamp Housing, showing Arrangement of Mirror, Lamp, and Condenser

Objective lenses in common use with arc lamps are 1½ in. and 1¾ in. in diameter. There are available standard lenses of 2½-in. diameter. These latter lenses will transmit exactly double the illumination of a 1½-in. lens, and it is highly desirable to use the larger

TABLE II

COMPARATIVE COST DATA MAZDA LAMP *VS.* ARC LAMP FOR MOTION-PICTURE PROJECTORS

Type of Arc	Type of Arc Control	Renewal Cost of Carbon per 10-hour Period Based on Cost in New York City	Renewal Cost of Mazda per 10-hour Period Based on Net Price of $6.00 Per Lamp Giving Life of 100 Hours	Additional Cost per 10-hour Period of Mazda Renewals Over Carbon Renewals with Mazda Life of 100 Hours	Cost of Current per 10-hour Period for Arc at Kw-hr. Rate		Cost of Current Per 10-hr. Period for Mazda Lamp	Saving in Cost of Current for 10-hour Period for Mazda Over Arc	Total Saving per 10-hour Period Over Arc with Life of 100 Hours
					Rate	Cost			
35-50 amp. (a-c. or d-c.)	Rheostat	$0.30	$0.60	$0.30	$0.10	$4.62	$0.85	$3.77	$3.47
					.08	3.67	.68	2.99	2.69
					.06	2.76	.51	2.25	1.95
35-50 amp. (a-c.)	Compensator	.30	.60	.30	.10	2.36	.85	1.51	1.21
					.08	2.09	.68	1.41	1.11
					.06	1.42	.51	.91	.61
35-50 amp. (d-c.)	Motor-Generator	.30	.60	.30	.10	2.15	.85	1.30	1.00
					.08	1.72	.68	1.04	.74
					.06	1.29	.51	.78	.48
60-75 amp. (a-c. or d-c.)	Rheostat	.39 A-C. .37 D-C.	.60	.21 .23	.10	7.48	.85	6.63	6.40
					.08	5.98	.68	5.30	5.07
					.06	4.48	.51	3.97	3.74
60-75 amp. (a-c.)	Compensator	.39 A-C.	.60	.21	.10	3.74	.85	2.89	2.68
					.08	2.99	.68	2.31	2.10
					.06	2.24	.51	1.73	1.41
60-75 amp. (d-c.)	Motor-Generator	.37	.60	.23	.10	3.40	.85	2.55	2.36
					.08	2.99	.68	2.04	1.81
					.06	2.04	.51	1.53	1.30

lens when changing from an arc to a Mazda lamp in large motion-picture projectors.

The use of a Mazda lamp as a light source for the motion-picture machine has the following advantages:

1. Large reduction in operating cost as given in Table II.
2. Better pictures giving less eye fatigue, due to better color and greater steadiness of light.
3. Reduction in wear and tear on machines and film, due to ash from carbon arc.
4. Less heat in the operator's booth.
5. Simpler control.

The 750-watt lamp will replace any alternating-current arc on the market and direct-current arcs up to 40 amperes and will project pictures 12 feet wide on a white plaster or cloth screen, or 16-foot pictures on a metallic, fiber, or glass screen.

Developments in Switchboard Apparatus

OUTDOOR DISCONNECTING SWITCHES, FUSES, AND CHOKE COILS FOR USE UP TO 150,000 VOLTS

The type of high-tension disconnecting switch used for two- and three-phase outdoor circuits up to 110,000 volts is shown in Fig. 1. From 110,000 volts up, the construction of the switch is similar except that there are two blades in series in each phase, Fig. 2.

When choke coils or fuses, or both, are used in combination with the disconnecting switch, the upper voltage limit is 70,000. A 35,000-volt combination switch, fuse, and choke coils is shown in Fig. 3.

In apparatus of this type, four combinations are in general use:

(1) *Switch, Choke Coil, and Fuse*—for a complete substation equipped with lightning arrestors; where the normal capacity of the line is not greater than 50 amperes, where short-circuit protection only is required, and where the switch need open only the line charging current.

(2) *Switch and Fuse*—primarily for stations similar to (1) but where no lightning arrestors are used.

(3) *Switch and Choke Coil*—same as (1) except that an oil circuit-breaker replaces the fuse because (a) the normal capacity of the line is greater than 50 amperes, (b) automatic overload protection is required, and (c) the line must be opened under power load.

(4) *Switch*—same general use as for indoor disconnecting switch.

The disconnecting switch is designed for large capacity outdoor stations under weather conditions of any character, and it is always mounted on channel-iron bases. Each phase has a separate channel iron fastened horizontally to the supporting structure (usually a steel tower) by means of lag screws and bolts. Thus the switch will not jar loose or out of alignment, even if the supporting structure should be moved; for the alignment of the insulators, on which the switch is mounted, is dependent entirely on the alignment of the channel-iron bases. All the insulators are of the petticoat type.

The switch is opened and closed when movable insulators (one for each pole of the switch and connected together by means of pipe joining bell-cranks fastened to the insulator pins) are turned by an operating handle located near the ground and connected to one movable insulator by means of a suitable length of pipe. The operating lever can be locked in the open or the closed position.

As the rotating insulator is turned by means of the operating handle, a crank shaft transmits motion to the switch blade which describes an arc of 90 degrees in a plane perpendicular to the base of the switch. The end of the switch blade fits over a stationary wedge-shaped contact as shown in Fig. 4. By means of this construction all ice or snow is removed each time the switch is operated,

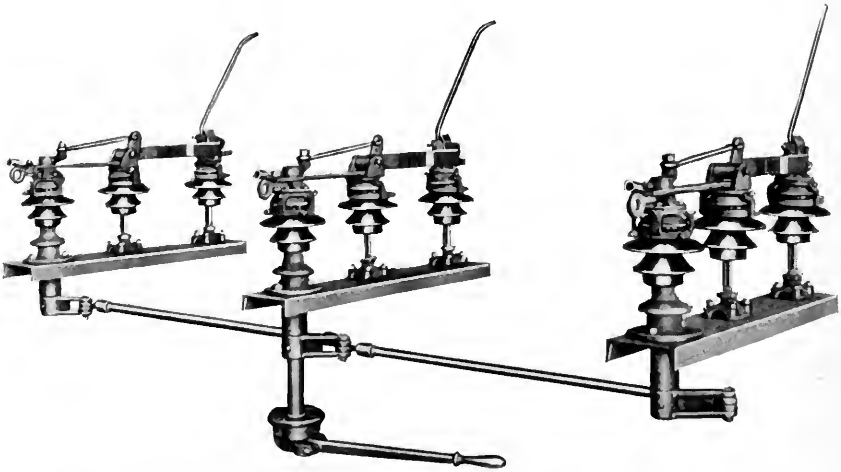


Fig. 1. Disconnecting Switch for Two- and Three-phase Circuits up to 110,000 Volts

the effect being the same as drawing a sharp edge against each side of the wedge-shaped contact.

The switch is equipped with horn-type arc-deflectors, fastened on the inside of the cap which supports the stationary contact, and it is so shaped that when the blade is opened the horn fits into the split part of the blade. As the blade moves upward, the arc is formed between the horn deflector and the top of the blade with an ever increasing distance between the opening. This definitely confines the arc to the horn and blade, and quickly ruptures the arc without short-circuiting the line or involving adjacent apparatus.

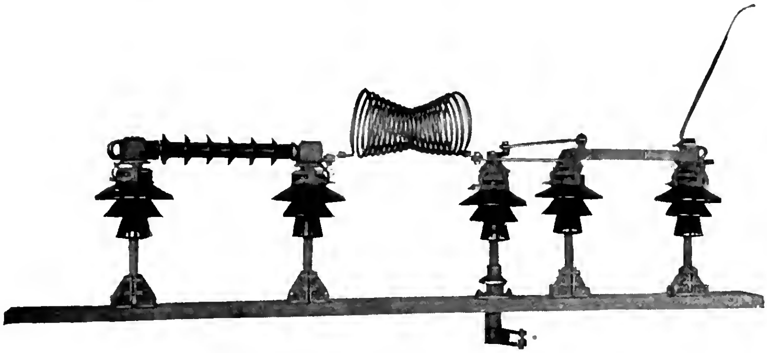


Fig. 3. Combination Switch, Fuse and Choke Coil for 35,000 Volts

Eye holes are provided on each end of each single-pole unit to take the strain off the terminal and to prevent the connection between the line and the switch from becoming broken or disconnected from the switch. Separate strain insulators are used for dead ending the line.

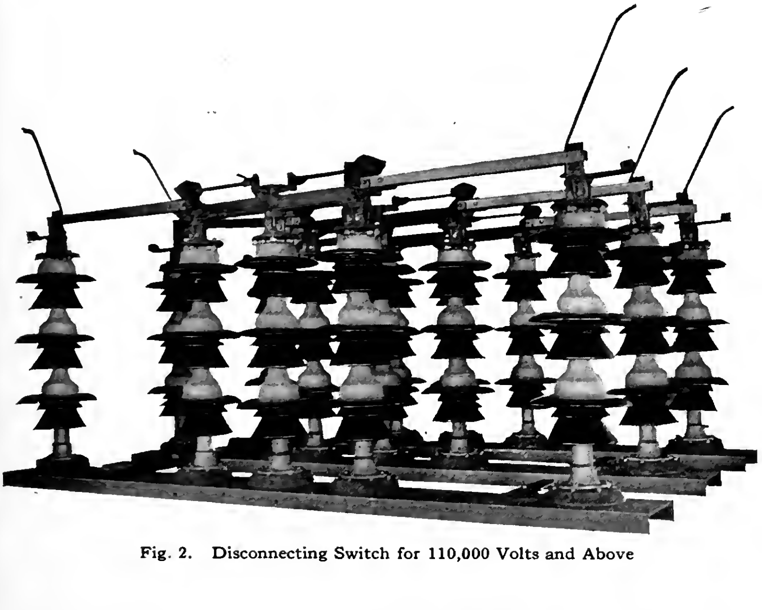


Fig. 2. Disconnecting Switch for 110,000 Volts and Above

The switches are suitable for breaking the exciting current of transformers up to 15,000 kv-a. The essential features are as follows:

(1) Each phase of the circuit is connected to separate poles of the switch which are mounted on a separate channel-iron base.

(2) Correct spacing is secured by means of connection rods of proper length.

(3) The break is in a plane vertical to the base of the switch.

(4) The arc-horn, which is bolted in the middle of the stationary clip in conjunction with the upward movement of the switch blade, assists the arc in mounting the arc-horn.

(5) The opening and closing of the switch is controlled by an operating handle insulated from the live parts and located near the ground. The handle can be locked either in the open or closed position.

(6) For each phase there are only two moving parts, the rotating insulator and the hinge blade.

(7) The mechanical construction is strong the switch is rust-proof, and weather-proof.

The fuses are quite similar to the fuse and disconnecting switch described in the General Electric Review, November 1917, p. 901, except that the former is for horizontal mounting.

The holder for the fuse consists of a brass and fiber tube enclosed in a suitable porcelain housing. On each side of the ends of the tube is a round contact which fits into the clip which holds the tube in place. These clips have a spring that insures a constant pressure of the holder and prevents it from being removed by jar. The clips are enclosed in a suitable shield which prevents ice or snow from interfering with the proper operation of this holder.

Hour-glass type choke coils for outdoor use have the same general construction, from 10,000 to 70,000 volts, as standard indoor coils on steel bases, except that the outdoor coils are mounted on petticoat insulators.

Conservation in Use of Coal

The Committee on Coal Conservation of the Chamber of Commerce of the United States has addressed a circular to the members of the Chamber on "Conservation in Use of Coal," with the intention of influencing owners and managers of power plants to employ more efficient methods of burning coal under boilers. On this committee are such prominent men as John W. Lieb, Vice-President, New York Edison Company; Ira N. Hollis, President, Worcester Polytechnic Institute, and President of the American Society of Engineers; Lester P. Breckenridge, Professor of Mechanical Engineering, Sheffield Scientific School, Yale University, and P. H. Gadsden, President, Consolidated Railway and Lighting Company, Charleston, S. C The coal situation is now so acute that we are publishing the comments and recommendations of this circular in the hope that their wider publicity will be of assistance in relieving the situation.—EDITOR.

Costs of production have more attention today than ever before. The costs of coal for generation of power has in many instances not had the same consideration as other costs, because coal has been cheap and obtainable in abundance; cheap coal and cheap labor sometimes made it apparently economical in dollars and cents to install and run an inefficient plant.

Coal has now become expensive. It is hard to obtain. Efficiency in its use and avoidance of waste have become of first importance, since without power other materials cannot be utilized.

These conditions make it imperative for every owner or manager of a power plant to examine into the cost of the power his establishment uses, the economy with which it is generated and applied, and the increase in efficiency that is possible. Some of the steps that an owner or manager should take are to:

Reconsider the Advantage of Buying Heat and Power from a specialized plant that makes nothing else and can afford the investment and supervision that gets a maximum of value out of each pound of coal; in some localities hydro-electric power may be available;

Find the Nearest Source of Coal that will meet the requirements, even if it does take a little more trouble to use it; the tax on the transportation system will thus be reduced so far as haulage by rail is shortened; coal is mined in twenty-six states, and these states extend partically across the continent and from the northern to the southern borders;

Give to the Power Plant and its Personnel Recognition and Encouragement such as is due an expert and important department, thus getting new effort and attention to offset the extra attention and care needed with coal inferior in grade and preparation to the coal formerly available;

Seek to Increase Skill and Proficiency in the men who handle the coal; a fireman at a hand-fired boiler shovels three to ten tons of coal a day—or as great a value in material as many skilled men in other departments;

Put the Fuel-using Equipment into as Perfect Condition as Possible; provide at hand-fired plants an ample firing floor with a good surface, together with a smooth-bottomed coal car if it can be used; eliminate leaks in the boiler setting, see that fire-doors fit properly, replace defective grate bars, make sure that smoke connections are clean and tight; if mechanical stokers are used, see that they are in good repair and that directions for using them are being followed; in general, make the plant and the fire-room of such character that an efficient man will stay on the job;

Install Simple and Convenient Means by Which the Fire-room Force May See Results; scales for weighing fuel and ash, meters for measuring water fed to the boiler, and devices for determining the quality of flue gases, the draft over the fire, etc., can be made to interest the men in the fire-room and show the actual results of efforts to economize; convenient means for operating the flue damper must be installed;

Endeavor to Run Boilers in Service at their Capacity; if efficiency is increased, one or more boilers in a battery may be dropped;

Provide Water that is Free from Scale by using, when necessary, water-treating devices if the plant is large, and special feed-water heaters in small plants;

Reduce Loss of Heat After it is Generated: see that boiler surfaces and steam pipes are properly covered; the simplest and most inexpensive covering will reduce loss by eighty per cent; in the engine room cut out useless steam lines, have valves properly set, reduce the small auxiliary pumps, etc., to a minimum, provide the repairs the engineer has been asking;

Obtain Expert Advice; good steam engineers are familiar with well tried ways of reducing both consumption of coal and consumption of heat; their advice should be obtained in all practical cases; this is not a time for radical innovations but for utilizing tried experience.

One pound of coal per hour has yielded a horse power per hour. That is the record of present possibility. It cannot by any manner of means be attained by every plant. But the fact that at present the average attainment throughout the country is but one-third or one-fourth of this record is indicative of the possible savings that can be made if the care and attention which the power plant deserves are actually given to it.

Most users of coal can join in promoting efficiency of coal. Railways have made real progress in firing locomotives; they can often go farther. Gas works can generally effect further saving by using careful technical direction. Manufacturing plants of every degree can show great results in the aggregate.

The Bureau of Mines on behalf of the federal government has gathered a great deal of information about the use of coal and has expert advice to give regarding means of economy. Some of the publications in which the Bureau of Mines has embodied the results of its experiments and made practical suggestions based upon expert observations and conclusions of its staff and other engineers are indicated in the following list. In many instances state agencies, too, have data and suggestions which are to be had for the asking.

COMBUSTION IN THE FUEL BED OF HAND-FIRED FURNACES. Technical Paper No. 137. Price 15 cents.

HAND-FIRING SOFT COAL UNDER POWER-PLANT BOILERS. Technical Paper No. 80.

FACTORS GOVERNING THE COMBUSTION OF COAL IN BOILER FURNACES. Technical Paper No. 63. Price 5 cents.

EXPERIMENTS WITH FURNACES HAVING HAND-FIRED RETURN TUBULAR BOILER. Technical Paper No. 34.

ECONOMIC METHODS OF UTILIZING WESTERN LIGNITES. Bulletin No. 89.

THE SMOKELESS COMBUSTION OF COAL IN BOILER FURNACES. Bulletin No. 40. Price 20 cents.

CITY SMOKE ORDINANCES AND SMOKE ABATEMENT. Bulletin No. 49.

DETERIORATION AND SPONTANEOUS HEATING OF COAL IN STORAGE. Technical Paper No. 16.

THE DETERIORATION OF STORED COAL. Bulletin 136.

OPERATING DETAILS OF GAS PRODUCERS. Bulletin 109. Price 10 cents.

DIRECTIONS FOR SAMPLING COAL FOR SHIPMENT OR DELIVERY. Technical Paper No. 133.

GRAPHIC STUDIES OF ULTIMATE ANALYSIS OF COALS. Technical Paper No. 93. Price 10 cents.

SAVING FUEL IN HEATING A HOUSE. Technical Paper No. 97.

Where a price is indicated, the pamphlet is obtainable only by purchase from the Superintendent of Documents, Government Printing Office, Washington, D. C. Remittance by money order should accompany orders. Copies of other pamphlets may be obtained without charge from the Bureau of Mines, Department of the Interior, Washington, D. C. Upon application to the Bureau of Mines a complete list of its publications can be obtained.

Subscriptions to Second Liberty Loan by General Electric Employees

The response by the Company's employees to the Government's call for subscriptions to the Second Liberty Loan was even more liberal than that to the first loan. The showing is all the more significant when it is considered that the greater portion of subscribers to the second loan were also subscribers to the first loan on the weekly or monthly payment basis, and as these payments have not yet been completed, these employees in subscribing to the second loan are required to make payment on the two loans simultaneously for a period of several months. The subscription per capita of the 72,000 employees of the Company to both loans is $90.

At the Schenectady Works a committee of seven chairmen, headed by Mr. G. E. Emmons, and assisted by 100 departmental committees with a total membership of 1000, inaugurated a campaign having for its slogan, "Over the Top for a Million." The work of this committee soon kindled the enthusiasm that assures success, and at once spirited rivalry between departments began. Thousands of signs all over the plant indicated the progress of the loan in the several departments, the goal most vigorously striven for being "100 per cent employees subscribing."

On Thursday, October 25th, the result of the campaign was announced during the noon period. Some preparation by the employees for a demonstration was planned, as it was known that the million dollar mark had been attained; but when Mr. Emmons announced the amount as being $1,500,000 the enthusiasm of the crowd overflowed all bounds. Practically the entire factory force of 21,000 men and women paraded through Schenectady bearing signs, effigies of the German Kaiser, and all manner of noise-making contraptions. The accompanying photographs show some of the incidents connected with the campaign at the Schenectady Works.

	FIRST LOAN		SECOND LOAN	
	Number Subscribers	Amount	Number Subscribers	Amount
Schenectady Works, including General Offices	13,309	$1,057,400	20,905	$1,497,600
Lynn Works	8,737	559,800	9,111	555,000
Pittsfield Works	4,145	287,400	4,413	289,050
Erie Works	2,384	177,450	2,360	160,050
Fort Wayne Works	2,129	152,050	2,922	196,600
Edison Lamp Works	3,212	213,650	3,387	200,250
Sprague Electric Works	802	57,850	594	56,450
National Lamp Works	3,389	278,200	2,908	250,400
District Offices	1,748	219,050	1,717	224,100
	39,855	$3,002,850	48,317	$3,429,500
Foreign Selling Companies			23	18,000
	39,855	$3,002,850	48,340	$3,447,500

DISTRICT OFFICES

	FIRST LOAN		SECOND LOAN	
	Number Subscribers	Amount	Number Subscribers	Amount
Atlanta	68	$ 8,400	20	$ 2,100
Boston	177	26,750	134	34,800
Chicago	377	41,350	242	22,800
Cincinnati	109	16,450	150	20,000
Denver	32	3,000	24	5,400
New York	358	47,500	497	52,000
Philadelphia	226	25,350	257	28,350
Pacific Coast	225	31,800	166	25,150
St. Louis	84	10,250	87	17,300
Southwest	92	8,200	140	16,200
	1,748	$219,050	1,717	$224,100

Announcement Meeting, Looking East

Announcement Meeting, Looking West

Liberty Loan Mass Meeting

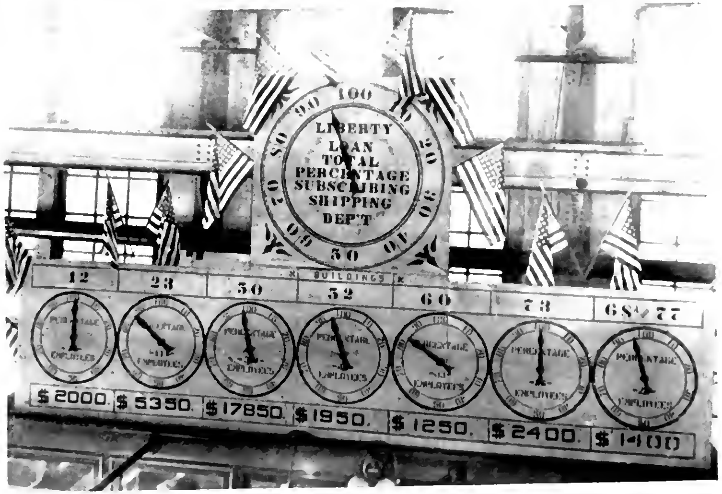
Liberty Loan Parade Leaving Works

Scenes in Connection with Second Liberty Loan Campaign at Schenectady Works of General Electric Company
(Also see following page)

Uncle Sam, Miss America, and Liberty Girls

Red Cross Girls

The Master Liberty Loan Clock



One of the Departmental Liberty Loan Clocks

Scenes in Connection with Second Liberty Loan Campaign at Schenectady Works of General Electric Company

ROLL OF HONOR

EMPLOYEES OF THE GENERAL ELECTRIC COMPANY WHO HAVE ENTERED THE MILITARY SERVICE OF THE UNITED STATES

Supplement to
GENERAL ELECTRIC REVIEW
November, 1917

"The White House, Washington.

"To the Soldiers of the National Army:

"You are undertaking a great duty. The heart of the whole country is with you. Everything that you do will be watched with the deepest interest and with the deepest solicitude not only by those who are near and dear to you but by the whole nation besides. For this great war draws us all together, makes us all comrades and brothers, as all true Americans felt themselves to be when we first made good our national independence.

"The eyes of all the world will be upon you because you are in some special sense the soldiers of freedom. Let it be your pride therefore to show all men everywhere not only what good soldiers you are but also what good men you are, keeping yourselves fit and straight in everything and pure and clean through and through. Let us set for ourselves a standard so high that it will be a glory to live up to it and then let us live up to it and add a new laurel to the crown of America.

"My affectionate confidence goes with you in every battle and every test. God keep and guide you!

"Woodrow Wilson."

SCHENECTADY WORKS

NAME	DEPARTMENT	BRANCH OF SERVICE
Adams, C. S.	Test	Navy
Affieri, V	Motor	Army
Aird, A. W.	Test	O. T. C.
Aldour, V.	Swbd. Screw Machine	Army
Alex, W.	Swb'd Polishing	Army
Alexander, J.	Test	N. G.
Alexander, W.	Swbd. Polishing	Army
Alfieri, V.	Sec. I Motor	Army
Alger, H.	Sec. I Motor	Army
Allen, F. O.	Field Coil Winding	N. G.
Allen, J. W.	Sec. I Motor	N. G.
Allen, L. M.	Induc. Motor Eng.	N. G.
Allen, M.	Foreign	O. R. C.
Allewelt, R. L.	Mfg. General	N. R.
Allison, A. J.	Industrial Control	Army
Althouse, V.	Screw Mach.	Army
Anderson, D.	Armature	Army
Anderson, G. B.	Test	Army
Anderson, G. H.	Drafting	N. G.
*Anderson, W.	Power & Mining	O. R. C.
Anderson, W. F.	Machine Shop No. 9.	Army
*Andrews, J. M.	Power & Mining	N. G.
Angeramo, C.	Swb'd Assembly	Army
Anthony, H.	Shipping	Army
Anunziatta, M.	Insul. & Car. Brush	Navy
Armstrong, S. W.	Cost	Navy
Arnold, E.	Test	N. G.
Atkinson, F. C.	Drafting	Navy
Atkinson, M. H.	Research Lab.	Army
Aylward, J.	Screw Mach.	Army
Baer, W.	Wire & Cable	N. G.
Bahan, W.	Rheostat	N. G.
Bahr, W. C.	Turbine	Navy
Bailey, C. C.	Railway Com'l	O. R. C.
Baker, C. E.	Test	Army
Baker, L. R.	Sec. I Motor	Army
Baker, W. M.	Brush Holder	N. G.
Bancroft, A. J.	Swb'd Assembly	Army
Banders, A. J.	Wire & Cable	N. G.
Bander, A. J.	Changing Reels	N. G.
Banning, H.	Test	N. R.
Barber, H.	Rheostat	Navy
Barbour, C.	Sec. I Motor	N. G.
Bressette, W.	Sec. I Motor	N. G.
Bardin, H. N.	Test	O. T. C.
Barker, H.	Rheostat	N. G.
Barrett, F.	Turbine	N. G.
Beaver, G.	Test	N. G.
Benham, H.	Die & Tool Room	Army
Benham, L. H.	Apprentice	Army
Bentley, G.	Apprentice	Army
Berenek, W.	Punching	Army
Berganni, G.	Grounds & Bldg.	Army
Berrson, E. J.	Power Station	N. R.
Best, T. G.	Test	Army
Beszterda, F.	Punch Press Oper.	Army
*Betley, M. A.	Turbine	Navy
*Bill, E. M.	Railway Equip.	O. R. C.
Binks, E.	Punch Press Oper.	N. G.
*Bird, H.	Power & Mining	N. G.

NAME	DEPARTMENT	BRANCH OF SERVICE
Bisbing, I. S.	Swb'd Sales	N. G.
Bishop, H. N.	Turbine	Navy
Bishop, L.	Power & Mining	N. G.
Blackburn, E. J.	Motor	N. R.
Bleau, A. J.	Armature	N. G.
Blesser, J.	Wiring Supplies	N. G.
Blum, L.	Drafting	Army
Bohauske, J. T.	Armature	Navy
Bolster, W. A.	Turbine	O. R. C.
Bosley, G.	Motor	Army
Bosworth, W. S.	Construction	Army
Boucher, A. J.	Mica	Army
Bowman, G.	Customer's Index	Army
Boyd, R.	Payroll	N. G.
Boyd, R. A.	Contactor Control	N. G.
Braccio, M.	Punching	Army
Bramer, A.	Rheostat	N. G.
Bratt, E. T.	A-C. Engrg.	N. G.
Bratt, G.	Rheostat	N. G.
Brinkman, L. M.	Testing Lab.	N. G.
Britten, J.	Flow Meter	Army
Brockway, R. M.	Industrial Control	O. T. C.
Brooks, W. E.	Turbine	Army
Brophy, C. S.	Purchasing	Army
Brosokie, A.	Turbine	N. G.
Brown, C. A.	Motor	N. G.
Brown, G. C.	Mica	Army
Brown, H.	Wiring Supplies	N. G.
Brozozowski, A.	Wiring Supplies	Army
*Bruns, C. B.	Piece Rate	O. R. C.
Brush, K. F.	Stand. Lab.	N. R.
Buhrmaster, L. A.	Meter	N. G.
Bulnes, W. F.	Piece Rate	Navy
*Burns, C. B.	Rheostat	O. R. C.
Butler, A. I.	Test	O. R. C.
Butler, T. W.	Test	Navy
*Button, J. S.	Lighting	N. G.
Byrne, J.	Turbine	Army
Caliusac, C. J.	General Acct.	Army
Callahan, J.	Grounds & Bldg.	O. T. C.
Camemzo, M.	Rheostat	Navy
Cameron, A.	Shipping	Army
Cameron, A. D.	Supply	O. T. C.
Campbell, R. E.	Test	O. T. C.
Campbell, R. V.	Swb'd Detail	Army
Campbell, W.	Drafting	Canadian Army
Canaby, B.	Tinsmith	Navy
Cappele, A.	Turbine	Army
Caride, G.	Punch Press Oper.	Army
Carle, L. A.	Swb'd Detail	N. G.
Carlson, G. W.	Crane	N. G.
Carmino, R.	Transportation	Army
Carniight, F. J.	Armature	N. G.
Carpinelli, F.	Shipping	Army
Carlo, J. A.	Sec. I Motor	Army
Caropellucci, G.	Wire & Cable	Navy
Case, G. J.	Sec. I Motor	Navy
Catapano, A.	Swb'd Polishing	Army
Catell, G. W.	Research Lab.	Navy
Caul, C.	General Acct.	Navy

*Commissioned Officer. N.G., National Guard. N.M., Naval Militia. N.R., Naval Reserve. O.R.C., Officers' Reserve Corps. O.T.C., Officers' Training Camp.

Name	Department	Branch of Service
Cauthers, A.	Contactor Control	Army
Cellini, J.	Armature	Army
Chambers, W. C.	Shipping	N. G.
Chase, H.	Wire & Cable	N. G.
Chesebro, E.	Turbine	N. R.
Christman, F. N.	Publication Bureau	Army
Christman, W.	Wiring Supplies	N. G.
Chrysler, H. M.	Sec. I Motor	Navy
Citraro, W.	Sec. I Motor	Army
Citraro, U.	Motor	Army
Civisca, G.	Contactor Control	Army
Clapp, E. N.	Test	O. R. C.
Clark, H.	Contactor Control	Army
Clark, P. F.	Armature	N. G.
Clarkson, W. B.	Industrial Control	Army
*Clinton, J. S.	Collection	N. G.
Clement, A. W.	Stand. Lab.	N. G.
Clough, J. H.	Research Lab.	Army
Clute, G. P.	Draftsman	Army
Coburn, C.	Power & Mining	Army
Cohen, J. E.	Swbd. Detail	Army
Coipeland, R. C.	Test	O. T. C.
Coleman, J.	Swb'd. Assemby	Navy
Collem, F.	Swb'd—Oil Switch	N. G.
Comstock, F. H.	Turbine	Navy
Conde, O.	Armature	Army
Condit, W. F.	Contactor Control	N. G.
Congress, A.	Drafting	Army
Connel, W. N.	Armature	Navy
Conte, A.	Swb'd—Switch	Army
Cooper, J.	Rheostat	Army
Copkeley, E.	Machine Shop No. 16	Army
Coppolo, F.	Motor	Army
Corlette, L. H.	Local Sales	O. T. C.
Cornick, H. F.	Wire & Cable	Army
Corrigan, J.	Wiring Supplies	Army
Corrigan, J. E.	General Acct.	Army
Cotton, A.	Screw Mach. Oper.	N. G.
Cramer, S.	Punch Press Oper.	Army
Crandall	Steam Fitting	Army
Crawford, J. H.	Supply	O. T. C.
Crego, A.	Shop Electric	N. G.
Crego, E. R.	Stand. Lab.	N. G.
Cretico, G. D.	Turbine	Army
Crosthwait, F.	Turbine	Army
Crosthwaite, J.	Industrial Control	Navy
Crowe, J.	Crane	N. G.
Cudney, F. P.	Armature	N. G.
Cullen, F. J.	Drafting	N. G.
Cullings, R. E.	Swb'd Assembly	N. G.
Cummings, F.	Controller	Army
Cunningham, M.H.	Production	Army
Cuomo, T.	Wiring Supplies	Army
Curley, J. S.	Foreign	N. G.
Cutler, G. H.	Shipping	Army
Dadson, W.	Wiring Supplies	Navy
Daley, S. J.	General Acct.	Army
Damp, H.	Grounds & Bldg.	N. G.
Dana, D.	Lighting	Army
Dargis, D.	Machine Shop No. 16	Navy
Dascola, D.	Commutator	Army
*Davenport, G.	Publication Bureau	N. G.
Davignon, J.	Turbine	Army
Davis, E. C.	Controller	Army

Name	Department	Branch of Service
Davis, H.	Swb'd Assembly	N. G.
Davis, K.	Shipping	N. G.
Davis, M. W.	Sec. I Motor	N. G.
Dawson, E. S., Jr.	Research Lab.	O. T. C.
DeFelice, P.	Sec. I Motor	Army
Degenaar, C. B.	Drafting	N. G.
Deichman, K. S.	Foreign	N. R.
Deicke, H. G.	Shipping	Army
Della Rocca, S.	Swb'd Detail	Army
DeLaVergne, L.	Foreign	O. T. C.
Delongchamp, J. J.	Contactor Control	Army
De Mars, P. A.	Test	Army
Dessar, D.	Swb'd Sales	O. T. C.
Deuell, A. R.	Drafting	N. G.
Devevo, T.	Swb'd Polishing	Army
Dewar, F.	Mica	Army
*DeWitt, H. A.	Foreign	Army
Dexter, H. E.	Industrial Control	Army
Dibble, E. B.	Drafting	Army
DiCerbo, G.	Testing Lab.	Army
Dichman, E. W.	Foreign	O. R. C.
Dickenson, W.	Motor	N. G.
Dickie, A.	Test	O. T. C.
Diefendorf, G.	Controller	Navy
Dillon, J. J.	Swb'd Punchings	Army
Dillon, T.	Wire & Cable	N. G.
DiLorenzo		Army
*Dingley, N.	Stand. Lab.	Army
Dolley, H. B.	Employment Bureau	N. G.
Donald, C.	Controller	Army
Donnelly, M.	Sec. I Motor	Navy
Doubler, C. D.	Drafting	O. R. C.
Dowd, P. C.	Railway Equip.	Army
Doyle, J.	Swb'd—Oil Switch	N. G.
Drach, E. W.	Test	Navy
Drake, G. H.	Switchboard	Army
Drazen, J.	Sec. I Motor	N. G.
Drumn, H.	Brush Holder	N. G.
Duble, A. G.	Test	O. R. C.
DuCharme, M. A.	Motor	N. G.
Dufel, A. H.	Apprentice	Army
Dugett, F. X.	Drafting	Army
Duncan, H. J.	Industrial Control	Army
Dunn, G.	Motor	Army
Dunn, G. M.	Sec. I Motor	Army
Dunn, G. N.	Gen. Screw Mach.	Army
Dunn, P. H.	Field Coil Wind.	Army
Dunphy	Shipping	Army
Durette, P. J.	Swb'd Assembly	Army
Durham, C.	Swb'd—Switch	Army
Dyer, H. A.	Research Lab.	O. R. C.
Dyke, C. T.	Industrial Control	Army
Eagel, S.	Punch Press Oper.	Army
Eaton, C. C.	Publication Bureau	Army
Eaton, I. V.	Mica	Army
Edwards, C. B.	Advertising	Marines
Eddy, W.	Stand. Lab.	O. R. C.
Ellis, C. H.	Swb'd Detail	Navy
Ellsworth.	Carpenter	O. R. C.
Ellsworth, L. R.	Motor	Army
Emrick, L. H.	Test	Navy
Erickson, J.	Swb'd Assembly	Army
Ernst, D. F.	Stand. Lab.	Navy
Eshleman, C.	Test	N. G.

*Commissioned Officer. N.G., National Guard. N.M., Naval Militia. N.R., Naval Reserve. O.R.C., Officers' Reserve Corps. O.T.C., Officers' Training Camp.

Name	Department	Branch of Service
Ettinger, L. E.	Drafting	Army
Evans, W. T.	Special Tool Room	Navy
Fairchild, D.	Motor	Army
Fallon, F. J.	Crane	Army
Fallon, G. J.	General Acct.	Army
Farrington, E. O.	Stand. Lab.	N. G.
Farrington, J. K.	Rheostat	N. G.
Farini, G.	Turbine	N. G.
Fasullo, A.	Machine Shop No. 9.	Army
Faulkner, F.	Armature	Army
Fedigan, L.	Shipping	Army
Ferguson, C. S.	Research Lab.	Army
Ferruccio, G.	Motor	Army
Fiala, F.	Armature	Army
Finley, P. T.	Motor	Army
Finnigan, W. J.	Contactor Control.	Army
Fiorillo, J.	Sec. I Motor	Army
Fishbaugh, C.	Wiring Supplies	N. G.
Fitch, J. C.	Swb'd Test	Army
Fitzgerald, W. J.	Drafting	Army
Fiumo, C.	Blacksmith	Army
Flansburg, J.	Rheostat	N. G.
Flicker, C. J.	Sec. I Motor	N. G.
Flood, E. J.	Shipping	Army
Ford, J.	Research Lab.	Army
*Forsberg, P.	Railway Equip.	O. R. C.
Foti, J.	Contactor Control.	Army
Fountain, E.	Rheostat	N. G.
Fountain, F. F.	Swb'd Detail	Army
Fowler, W. K.	Test	O. T. C.
Fox, E. D.		Army
Foy, L. J.	Sec. I Motor	Navy
Foy, W. J.	Rail Bond	Army
Frame, E.	Machine Shop No. 16.	Army
Frame, C. E.	Comm. & Mach.	Army
Franklin, E.	General Acct.	
Frantzman, E.	Armature	Army
Frazer, H. C.	General Acct.	Army
Frazier, G. H.	Production	Army
Frederick, H.	Contactor Control.	Navy
Frisbie, L. R.	Tool Dept. No. 60.	N. G.
Fudowicz, V.	Wiring Supplies	Army
*Fuller, W.	Blacksmith	N. G.
Fullom, E. J.	General Acct.	Army
Fumel, E. D.	Brush Holder	N. M.
Funk, C. J.	Publication Bureau	N. G.
Gagnier, J.	Field Coil Wind.	Army
Gale, H.	Armature	Navy
Gallagher, E.	Armature	Army
Gamble, K. P.	General Acct.	Navy
Garahan, T. F.	Production.	O. T. C.
Gardner, E.	Searchlight	N. G.
Garling, E.	Rheostat	Navy
George, A.	Swb'd Punchings	N. G.
*Gibbes, L.	Receiving	N. G.
Giddings, B.	Switchboard	Army
Gilbert, J. W.	Switchboard	Army
Gillan, J. E.	Controller	N. G.
Gillespie, A.	Machine Shop No. 9	Navy
Gilmore, C. J.	Shipping	Army
Girard, L. E.	Sec. I Motor	Navy
Girrard, A.	Carpenter	N. G.
Gisner, O. G.	Turbine	N. R.
Goetzenberger, R. L.	P. & M. Eng.	Army

Name	Department	Branch of Service
Goggins, H.	Sec. 1 Motor.	Navy
Gorciekie, E.	Swb'd—Switch	Navy
Gosling, T. A.	Sec. 1 Motor.	Navy
Goss, H.	Steam Fitting	Army
Graves, R.	Cost	Navy
Graubait, B.	Controller	Army
Green, A.	Wiring Supplies	Army
Green, J. L.	Test	Navy
Greene, C.	Shipping	Army
Greene, R. E.	Test	Navy
Greenough, C.	Publication Bureau	Army
Gregson, E. J.	Swb'd Sales	British Army
Grehulski, S. T.	Sec. I Motor	Army
Griffin, M. C.	Sect. "E" Bldg. 56	N. G.
Griffin, W. J.	Drafting	N. G.
Grismer, J.	Turbine	Navy
*Grosbeck, E.	Cost	Army
Gross, J. J.	Turbine	Army
Guena, R.	Turbo-Winding	Army
Guzokowski	Swb'd Polishing	Army
Haas, P. A.	Swb'd—Oil Switch	Army
Hadden, G.	Wiring Supplies	Army
Haddy, G. R.	Sec. I Motor	N. G.
Haig, A.	Test	O. R. C.
Haire, J. M.	General Acct.	Army
Halbert, C. T.	Test	Army
Halleck, W.	Shipping	Army
Hallenbeck, R.	Swb'd—Oil Switch	N. G.
Hamilton, E.	Searchlight	N. G.
Hampel, O.	Die & Tool Room	Army
Hann, R. S.	Contactor Control	Navy
Hanson, H.	Switch No. 24	Army
Harbison, H.	Rheostat	N. R.
Harmon, H. M.	Switchboard	Army
Harper, J.	Turbine	Marines
Harris, L. B.	Research Lab.	Army
Harris, M.	Swb'd Assembly	N. G.
Harris, P.	Contactor Control.	N. G.
*Harris, W. C.	Rwy. Motor Engrg.	O. R. C.
Harrison, W. H.	Sec. I Motor	N. G.
Hart, E. H.	Sec. I Motor	Army
Hart, J. E.	Commutator	Army
Hart, H. W.	Turbine	N. G.
*Hart, M. S.	Power & Mining	O. R. C.
Hartman, C. E.	Swb'd Assembly	N. R.
Hartman, H. W.	Research Lab.	Army
Harvey, J. W.	Power & Mining	O. T. C.
Harvey, W. A.	Turbine	Army
Haskuis, A. K.	Solenoid Brake 35	O. T. C.
Hastings, D.	Turbine	Navy
Haubner, C. J.	Motor	Navy
Haupt, W.	Die & Tool Room	N. G.
Haus, J.	Swb'd—Oil Switch	Army
Hauson, R.	Power & Mining	Navy
Haverly, E. H.	General Acct.	Army
Hawkins, C. F.	Drafting	O. R. C.
Heart, H. L.	Test	O. R. C.
Heath, R. D.	Armature	N. G.
Hefferman, J.	Swb'd Detail	Army
Hefner, C. B.	Test	O. T. C.
Heine, H. H.	Test	N. R.
Heitkamp, N.	Shipping	N. G.
Henderson, G. A.	Foreign	Army
Henke, R.	Swb'd—Oil Switch	Army

*Commissioned Officer. N.G., National Guard. N.M., Naval Militia. N.R., Naval Reserve. O.R.C., Officers' Reserve Corps. O.T.C.. Officers' Training Camp.

Name	Department	Branch of Service
Henley, E. K.	Test	Army
Henyan, G. W.	Test	O. T. C.
Herrgesell, E.	Turbine	Army
Herzog, E.	Drafting	N. G.
Hibbard, E. I.	Transportation	Army
Hickey, P. C.	Swb'd—Oil Switch	Army
Hickey, T.	Turbine	Navy
Hidegh, J.	Controller	N. G.
Hiefeaman.	Swb'd Detail	Army
Hield, J. W.	Contactor Control	Navy
Hilderbrand, M. J.	Apprentice	N. G.
Hillard, A. J.	Sec. I Motor	Army
Hillman, C. R.	Crane	Army
Hinkle, A. E.	Test	Navy
Hoehn, G.	Motor	Army
Hoffman, J.	Swb'd Detail	N. R.
Hogan, A.	Drafting	N. G.
Hogan, G. E.	Machine Shop No. 16	Navy
Honor, H.	Commutator	Navy
*Hoose, J. L.	Turbine	O. R. C.
Hopkins, E. O.	Receiving	Army
Hoppe, G. H.	Research Lab.	Army
Hopper, R. W.	Motor	Navy
Horne, R.	Turbine	Navy
Horstman, H.	Shipping	Army
Hortkotte, E. H.	P. & M. Eng.	O. T. C.
Houck, D.	Mica	Army
Howard, M.	Transportation	Navy
Howe, G.	Research Lab.	Army
Howe, W.	Payroll	Army
Howell, V. C.	Motor	Army
Hoyt, H. A.	Test	O. R. C.
Hudson, W. F.	Test	N. R.
Huffmire, F.	Apprentice	Army
Huffmire, F. C.	Rail Bond	Army
Hughes, C. N.	Production	N. R.
Hughes, J. E.	Production	N. G.
Hulse, P.	Searchlight	Army
Hunter, I.	Drafting	N. G.
Hurstman, H.	Shipping	N. G.
Huzzar, F.	Swb'd—Switch	Army
Hyson, W. A.	Sec'l Motor	Marines
Iacussa, P.	Swb'd—Switch	Army
Irish, M. H.	Shipping	N. G.
Ivers, W. F.	Test	O. T. C.
Ives, E. C.	Production	Navy
Iwanski, H. K.	Mica	Army
Jackson, H	Steam Fitting	Army
Jackson, J.	Transportation	Army
Jacoboski, B. J.	General Credit	Army
Jacuessa, P.	Swb'd Assembly	Army
Jahn, E.	Drafting	O. T. C.
Jakoboski, B. J.	General Credit	Army
Jenkins, G.	Swb'd Assembly	Army
Jensen, L. M.	Tool Dept., Bldg. 60	N. G.
*Jewell, W. S., Jr.	Rwy. Motor Engrg.	O. T. C.
Johansen, C.	Armature	N. G.
John, H. M.	Turbine	Army
Johns, R.	Apprentice	N. G.
Johnson, D. C.	Contactor Control	N. R.
Johnson, G.	Steam Fitting	Army
Johnson, J.	Research Lab.	Army
Johnston, R. J.	Illg. Eng. Lab.	Navy
*Jones, A. L., Jr.	Power & Mining	O. R. C.

Name	Department	Branch of Service
Jones, H.	Wiring Supplies	N. R.
Jones, J. A.	Test	O. R. C.
Jones, R.	Rheostat	N. G.
Josephs, L. C.	Rwy. Locomotive	O. R. C.
Joyce, J. E.	Motor	Army
Junken, L. H.	Test	O. T. C.
Jutton, F. L.	Commutator	N. G.
Kankie, Louis	Oil Switch	N.G.
Karborski, V.	Swb'd—Switch	N. G.
Kasper, C. F.	Flow Meter	Army
Kastelberg, L.	Apprentice	Army
Kastelberg, L.	Wiring Supplies	Army
Kaupp, C. O.	Test	O. T. C.
Kazda, F.	Motor	Navy
Keatur, H.	Shipping	Army
Keefe, T.	Swb'd Assembly	N. G.
Keene, A. D	Ind. Control	O. R. C.
Kehrer, P. S.	Turbine	Army
Keift, W.	Swb'd—Switch	Navy
Keiser, D. S.	Test	N. M.
Keith, R. B.	General Acct.	Army
Kelsfant.	Swb'd Punchings	Army
Kelafant, F. M.	Apprentice	N. G.
Kelafant, M. A.	Apprentice	Army
Kelly, A. J.	Armature	Army
Kelly, W. J.	Drafting	Army
Kemp, C. E.	Drafting	Navy
Kennedy, A.	Induction Motor	Army
Kennedy, W. A.	Publication Bureau	Army
Keer, K. J.	Brush Holder	Army
Kerrigan, A. J.	Test	Navy
Keyser, S.	Sec. I Motor	Army
Kieft, A. B.	Transportation	Navy
Kiicciak, A.	Motor	N. G.
Kildare, R.	Research Lab.	Navy
King, H. L. P.	Test	O. R. C.
King, J.	Publication Bureau	Army
Kingsbury, C.	Test	N. G.
Kinlock, E.	Payroll	Army
Kirchner, J.	Cost	N. G.
Kistler, R. E.	Test	N. R.
Kling, G.	Wire & Cable	N. G.
Klocek, J.	Armature	Army
Klotz, F.	Swb'd. Assembly	N. G.
Knight, G. R.	Construction	Army
Knights, P.	Shop Electric	N. R.
Kniociak, A.	Sec. I Motor	Army
Kniskern, L.	Motor	Army
Knowlton, D.	Rheostat	Navy
Koening, S. A.	Test	O. T. C.
Koontz, W. J.	Crane	Army
Kotz, G.	Drafting	N. G.
Koutney, A.	Porcelain	Army
Kovell, J. J.	Rheostat	Navy
Kozak, W.	Armature	Army
Krida, H.	Swb'd Test	N. G.
Kubes, J. F.	Swb'd—Oil Switch	Army
Lackie, H. M.	Punch Press Oper	Army
Lahey, E.	Stock	N. G.
Lamb, H. J.	Lighting	Army
Lambertson, H.	Swb'd—Switch	Army
Lambertson, H.	Swb'd Assembly	Army
Lambertson, H.	Switchboard	Army
Lang, F. W.	Mail Clerk	Navy

*Commissioned Officer. N.G., National Guard. N.M., Naval Militia. N.R., Naval Reserve. O.R.C., Officers' Reserve Corps. O.T.C., Officers' Training Camp.

Name	Department	Branch of Service
Lange, A.	Sec. I Motor	N. G.
Lasher, J.	Screw Mach. Oper.	Navy
Laskey, W. G.	Test	Army
LaTarte, A. J., Jr.	Test	N. G.
Lauder, H. W.	Test	O. T. C.
Law, C.	Switchboard	Navy
Lawyer, C.	Rheostat	N. G.
Lazzi, J.	Sec. I Motor	Army
Le Doux, F. A.	Sec. I Motor	N. G.
Lee, A.	Research Lab.	Army
Lee, F. J.	Sec. I Motor	Army
Le Gasse, W.	Payroll	Army
Leonard, H. R.	Supply	O. R. C.
Lese, S.	Motor	Army
Levens, H.	Drafting	N. G.
Lewis, H. M.	Research Lab.	Army
Lichtenburg, C.	Swb'd. Engineering	O.T.C.
Lincoln, L. B.	Contactor Control.	Army
Lisiscki, S.	Ins. & Car. Brush	N. G.
Little, J.	Armature	Navy
Loiselle, A.	Gen. Screw Mach.	N. G.
Lonergan, J. B.	Shipping	Navy
Lorenzo, V,	Switchboard	Army
Losee, E. B.	Sec. I Motor	N. R.
Loucks, H.	Order & Stock	Army
Loyche, T.	Steam Fitting	Army
Lukasewitz, C.	Swb'd—Switch.	Navy
Lund, C.	Sec. I Motor	Navy
Lundberg, E.	Machine Shop No. 9.	Navy
Lupkin, J. S.	Sec. I Motor	Army
Lupold, M. B.	Test	O. R. C.
Lux, H. E.	Test	O. T. C.
McAttee, F. R.	Stand. Lab.	Army
McCann, J.	Armature	Army
McCarthy, J. F.	Motor	N. G.
McCullough, M.	Swb'd Detail	Army
McDonald, F.	Turbo-Winding	Army
McDonald, G.	Research Lab.	Army
McDonald, H.	Sec. I Motor	Army
McDonald, J. T.	Turbine	Army
McDonald, R.	Test	N. R.
McFadyen, G. L.	Swb'd. Sales	Army
McGinnis, J.	Swb'd—Switch.	Army
McGovern, A. J.	Drafting	N. G.
McGovern, L. J.	Turbine	N. G.
McGowan, H.	Rheostat	Marines
McInturff, R. H.	Test	Army
McKeown, C. V.	Sec. I Motor	Army
McLaughlin, V.	Mica	Army
McMaster, J. A.	Swb'd—Oil Switch	N. G.
McOleer, E. C.	Switchboard	Army
McPartlon, T. J.	Draftsman	Army
McRae, C.	Rwy. Commercial	Army
MacFadyen, G. L.	Swb'd Sales	Army
Mabie, D.	Sec. I Motor	N. G.
Madden, J.	Swb'd Detail	Navy
Madigan, J.	Steam Fitting	Navy
Madison, E. C.	Turbine	N. R.
Madison, G.	Machine Shop No. 10.	N. R.
Magadieu, W. J.	Armature	N. G.
Mahan, H. E.	Illg. Eng. Lab.	O. T. C.
Male, H.	Commutator	Navy
Mallia, W. M.	Gen. Screw Mach.	Army
Malone, F.. A.	Swb'd—Oil Switch	N. G.

Name	Department	Branch of Service
Man, W. B. C.	Turbine	Army
Manderson, E.	Turbine	Army
Mann, W. C.	Power & Mining	Army
Manns, C.	Grounds & Bldg.	Army
Marble, G.	Insulator	Army
Marciniak, F.	Punch Press Oper.	Army
Marconi, T.	Gen. Screw Mach.	Army
Mariano, C.	Swb'd—Oil Switch	Army
Marlow, J.	Punch Press Oper.	Navy
Martin, D. S.	Publication Bureau	Brit. Army
Miller, W. J.	Production	Army
Millham, R.	Apprentice	Army
Mingonet, A. J.	Swb'd. Assembly	Army
Mitchell, F.	Motor	N. G.
Mitchell, G. W.	General Acct.	N. G.
Mitchell, S. L.	Shipping	Army
Monroe, H. B.	Mfg. General	Army
Monzo, P.	Blacksmith	Army
Moore, Thos. R.	Gen. Screw Mach.	N. G.
Moot, R. D.	Law	O. T. C.
Moran, T.	Apprentice	Navy
Moras, J. C.	Rwy. Commercial	Army
Morgan, G. R.	Test	O. R. C.
Morgan, H. D.	Swb'd Punchings	Army
Morgan, J. E. P.	Collection	British Army
Morgan, W. L.	Apprentice	Navy
Morgan, W. L.	Sec. I Motor	N. G.
Morris, G. W.	Power & Mining	O. T. C.
Mortenson, L.	Steam Fitting	Army
Mott, W. C.	Arma. Assembler	Army
Mudge, W. A.	Research Lab.	O. T. C.
Mulford, A.	Foreign	O. T. C.
Murphy, C. F.	Swb'd Test	Army
Murphy, H.	Turbine	Army
Murray, J.	Swb'd Assembly	Army
Martin, W. A.	Sec. I Motor	Navy
Martinelli, G.	Grounds & Bldg.	Army
Massey, F.	Turbine	Army
Matheson, G.	Steam Fitting	Army
Mathias, H.	Transportation	Navy
Maxson, E.	Swb'd Assembly	N. G.
Maxwell, J. J.	Turbine	N. G.
Mayer, W. F.	Drafting	N. G.
Mazzuccio, J.	Armature	N. G.
Meaney, R.	Shipping	Army
Meaton, E.	General Acct.	Army
Memelo, J.	Swb'd—Switch.	N. G.
Merkel, F. W.	Test	Army
Merrihew, R. W.	Motor	Army
Messaro, M.	Turbine	Army
Meyers, H.	Searchlight	Navy
Michael, H. S.	Power & Mining	Army
Migonet, A.	Swb'd Assembly	Army
Miller, E.	Swb'd—Switch.	Navy
Miller, G.	Swb'd Detail	N. G.
Miller, G. W.	Die & Tool Room	Army
Miller, H. F.	Turbine	N. G.
Miller, J.	Motor	Army
Miller, J. E.	Field Coil Winding	Army
Miller, W.	Swb'd Assembly	N. G.
Murray, R.	Grounds & Bldg.	N. G.
Myers, R. F.	Shipping	Army
Myres, N.	Painter	Army
Myrick, E. B.	Test	O. R. C.

*Commissioned Officer. N.G., National Guard. N.M., Naval Militia. N.R., Naval Reserve. O.R.C., Officers' Reserve Corps. O.T.C., Officers' Training Camp.

Name	Department	Branch of Service
Nealon, J.	Armature	Army
Neander, H.	Turbine	N. G.
Neilsen, C.	Crane Oper.	N. G.
Nekola, T., Jr.	Bench Hand	N. G.
Nelson, J.	Commutator	Army
Nerling, A.	Commutator	N. G.
Neville, C. B.	Apprentice	Navy
Nielson, O. E.	Switchboard	Army
Nightingale, R.	Swb'd—Switch	Army
Nold, F. M.	Production	N. G.
Nolte, H. C.	Die & Tool	Navy
Norton, G.	Swb'd. Detail	Army
Noxkowiak, A.	Armature	Army
Nunn, P. H.	Advertising	Army
Oatting, W. H.	Publicity Clerk	N. G.
Oatting, W. H., Jr.	Apprentice	N. G.
Oatting, W. H.	Machine Shop No. 16	N. G.
O'Brien, J.	Gen. Screw Mach.	N. G.
O'Connor.	Research Lab.	Army
O'Connor, J.	Armature	Army
O'Connor, J.	Millwright	Navy
O'Connor, T.	Sec. I Motor	N. G.
O'Connor, W.	Drafting	N. G.
O'Connor, W. F.	Apprentice	N. G.
Odell, J. B.	Publication Bureau	Army
Oneal, L. E.	Test	N. R.
Onion, W. E.	Sec. I Motor	N. G.
Ormand, J.	Swb'd Detail	N. G.
Orminski, B.	Punch Press Oper.	N. G.
O'Rourke, C. D.	Armature	Army
Ossing, E. J.	Brush Holder	Army
Osterberg, O. L.	Drafting	N. G.
Osterlitz, H.	Swb'd—Oil Switch	Army
Ottman, F. L.	Research Lab.	Army
Pace, L.	Swb'd—Oil Switch	N. G.
Packer, J.	Turbine	Army
Page, A. B.	Research Lab.	Army
Paiewski	Porcelain	N. G.
Palancez, J.	Rheostat	N. G.
Palmer, M.	Turbine	Army
Palmer, W. W.	Test	Navy
Palmieri, Jos.	Sec. I Motor	N. G.
Pangburn, E. C.	Foreign	N. G.
Panquay, L.	Grounds & Bldg.	N. G.
Papazian, N.	Draftsman	Army
Parkhurst	Research Lab.	Army
Parkhurst, E.	Apprentice	Navy
Parks, E.	Punch Press Oper.	Army
Pateigo, C.	Transportation	Army
Patnode, A.	Rheostat	N. G.
Pattee, I.	Die & Tool Room	Army
Payne, V. J.	Shipping	N. G.
Peck, D.	Turbine	Navy
Pellerin, A.	Swb'd—Switch	N. G.
Penkoske, J. R.	Rail Bond	Army
Penney, F. H.	Industrial Control	O. T. C.
Penrose, R.	Blacksmith	Navy
Pentavalle, N.	Controller	Navy
Pepper, E.	Production	N. G.
Perkins, A. L.	Switchboard	Army
Peterson, P. L. O.	Controller	Navy
Petrica, L.	Laborer	Army
Petrol, M.	Punch Press Oper.	Navy
Phiffer, C.	Swb'd—Oil Switch	N. G.
Pierpont, N. M.	Swb'd Inspection	N. G.

Name	Department	Branch of Service
Pohl, W. J.	Swb'd—Oil Switch	Army
*Pollock, R.	Rheostat	O. R. C.
Polsinello	Punch Press Oper.	Army
Popky, C. H.	Test	O. R. C.
Potter, C. C.	Drafting	N. G.
Powe, W. C.	Test	Navy
Powell, L. C.	General Credit	N. G.
Powell, S. F.	Field Winder	Army
Pratt, J. W.	Swb'd—Oil Switch	N. G.
Prior, J.	Punch Press Oper.	Army
Pritchard, L. W.	Gen. Screw Mach.	Navy
Prock, S.	Swb'd—Switch	Army
Provoss, I.	Steam Fitting	Army
Puderbaugh, E. T.	General Acct.	Army
Putnam, G. H.	General Acct.	Navy
Pyle, C. W.	Test	O. R. C.
Quay, W.	Swb'd No. 24	Army
Raemer, J. J.	Turbine	Navy
Raffele, S.	Turbine	Army
Ralph, C. J.	Research Lab.	Army
Ralph, F. C.	Production	O. T. C.
Ramsey, G.	Turbine	N. G.
Randall, P. M.	Test	O. T. C.
Randall, W. H.	Draftsman	Army
Rankin, L. C.	Miller Oper.	Army
Razven, S.	Swb'd Polishing	Army
Redmond, J.	Insulator	Army
Rehm, E. R.	Drafting	Army
Reilley, F. K.	Stand. Lab.	Army
Reinhart, G.	Varnish & Japan	N. G.
Reinhart, H. M.	Shop Electric	Navy
Reittenger, S., Jr.	Tinsmith	N. G.
Renaud, C.	Research Lab.	Army
Renfro, C. H.	Test	O. R. C.
Renwick, T.	Turbine	Army
Renze, P.	Armature	Army
Rextrew, H.	Production	N. G.
Rhodes, T. W.	Swb'd. Sales	Army
Riccio, F.	Swb'd—Switch	Navy
Rice, H. J.	Power & Mining	O. T. C.
Richter, R. O.	Mica	Army
Rideldoffer, W. A.	Test	O. T. C.
Rider, M. G.	Turbine	Army
Ridings, F.	Turbine	Navy
Rifenbark, G. E.	Drafting	N. G.
Rilday, M. P.	Shipping	Army
Riley, H. J.	Motor	Navy
Riley, J. A.	Crane & Elev.	Army
Rimz, P.	Porcelain	Army
Ritter, R.	Research Lab.	Army
Roberts	Rheostat	Navy
Roberts, C.	Commutator	Army
Robinson, W. C.	Swb'd—Switch	N. G.
Rogers, A.	Research Lab.	Army
Rogers, J.	Drafting	N. G.
Rogers, M.	Contactor Control	N. G.
Rollins, R. H.	Production	Army
Romano, T.	Punch Press Oper.	Navy
Ronoakowski, L.	Armature	Army
Rooney, W. T.	Cost	Army
Roscorla, R.	Turbine	N. G.
Rosecrans, H. E.	Collection	Marines
Rossi, D.	Turbine	N. G.
Rossi, J.	Wire & Cable	N. G.
Roth, E. R.	Illg. Eng. Lab.	Army

*Commissioned Officer. N.G., National Guard. N.M., Naval Militia. N.R., Naval Reserve. O.R.C., Officers' Reserve Corps. O.T.C., Officers' Training Camp.

NAME	DEPARTMENT	BRANCH OF SERVICE
Rothmyer, H.	Turbine	Army
Rounds, E. W.	Test	Army
Rowe, L. L.	Motor	Army
Ryan, J.	Swb'd Detail	N. G.
Ryan, J. M.	Shipping	Army
Saaf, C.	Swb'd Assembly	Army
Salmon, C.	Rheostat	N. G.
Sams, J. A.	Stand. Lab.	Army
Sanborn, R. P.	Power & Mining	N. R.
Sandquist, H.	Mica	Army
Sankowski, W.	Wiring Supplies	Army
Sauter, L.	Swbd. Assembly	Army
Schafer, R.	Armature	Navy
Schaffer, P.	Swb'd—Oil Switch	Army
Schaffer, P.	Shop Electric	Army
Schaidt, F.	Swb'd Assembly	N. G.
Schaufelberger, E.	Swb'd Assembly	N. G.
Scheffer, R. E.	Test	O. T. C.
Schell, A.	Test	N. G.
Scheppach, M. A.	Test	O. T. C.
Schermerhorn, C. F.	Motor	Navy
Schermerhorn, I.	Turbine	Navy
Schermerhorn, W.	Rheostat	N. G.
Schilling, F. F.	Illg. Eng. Lab.	O. T. C.
Schmich, J. E.	Test	Army
Schnitzlein, F.	Motor	Army
Schoonmaker, W. F.	Publication Bureau	N. G.
Schoufler, F.	Screw Mach.	Army
Schuenberg, G. G.	Test	Army
Schult, W. F.	Shipping	N. G.
Scott, Chas. E.	Motor	Army
Scott, J. E.	Ind. Motor Engr.	O. T. C.
Scott, R. J.	Supply	O. T. C.
Searles, W.	Rheostat	N. G.
Seckman, J. R.	Test	Navy
Seeds, E. C.	Test	N. G.
Seekman, J. R.	Foreign	N. R.
Selke, O.	Gen Screw Mach.	N. G.
Sellers, J. E.	Armature	Army
Semerad, J. V.	Sec. I Motor	O. T. C.
Senior, F.	Swb'd Detail	Army
Senior, F. E.	Sen. Dr. Press	Army
Service, J. H.	Test	Army
Seward, L. E.	Production	Army
Shaffer, M.	Research Lab.	Navy
Shannon, W.	Rheostat	Army
Shaw, C. B.	Purchasing	Army
Shell, A.	Wiring Supplies	N. G.
Shephard, M. A.	Induc. Motor Engr.	Army
Sheridan, W.	Steam Fitting	Army
Sherman, R. H.	Apprentice	Army
Sherwood, A. W.	Test	O. T. C.
Shiely, H. J.	Sec. I Motor	N. G.
Shirley, A. A.	Industrial Control	Army
Shriver, H. D.	Test	O. R. C.
Siegel, F. C.	General Acct.	N. G.
Simmons, R.	Crane	Navy
Simone, S.	Sec. I Motor	Army
Sindy, J.	Punch Press Oper.	Army
Siska, Jos.	Motor	Army
Sitterly, O.	Apprentice	Navy
Skoda, J.	Cabinet Shop	Navy
Skolka, J.	Supply	Army
Skolka, K.	Wiring Supplies	Army
Slater, F. D.	Apprentice	Army
Slocum, A.	Insulator	N. G.
Small, R.	Wiring Supplies	N. R.
Smith, L. W.	Swb'd. Sales	Army
Smith, B. D.	Test	Army
Smith, C.	Rheostat	N. G.
Smith, E. A.	Research Lab.	Army
Smith, E. J.	Turbine	Navy
Smith, E. N.	Sec. I Motor	Army
Smith, F. S.	Piece Rate	Army
Smith, J. D.	General Acct.	N. G.
Smith, W. W.	Motor	Army
Smock, H. E.	Test	O. T. C.
Snell, H.	Receiving	Army
Snow, A. T.	Test	Navy
Snyder, C. F.	Testing Lab.	Army
Synder, M. E.	Swb'd—Oil Switch	Army
Synder, W. J.	Wire & Cable	N. R.
Sommerman, G. H.	Apprentice	Navy
Sommerman, G.	Tool Dept No. 60	Navy
Sonn, L.	Rheostat	Navy
Sorensedn, B. N.	Construction	Army
Sorgeus, W.	Stand. Lab.	Army
Spoor, B.	Swb'd—Oil Switch	N. G.
Sprigg, L. R.	Motor	Army
Spurck, J. S.	Swb'd Sales	N. G.
Squillace, D.	Sec. I Motor	Army
Squires, L.	Drafting	Army
Stacy, T. M.	Piece Rate	Navy
Stanford, J. C.	Apprentice	Army
Steiner, P.	Sec. I Motor	N. R.
Stephenson, D.	Swb'd Assembly	Army
Stephenson, W.	Apprentice	N. G.
Stephenson, W.	Searchlight	N. G.
Stevens, B.	Sec. I Motor	Navy
Stevenson, A. R.	Research Lab.	Army
Stiles, H.	Publication Bureau	Army
St. John, O.	Tinsmith	N. G.
Stoddard, S.	Steam Fitting	N. G.
Stone, R. E.	Publication Bureau	Navy
Stote, G.	Sec. I Motor	Army
Strickland, J. J.	Test	Army
Strongnell, J. G.	Shipping	N. G.
Stroops, B.	Controller	Navy
Summers, C.	Swb'd—Oil Switch	Army
Sutcliffe, J.	Drafting	N. G.
Sutherland, H. M.	Power & Mining	Army
Sutton, J. E.	Motor	N. G.
Swain, E. H.	Test	N. R.
Swanker, W.	Shipping	Army
Swanson, W. A.	Cost	O. T. C.
Swartz, H.	Rheostat	Navy
Swensen, L. N.	Motor	Navy
Swiegart, G. J.	Works Billing	Army
Szarowucz, F.	Crane	Army
Talbot, G. E.	Armature	N. G.
Taylor, A.	Piece Rate	Army
Taylor, C. W.	Test	N. G.
Taylor, N.	Test	Army
Taylor, W. C.	Test	Navy
Tazzi, J.	Motor	N. G.
Telfer, G. R.	Construction	Army
Terk, G. A.	Power & Mining	Navy
Tetrault, J. M.	Motor	Army
Thiebaud, M.	Tool Dept. No. 60	Army
Thibodeau, A.	Switch No. 24	Army

*Commissioned Officer. N.G., National Guard. N.M., Naval Militia. N.R., Naval Reserve. O R.C., Officers' Reserve Corps. O.T.C., Officers' Training Camp.

Name	Department	Branch of Service
Thomas, O.	Tool Dept. No. 60	Army
Thompson, W.	Armature	N. G.
Towle, J.	Wiring Supplies	Army
Travis, A. G.	Motor	Army
Tressler, Q. D.	Apprentice	Navy
Trojakowski, E.	Drafting	N. G.
Troy, R.	Supply	Army
Truax, H.	Shipping	N. R.
Trudeau, L.	Stand. Lab.	Navy
Tryon, F. E.	Preliminary Test	Army
Tryson, F.	Motor	Army
Tulio, N.	Motor	Navy
Turnbull, A. M.	Shipping	Army
Turner, C. H.	Section "A"	Army
Turner, F. S.	Switchboard	Army
Turner, J. L.	Contactor Control	Army
Turpin, H. J.	Drafting	Army
Turpin, J. J.	Contactor Control	Army
Underwood, F. J.	Test	Army
Underwood, J. G.	Drafting	Army
Ukhoff, L. S.	Research Lab.	Army
Uppleby, J.	Wiring Supplies	N. G.
Urbano, V.	Motor	N. G.
Urys, J.	Punch Press Oper.	Army
Utman, F.	Searchlight	Army
Van Auken, J. W.	Sec. I Motor	Army
Van Bramer, P.	Motor	N. R.
Van Buren, F.	Armature	Army
Van Husen, L.	Rheostat	N. G.
Van Laak, W. F.	Contactor Control	Army
Van Natten, W.	Carpenter	N. G.
VanOstenburgge, H.	Controller	N. G.
Van Patten, W. J.	Armature	Army
Van Sothen, C. E. H.	P. & M. Eng.	Army
Van Voast, S.	Motor	N. R.
Van Voorhis, F.	Test	Navy
Van Vorst, P. L.	Apprentice	Army
Van Wormer, W.	Wire & Cable	Army
Vaughn, G. W.	Test	Navy
Vedder, H. V.	Test	Navy
Vegelahn, F.	Coat	Navy
Vernon, G. M.	Die & Tool	Navy
Verwiebe, H. G.	Production	N. G.
Viall, R.	Sec. I Motor	N. G.
Vincent, D.	Turbine	Army
Volk, G.	Contactor Control	Navy
Vollmer, C.	Turbine	N. G.
Voris, E.	Swb'd—Oil Switch	Army
Vrooman, H.	Screw Mach.	N. G.
Walker, C. A.	Test	Army
Wallace, J. W.	General Acct.	N. G.
Walsh, J. C.	Construction	Army
Walters, H.	Sec. I Motor	Army
Walz, C. D.	Power Station	N. R.
Ward, B. E.	Lighting	N. G.
Ward, R.	Contactor Control	Army
Warner, R. J.	Flow Meter	Navy
Warren, C. L.	Test	Navy
Wasson, G. C.	Production	N. G.
Waterhouse, G.	Swb'd—Switch	Army
Waters, H.	Coil Varnisher	Army
Watson, J.	Armature	Navy
Watts, G.	Wiring Supplies	N. R.
Way, A.	Research Lab.	Army
Weaver, A.	Test	O. T. C.

Name	Department	Branch of Service
Weinhold, H.	Armature	Army
Weir, J.	Publication Bureau	N. G.
Welch, N. J.	General Acct.	Army
Wells, L.	Insul. & Car. Brush	N. G.
Wert, I.	Stand. Lab.	Army
Werth, J. R.	Lighting	O. R. C.
West, A. K.	Stand. Lab.	Army
Westover, W.	Test	Army
White, A.	Transportation	Army
White, B.	Rheostat	N. G.
White, J.	Research Lab.	Army
White, L. F.	Turbine	N. G.
White, T. E.	General Acct.	N. G.
Whitmyre, C. F.	Sec. I Motor	Army
Whitmyre, R.	Armature	Army
Whyland, C.	Armature	Army
Wiazkniski, B.	Swb'd Polishing	Army
Wickham, R.	Rheostat	N. R.
Wilbur, H.	Publication Bureau	Army
Wilkie, C.	Steam Fitting	Army
Wilkins, J. A.	Drafting	Navy
Williams, A.	Armature	N. G.
Williams, A. F.	Drafting	N. G.
Williams, C. B.	Test	Army
Williams, C. B.	Rail Bond	N. G.
Williams, F.	Punch Press Oper.	Army
Williams, F. E.	Sec. I Motor	Navy
Williams, F. E.	Test	Army
Williams, H.	Industrial Control	Army
Williams, R.	Flow Meter	N. R.
Williams, W.	Machine Shop No. 9	Army
Willoschat, W. T.	Foreign	N. G.
Wilson, L. M.	Drafting	N. G.
Wilson, O. E.	Swb'd—Oil Switch	Army
Wilson, W.	Switchboard	N. G.
Wiman, L. E.	A-C. Eng.	O. T. C.
Winckler, C.	Shop Electric	Army
Winslow, F. E.	Power & Mining	Army
Winters, W. B.	Sec. I Motor	N. G.
Witt, O.	Die & Tool	Army
Wolff, C. J.	Motor	Army
Worthington, H.	Test	O. R. C.
Wood, E.	Contactor Control	Navy
Wood, M. L.	Motor	Army
Woodcock, R.	Grounds & Bldg.	Navy
Wolff, C. J.	Sec. I Motor	Army
Worthington, G. R.	Punch Press Oper.	Army
Wrazkowski, B.	Swb'd. Polishing	Army
Wright, C.	Steam Fitting	N. G.
Wright, G. W.	Swb'd—Switch	N. G.
Wright, W. F.	Test	O. R. C.
Wroblewski, S.	Comp. Coil Winder	Army
Wynkoop, F. J.	Switchboard	Army
Wysoniski, F.	Rheostat	Army
Yager, F.	Wire & Cable	Marines
Yetto, C. W.	Swb'd—Switch	N. G.
Young, E. G.	Sec. I Motor	O. T. C.
Yovits, I.	Motor	Army
Yude, J. J.	Foreign	Army
Zant, L. M.	Test	Army
Zeh, E.	Stand. Lab.	Army
Zeigler, J.	Swb'd Detail	N. G.
Zimmer, H.	Switchboard	O. R. C.
Zway, W.	Swb'd. Switch	Army

*Commissioned Officer. N.G., National Guard. N.M., Naval Militia. N.R., Naval Reserve. O.R.C., Officers' Reserve Corps. O.T.C., Officers' Training Camp.

LYNN WORKS

Name	Occupation	Branch of Service
Anderson, C. J.	Drill Hand	N. G.
Anderson, C. H.	Arm. Winder	Army
Anderson, C. W.	Machine Hand	Navy
Andrews, J.	Clerk	N. G.
Arguet, E. C.	Machinist	Army
Aucella, P.	Repair Man	Army
Augustine, P.	Craneman	N. G.
Ayles, W. R.	Field Winder	Army
Babine, J.	Buffer Plaster	N. G.
Bain, A. C.	Apprentice	N. M.
Blarney, F. O.	Bench Worker	Navy
Balfour, N. W.	Apprentice	Army
Ballard, D. W.	Assembler	Navy
Barbour, J. J.	Clerk	N. G.
Barden, F. J.	Draftsman	Navy
Barnes, J. H.	Draftsman	Army
Barteaul, N. W.	Clerk	N. G.
Bartlett, L. S.		N. G.
Baston, E. H.	Meter Worker	N. G.
Baylor, S. H.	Apprentice	N. M.
Bently, A. N.	Apprentice	N. R.
Bernard, H.	Clerk	Army
Bisset, C. E.	Set-up Man	Army
Black, O. M.	Tester	N. R.
Blake, C.	Apprentice	Army
Blake, G.	Machinist	Army
Blinn, T. H.	Lining Job	Army
Blinn, W.	Clerk	Navy
Booth, R. I.	Specialist	Army
Borjeson, A.	Brazing	Army
Borkoski, H	Drill Hand	Army
Boud, S.	Machinist	Army
Brady, T. P.	Clerk	N. G.
Briggs, R. P.	Fitter	N. G.
Britton, C. W.	Clerk	Navy
Brown, C.	Inspector	Army
Brown, C. A.	Inspector	Army
Brown, H. A.	Clerk	Army
Brown, H. L.	Clerk	Army
Brown, R. E.	Assembler	Army
Broyderick, F. H.	Mach. Hand	Navy
Buchanan, M.	Oiler	Army
Burkart, G.	Tester	N. R.
Burke, G. E.	Repairs	N. G.
Burrill, G. F.	Assembler	Army
Bursey, C. G	Apprentice	Army
Butler, C. F.		Army
Butler, E.	Drafting	Army
Buttimer, G.	Clerk	Army
Bruni, J.	Operator	N. M.
Bynne, T. C. F.	Milling Mach.	Army
Callahan, D. F.	Stockkeeper	Army
Callahan, J. E.	Assembler	Army
Cameron, R. B.	Clerk	N. G.
Campbell, H. J.	Carpenter	N. G.
Campbell, W. H.	Hand Reamer	Army
Cann, G. R.	Watchman	Navy
Carr, H. V.	Chauffeur	Army
Carroll, M. F.	Chauffeur	Army
Carter, H.	Clerk	Navy
Carter, J. E.		Army
Carter, R. H.	Machinist	N. R.
Chapman, J.	Meter Worker	N. G.
Chisholm, E. D.	Tester	N. M.
Cilogey, J. G.	Press Hand	Navy
Clark, R. W.	Drill Hand	Army
Clarke, T.	Crane Operator	Army
Clements, H. B.	Apprentice	N. M.
Cloon, E. C.	Machinist	Army
Cochrane, D. G.	Apprentice	N. M.
Cody, C. A.	Coremaker	Army
Collins, J. J.	Guard	Army
Condon, W.	Assembler	Army
Cooper, C. J.	Assembler	Army
Cooper, P. J.	Inspector	Army
Corliss, F. W.		Army
Cote, G. O.	Cook	Army
Coughlin, J.	Watchman	Army
Coughlin, W. E.	Cleaner	Army
Couleman, H.	Screw Mach. Oper.	N. G.
Counihan, D. T.	Apprentice	Navy
Coulter, F. R.	Apprentice	N. M.
Cousson, W.	Tester	Army
Cox, E. H	Clerk	Army
Croft, C. R.	Lathe Hand	Army
Crosby, J.	Machinist	Army
Cuffe, P. J., Jr.	Machine Hand	N. G.
Cunningham, L.	Tester	N. G.
Curdo, L. A.		Army
Currack, L. H.	Machinist	Army
Curran, T., Jr.	Clerk	N. G.
Currie, C. S.	Apprentice	N. G.
Currie, C. S.		Army
Currie, E. L.	Winder	N. G.
Curtis, H. B.	Shear Hand	Army
Davis, J. J.	Machine Hand	Army
Davis, R. R.	Grinder	N. G.
Day, F. L.	Bucket Work	Army
De Angelis, E.	Transportation	Army
De Mont, T. E.	Checker	N. R.
Des Maisons, O. A.	Draftsman	Army
Deignan, T. J.	Machinist	Navy
Demanso, O.	Press Hand	N. R.
Dennis, L. F.	Drill Hand	Army
Dineen, J. J. M.	Hand Worker	Army
Dolan, F. T.	Bench Worker	Army
Donlan, T.	Mach. Worker	Army
Donnelley, J. B.	Clerk	Army
Donnelly, P.	Inspector	Army
Donohue, F. C. J	Screw Mach. Opr.	Army
Dolman, H.	Forming Coils	N. R.
Doucetter, W. J.	Crane Man	Army
Doyle, J. J., Jr.	Clerk	Army
DuCett, W. F.	Apprentice	Navy
Dudley, R. A.	Lathe Hand	Army
Dukeshire, W.E., Jr.	Apprentice	Army
Dunn, W. F.	Bench Hand	N. G.
Durgin, T. A.	Cutter Grinding	Army
Durnell, F. E.	Gear Cutter	Army
Eastman, C. E.		Army
Edwards, M. R.	Tracer	N. G.
Eliott, H. C.	Bench Hand	N. G.

N.G., National Guard. N.M., Naval Militia. N.R., Naval Reserve. O.R.C., Officers' Reserve Corps. O.T.C., Officers' Training Camp.

Name	Occupation	Branch of Service
Eliott, J. E.	Jewel Work	N. G.
Evans, R. B.	Repair Hand	Army
Evans, L. E.	Helper	Army
Evans, R. H.	Clerk	Army
Fairbanks, V. G.	Blueprinting	Army
Farley, E. B.	Lathe Hand	Navy
Farrell, J. T.	Guard	Army
Faulkner, K.	Tester	N. G.
Fenning, R.	Clerk	N. G.
Finn, G.	Clerk	Army
Fitzgerald, J. B.	Inspector	N. G.
Fitzgerald, J. P.	Screw Mach. Oper.	Army
Fitzgerald, R. M.	Shaft Work	Navy
Fletcher, F.	Clerk	Army
Floyd, C. L.	Helper	N. G.
Foley, J.	Inspector	Army
Ford, F.	Roll Mach. Oper.	Army
Ford, H. G.	Testing	N. M.
Foss, E. A.	Tool Maker	N. M.
Fredeen, A. R.	Mach. Work	Navy
Fullman, L. J	Apprentice	Army
Fyles, T. W.	Clerk	Canadian Army
Gallant, W. C.	Field Winder	N. R.
Gardiner, H. C.	Iron Worker	Army
Garvey, G. H.	Tester	Army
Garvin, J.	Carpenter	N. R.
Gass, Wm. C.	Turret Lathe	Army
Gates, D. D.	Screw Mach.	Navy
Gerber, A.	Packer	Army
Getchel, I. E.	Draftsman	N. M.
Gibbons, W. D.	Apprentice	Army
Gilbert, A.	Bench	N. G.
Gilkey, A. M.	Tester	Navy
Gillilunot, C. E.	Clerk	N. G.
Gilman, M.	Lathe	Navy
Gilman, M.	Machine Hand	N. R.
Gladu, C. E.	Apprentice	Army
Glode, A. G.	Inspector	Army
Godfrey, L. S.	Clerk	N. G.
Goloski, W.	Boxmaker	Army
Goodman, J. R.		Army
Goodrich, R. E.	Apprentice	Army
Gordan, D.	Die Maker	Army
Gosselin, F.	Motor Assem.	Army
Grady, W.	Checker	Army
Graham, H. B.	Screw Mach. Oper.	Army
Granger, W.	Bench	Army
Graves, R. P.	Clerk	
Gray, H. B.	Tester	Army
Gray, L.	Weigher	Army
Green, C. W.	Lathe Hand	Army
Green, L. G.	Grad. App.	Army
Grey, C.	Machinist	Army
Groham, T.	Cleaner	Army
Guay, W. J.	Machinist	Navy
Guion, O. H., Jr.	Tester	N. G.
Gunderman, M.	Brazing Wire	N. R.
Guppy, H.	Bucket Work	Army
Gustafson, N. R.	Tool Maker	Army
Hackett, J.	Lathe Hand	Army
Hackett, J.	Lathe Hand	Army
Haggerty, J.	Lathe	Army
Hague, R.	Coil Former	N. R.
Hamann, C.	Tester	Army

Name	Occupation	Branch of Service
Hanlon, P.	Machinist	Army
Hanscom, J.	Grinder	Army
Harriman, P. C.	Apprentice	N. M.
Harrington, A. T.	Apprentice	N. G.
Harrington, F.	Clerk	N. G.
Harrington, J.	Inspector	Army
Harris, P.	Draftsman	N. G.
Hart, L. A.	Iron Worker	Navy
Hastings, R.	Clerk	Army
Hays, L. E.	Electrician	Army
Healey, C. D.	Boring Mill Oper.	Army
Henderson, A.	Typewriter Repairer	Army
Hennigan, W.	Bench	N. G.
Heraty, P.	Crane Man	Army
Higgins, G.	Bench Hand	Army
Higgings, J.	Drill Hand	Navy
Hill, E.	Lay-Out	Army
Hill, H.	Specialist	N. G.
Hilyard, A.	Inspector	Army
Hodson, R.	Clerk	N. M.
Hobbs, A. C.	Painter	Army
Hobson, H. D.	Apprentice	N. G.
Hodder, A.	Crane Hand	Army
Hoey, P.	Machinist	Army
Hodgon, W.	Armature Winder	Army
Holmes, A.	Apprentice	Army
Holt, R.	Assembler	Army
Honor, H.	Carpenter	Navy
Hood, O. W.	Inspector	N. G.
Hopwood, J.	Packer	Navy
Horgan, J.	Drill	Army
Hosker, J.	Checker	Army
Howard, W. F.	Drill	N. R.
Huback, C.	Tester	Army
Hubbard, W.	Assembler	Army
Hutchinson, L.	Tester	N. R.
Hutchings, F. A.	Tester	O. R. C.
Isbister, W.	Apprentice	N. R.
Jackson, A.	Wireman's Helper	N. G.
Jacobs, J.	Bench Hand	N. G.
Jarvis, J. R.	Draftsman	N. G.
Gill, J.	Office Boy	Navy
Jenkins, W. W.	Winding	Army
Johnson, G. R.	Die Maker	N. G
Johnson, S.	Screw Mach. Oper.	Army
Johnson, W.	Steam Fitter	N. G.
John, E.	Repair Man	N. G.
Jones, E.	Machinist	N. R.
Jones, H. R.	Drill Hand	N. G.
Jones, R.	Bench	N. G.
Johnson, G.	Carpenter	Navy
Jordan, C.	Crane Man	Canadian Army
Jordan, F.	Leading Hand	N. R.
Jordan, G.	Laborer	N. G.
Joy, S. O.	Apprentice	Army
Kadra, W. M.	Repair Hand	N. R.
Kalmen, W.	Machine Hand	Army
Karlson, R. F.	Machine Hand	Navy
Keating, H. A.	Misc. Work	N. G.
Keefe, A.	Inspector	Army
Keefe, H. A.	Inspector	Army
Kelley, E.	Tool Maker	Army
Kelley, E. E.	Machine Hand	Army
Kelley, H. L.	Bookkeeper	Navy

N.G., National Guard. N.M., Naval Militia. N.R., Naval Reserve. O.R.C., Officers' Reserve Corps.
O.T.C., Officers' Training Camp.

NAME	OCCUPATION	BRANCH OF SERVICE
Kelley, P. J.	Ruling	N. G.
Kenerson, E. H.	Machinist	Army
Kenerson, N. L.	Apprentice	N. G.
King, M. M.	Machinist	N. G.
King, J. P.	Tester	Army
Knowles, E. J.	Clerk	Navy
Knowst, V.	Boring Mill Oper	Army
Kozel, V.	Boring Mill Oper	N. G.
Krause, E. F.	Calculator	Navy
Ladere, G. E.	Field Winder	Army
Laffy, J.	Meter Tester	O. R. C.
Lakeman, G. C.	Shipping Dept.	N. G.
Lambors, N.	Strip Armature	Army
Landry, J.	Repair Work	Army
Landry, J. J.	Press Work	Army
Landry, J. J.	Press Work	N. G.
Lane, P. T.	Piper	Army
Larrabee, G.	Detail Assembler	N. G.
Miller, H. E.	Apprentice	Army
Miller, S.	Tester	Army
Mitchell, A. C.	Apprentice	Army
Mitchell, N. P.	Apprentice	Navy
Mitchell, W. M.	Lathe Hand	N. G.
Moore, H. E.	Machinist	Army
Moore, P. H.	Grinder	N. G.
Morin, A. M.	Square Shafts	Army
Morin, E. J.	Plater	Army
Morrison, F.	Lathe Hand	N. G.
Morrison, R. E.	Winder	N. G.
Morse, G. V. M.	Clerk	Navy
Moulds, J. J.	Calculator	Army
Murphy, L. A.	Press Oper.	Army
Murry, A. J.	Mica Worker	N. R.
Murray, C. F.		Army
Murray, W. F.	Machine Hand	N. G.
McKechnie, E. P.	Draftsman	Army
McKenna, A. H.	Coil Work	Army
McKenna, J. J.	Machinist	N. G.
McNair, G. C.	Machinist	N. G.
McQuire, T. J.	Lathe Hand	Army
Madden, E.	Machinist	Army
Mahoney, W. H.	Core Worker	Army
Malley, E. J.	Guard	Army
Malloy, W.		Navy
Malouis, N. J.	Press Work	Army
Markham, O. I.	Student	Army
Maroni, F.	Press Hand	Navy
Martin, F.	Tester	N. R.
Martin, P. L.	Clerk	N. G.
Mason, H.	Bench Hand	Army
Matthews, A. K.	Shipper	Army
Matthews, C. L.	Enamel Wirer	N. G.
Matthews, R.	Wireman	Navy
May, L. G.	Clerk	N. G.
Mayhew, H. C.	Apprentice	N. G.
Mazrine, F.	Screw Mach. Oper.	Navy
McCarthy, J. J.	Press Oper.	Army
MacDonald, H. T.	Salver	Army
Merkel, W. C.	Student	Army
Melanson, F. P.	Specialist	Army
McBride, L.	Machinist	N. R.
Mieusset, C. E.	Clerk	Army
Larrabee, G.	Assembler	N. G.
Larson, A. R.	Draftsman	Navy
Lathe, W.	Apprentice	Army
Lavin, W. J.	Grinder	Army
Law, H. A.	Tester	Army
LeBlane, A. J.	Field Winder	Army
Lee, J. H.	Detail Work	N. G.
Leeman, G. W.	Lathe Hand	Army
Leger, F.	Carpenter	Army
Leighton, L.	Bench	N. R.
Lennon, T. A.	Meter Winder	N. G.
Leod, W. R.	Lathe Hand	Navy
Leomte, J. E.	Apprentice	Army
Leslie, G.	Helper	Navy
Lilley, E. J.	Drill Hand	N. G.
Lindquist, J. A.	Die Sinker	Army
Lindsay, A. B.	Clerk	N. G.
Lipson, E.	Tester	Army
Lizotte, J. T.	Piece Maker	Army
Logan, J. A.	Clerk	Navy
Longley, E. E.	Apprentice	Army
Lowell, E. B.	Apprentice	N. M.
Luce, E.	Apprentice	Navy
McBride, J.	Winder	Army
McClurg, R. F.	Tester	Army
McDonald, G.	Clerk	N. G.
McGauchy, G.	Machine Hand	Army
McGowan, W. D.	Assembler	N. G.
Newcomb, H. E.	Assembler	Army
Newcomb, L.	Drop Press	N. G.
Nichols, E. H.	Clerk	Canadian Army
Nichols, W.	Lathe Hand	British Army
Nicholson, T.	Brakeman	N. G.
Nicholson, E. N.	Clerk	N. G.
Nickerson, W. H.	Apprentice	N. R.
Nolan, E. J.	Bench Hand	Army
Nowell, H. R.	Machinist	Army
Oberlander, R. F.	Apprentice	N. R.
O'Brien, F.	Winder	Army
O'Connell, T.	Tool Maker	Army
O'Neill, E.	Drill Hand	Army
Orberg, A. W.	Draftsman	Army
Orrell, D.	Testing	Army
Ortengren, R.	Draftsman	Army
Palmarino, M.	Laborer	Army
Pastalla, J.		Army
Pasquale, J. J.	Inspector	Navy
Pearl, A. C.	Apprentice	Navy
Polletier, E. P.	Winder	N. R.
Pendergast, G. A.	Winder	N. G.
Perkins, H. M.	Tester	N. G.
Peterman, E.	Helper	Army
Petropolos, M.	Helper	Army
Pickett, J. L.	Coil Worker	Army
Picordi, J.	Oiler	Army
Piecewicz, J. M.	Lathe Oper.	Navy
Pilling, E. E.		N. G.
Pitcher, L. C.	Shaper	Army
Powers, J. G.	Grinder	N. G.
Pratt, W.	Crane Oper.	Army
Priest, A. L.	Clerk	N. G.
Prout, T. L.	Assembler	Navy
Prudden, J. M.	Clerk	Army
Pye, L. T.	Tinsmith	Army
Quinn, R. E.	Assembler	Army
Quirk, D. T.	Apprentice	N. G.

N.G., National Guard. N.M., Naval Militia. N.R., Naval Reserve. O.R.C., Officers' Reserve Corps.
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NAME	OCCUPATION	BRANCH OF SERVICE
Rankin, S. P.	Draftsman	N. G.
Rankin, H. G.	Case Mfg.	Army
Rafferty, J. F.	Machinist	Army
Reardon, J. A.	Apprentice	Army
Redfern, W. M.	Apprentice	N. M.
Regan, J. J.	Assembler	N. G.
Reynolds, S. D.	Wireman	Army
Rich, H. W.	Mill. Mach. Hand	Army
Richards, A.	Screw Mach. Oper.	N. G.
Richard, A.	Tool Maker	Navy
Richard, E.	Machinist	Navy
Richardson, E. L.	Calculator	Army
Robert, H. A.	Grinder	N. G.
Robertson, J. L.	Finisher	Army
Rodda, E.	Tool Work	Army
Roderick, E. G.	Clerk	Navy
Rogers, E. J.	Bench Hand	Army
Rose, E. J.	Lathe Hand	Navy
Rousseau, J. H.	Crane Man	N. R.
Rose, K.	Tester	Canadian Army
Ryan, J. L.	Carpenter	N. G.
Royal, G. A.	Testing	N. R.
Salerno, T.	Laborer	Army
Salter, G. H.	Machinist	N. G.
Salome, F.	Lath Oper.	Army
Saulnier, E. A.	Wood Worker	N. G.
Scadding, J. E.	Guard	N. G.
Scarnici, V.	Steam Fitter	Army
Schlimper, W. F.	Apprentice	Army
Schwart, M.	Punch Press Oper.	Army
Seely, F. J.	Draftsman	N. R.
Serven, H.	Grinder	Army
Sewell, C. W.	Insulator	N. G.
Sidell, C. V.	Clerk	Army
Silva, C. E.	Draftsman	Army
Sullivan, S.	Helper	Army
Shaffner, R.	Checker	N. G.
Shea, C. A.	Construction	Army
Shea, E. W.	Clerk	Army
Sheldon, J. F.	Machinist	Army
Shillady, S.	Moulder	N. G.
Shipman, R.	Office Boy	N. M.
Shmorad, S.	Blacksmith	Army
Sholes, W. E.	Assembler	N. M.
Simard, W.	Stockkeeper	Navy
Smith, A.	Testing	Army
Smith, E. E.	Apprentice	Army
Smith, K. L.	Apprentice	N. G.
Smith, M. H.	Tester	Army
Smith, S. C.	Electrician	N. G.
Specht, F. A.	Winder	Army
Speed, H. C.	Lathe Hand	N. M.
Spellman, E. J.	Inspector	Army
Sproul, H. T.	Screw Mach. Oper.	N. G.
St. Clair, L.	Machinist	Army
Steckel, F., Jr.	Meter Work	Navy
Stedman, P. R.		Army
Steel, E.	Plumber	Navy
Stege, D. P.	Apprentice	Army
Stevenson, E. W.	Clerk	Army
Stivens, C. W.	Insulation	Army
Stopper, A.	Helper	Army
Straw, S. H.	Apprentice	N. G.
Sullivan, F. E.	Coil Winder	Army
Swanson, C. F.	Machinist	Army
Sweetland, A. L.	Steam Fitter	N. G.
Sylvia, H. G.	Wireman	Navy
Talbot, R. W.	Screw Mach. Oper.	N. G.
Taylor, K. F.	Boring Mill Oper.	Navy
Thibeault, L.	Die Setter	N. G.
Titus, H.	Assembler	N. G.
Toof, R.	Apprentice	Army
Tracy, D. J.	Tester	Marines
Trainor, J. P.	Lathe Hand	Navy
Traynor, E.	Tester	N. G.
Tripp, E. C.	Repairer	Army
Twomey, J. T.	Carpenter	Army
Upham, G. W.	Clerk	N. M.
Voci, A.	Machine Helper	Navy
Vallier, E. E.	Drill Hand	Army
Vieno, E. J.	Machine Hand	Navy
Walata, W.	Machine Hand	Army
Wallace, R. C.	Tester	Army
Walsh, W. H.	Screw Mach. Oper.	N. G.
Watson, G. F.	Assembler	N. G.
Wardman, G.	Tool Work	Army
Webber, G. E.	Misc. Work	Army
Webster, H. E.	Repairer	Army
Welch, J.	Assembler	Army
Welsh, P. J.	Clerk	Army
West, D.	Apprentice	Army
West, M. N.	Cutter	Army
Weymouth, P. E.	Apprentice	N. R.
Wheaton, H. P.	Clerk	Marines
Wheelden, A. E.	Die Grinder	Army
Wheelock, L. A.	Clerk	N. G.
Whelpley, G.	Moulder	Navy
White, D. W.	Tester	Army
Whiting, J. W.	Wireman	N. G.
Whiting, J. W.	Wireman	Army
Whittier, P. G.	Draftsman	N. G.
Wilkinson, H. E.	Bucket Work	Navy
Wilkinson, A. A.	Screw Mach. Oper.	Army
Williamson, H. P.	Mould Mach. Oper	Navy
Witherell, R. B.	Tool Maker	Army
Wing, E. P.	Tester	N. G.
Winslow, A. S.	Tester	Army
Wolfendale, G.	Field Winder	Army
Woron, M.	Packer	Navy
Yery, W. K.	Bench Hand	Army
Young, M. J.	Tester	Army
Young, M. A.	Clerk	Army
Young, W. H.	Bucket Work	Army
Yourick, J. J.	Press Hand	Army
Zalneraitis, V.	Apprentice	Navy
Ziegler, A. A.	Apprentice	N. G.

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PITTSFIELD WORKS

NAME	OCCUPATION	BRANCH OF SERVICE
Abbot, W	Clerk	O. R. C.
Alexander, L.	Punch Press Oper	Army
Allessio, H.	Bench Hand	Army
Anderson, L.	Punch Press Oper.	Army
Archey, J.	Tool Maker	Army
Armsby, L.	Stockkeeper	N. G.
Asci, D.	Moulder	Army
Atkinson, E.	Draftsman	Army
Austin, H.	Machine Hand	Navy
Bailey, C.	Winder	N. G.
Barber, C.	Electrician	Army
Barker, L.	Shear Oper.	Army
Bastion, R.	Winder	Navy
Bauer, G.	Machine Hand	Army
Baumgartner, A.	Steam Fitter	Army
Bawden, A.	Apprentice	Navy
Beach, C.	Assembler	Army
Beauchaine, E.	Winder	Army
Beaudry, R.	Stockkeeper	N. G.
Beebe, H.	Apprentice	O. R. C.
Benoit, C.	Blacksmith	Army
Benson, F.	Assembler	Navy
Blackwell, J.	Draftsman	Army
Blais, A.	Clerk	Army
Blondo, F.	Assembler	Army
Bosma, J.	Assembler	Army
Bouchard	Punch Press Oper.	Army
Breen, J.	Lathe Oper.	Army
Brennan, H.	Drill Press Oper.	Army
Bringgs, W.	Lathe Oper.	Army
Brown, A.	Steam Fitter	Navy
Brown, P.	Making Insulation	N. G.
Burdick, A.	Machinist	N. G.
Burke, A.	Laborer	N. G.
Burns, H.	Helper	Navy
Byrne, J.	Clerk	Army
Canaran, J.	Clerk	Navy
Card, H. E.	Helper	Army
Carroll, M.	Winder	Army
Castronova, J.	Chipper	Navy
Chalker, J.	Electrician	Army
Chant, F.	Welfare Dept.	O. R. C.
Cidro, M.	Laborer	Army
Cinnamon, J.	Cabler	N. G.
Coffee, T.	Machine Hand	Army
Cohn, J.	Electric Welder	Army
Cole, E. K.	Assembler	N. G.
Collette, W.	Assembler	N. G.
Comerford, P.	Coil Taping	Army
Conners, A.	Drill Press Oper.	Army
Conney, J.	Winder	Army
Connors, A.	Drill Press Oper.	Army
Connors, J.	Blue Print Oper	Army
Conta, A.	Truckman	Army
Copeland, E.	Die Setter	Army
Corbin, B.	Tester	Army
Corley, H.	Winder	Army
Cos, C.	Laboratory Work	Army
Coudert, F.	Assembler	Army
Coughlin, J.	Making Mica Insul.	Army
Crosier, P.	Draftsman	Army
Cross, W.	Polisher	Army
Crossley, A.	Punch Press Oper.	N. G.
Croughwell, T.	Clerk	Army
Crowley, C.	Builder	Army
Daley, J.	Drill Press Hand	Army
Daley, L.	Punch Press Oper.	N G.
Davis, H.	Winder	N. G.
Decelles, E.	Assembler	Army
Decelles, E.	Apprentice	N. G.
Decoteau, W.	Painter	N. G.
Delevan, W.		Army
Delavan, W.	Draftsman	Army
Demos, S.	Polisher	Army
Demetroulos, S.		Army
Dempsey, M.	Marker	N. G.
Derosia, A.	Bench Hand	Army
De Sandres, A.	Draftsman	N. G.
Desantis, F.	Machinist	Army
Dieher, E.	Helper	Army
Dolan, E.	Builder	Army
Douglas, R.	Clerk	Army
Dougherty, D.	Winder	Army
Dunn, W.	Pressboard Insp.	Army
Edward, D.	Apprentice	N. G.
Elting, R.	Clerk	Army
Enos, J.	Helper	N. G.
Fallon, F.	Rigger	Army
Fanning, W.	Assembler	Army
Fake, C.	Carpenter	N. G.
Fasce, C.	Marker	Army
Fazzani, A.	Truckman	Army
Ferrell, A.	Inspector	N. G.
Finnegan, J.	Crane Man	N. G.
Flenniken, J.	Draftsman	O. R. C.
Freidman, F.	Testing Insulation	Army
Gaherty, T.	Punch Press Oper.	Army
Gallagher, C.	Helper	N. G.
Gannon, E.	Assembler	Army
Garner, C.	Machinist	Army
Garrity, E.	Truckman	Army
Gelinas, W.	Clerk	Army
Gepponi, L.	Truckman	Army
Goddette, W.	Assembler	Army
Gomes, D.	Laborer	Army
Goodwin, R.	Winder	Army
Coldstein, C.	Machine Hand	Army
Gould, V.	Builder	Navy
Granfield, J.	Clerk	N. G.
Green, L.	Inspector	Army
Guilbault, D.	Repair Man	N. G.
Haakensen, A.	Assembler	Army
Hall, F.	Stockkeeper	Army
Harwood, J.	Clerk	Army
Hayes, A.	Assembler	Army
Henchey, W.	Clerk	Army
Hickey, L.	Winder	Army
Hodecker, C.	Assembler	N. G.
Holvec, E.	Assembler	N. G.
Hooker, F.	Assembler	Army
Horahan, J.	Assembler	Army
Hornbeck, B.	Wire Oper.	Army
Hoyt, L.	Draftsman	Army
Hunter, R.	Testing	Army
Jandro, D.	Electrician	Army
Jarvie, G.	Winder	Army

N.G., National Guard. N.M., Naval Militia. N.R., Naval Reserve. O.R.C., Officers' Reserve Corps.
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NAME	OCCUPATION	BRANCH OF SERVICE
Jeffway, H.	Wireman	N. R.
Jerome, E.	Assembler	N. G.
Johnson, G.	Helper	Navy
Kammritz, E.	Tool Maker	Army
Kataski, J.	Operator	Navy
Kelley, J.	Tallyman	Army
Kelley, H.	Clerk	Army
Kelty, G.	Clerk	Army
Kearney, J.	Assembler	N. G.
Kiley, A.	Blacksmith	Army
Killelea, H.	Electrician	Army
Kilmer, J.	Assembler	N. G.
King, C.	Truckman	Army
Kirk, R.	Lathe Hand	N. G.
Kistler, R	Foreman	O. R. C.
Knoblock, F.	Helper	Army
Kopacz, B. K.	Polisher	Army
Kudlata, H.	Assembler	Army
Langlois, N. A.	Transit Man	O. R. C.
Lasure, H.	Assembler	N. G.
Lauder, H.	Testing	O. T. C.
Lerner, P.	Drill Press Oper.	N. G.
Lawrence, R.	Assembler	Army
Linberg, H.	Machinist	Army
Lolos, W.	Checker	Army
Lord, E.	Assembler	Army
Lundergran, W.	Pattern Maker	Army
Lux, H.	Testing	O. T. C.
Lusk, H.	Box Maker	N. G.
MacKie, T.	Clerk	Army
McCarthy, T.	Chauffeur	N. G.
McClintock, A.	Winder	Army
McCormick, F. H.	Engineer	Army
McGrath, P.	Drill Press Oper.	Army
McInnes, E. W.	Tester	N. M.
McIntosh, E.	Apprentice	Army
McLaughlin, R.	Tester	N. R.
McIntyre, J.	Draftsman	N. G.
Marcoux, A.	Assembler	Army
Marshall, A.	Wireman	Army
Massery, J.	Assembler	Army
Metheis, L.	Tester	N. G.
Miner, E.	Apprentice	Navy
Miner, S.	Testman	Army
Minsky, S.	Marker	Army
Morris, E.	Welder	Army
Morrison, J.	Electric Welder	N. G.
Moesley, W.	Helper	Army
Mountain, W.	Assembler	Army
Mulaney, F.	Tester	N. R.
Murphy, T.	Assembler	Army
Murphy, W.	Winder	N. G.
Nash, J.	Clerk	Army
Needham, R.	Assembler	Army
Normille, J.	Operator	Army
O'Brien, J.	Watchman	Army
Oldmixion, B.	Winder	N. G.
Oles, H.	Clerk	Navy
Oice, E.	Helper	Army
Opelchuch, M.	Trucker	Army
Otis, R.	Clerk	N. G.
Pagnoni, A.	Laborer	Army
Palino, J.	Truckman	Army
Palmer, D.	Screw Mach. Oper.	N. G.

NAME	OCCUPATION	BRANCH OF SERVICE
Patterson, J.	Calculator	N. G.
Parent, E.	Winder	Army
Pearson, W.	Assembler	Army
Peck, A.	Engineer	Army
Pendergast, P.	Chauffeur	Army
Peterson, J.	Draftsman	N. G.
Petit, R.	Helper	Navy
Perry, L. A.	Winder	Navy
Phillips, S.	Tester	Navy
Plouffe, P.	Cabler	Army
Poitras, F.	Clerk	Army
Polidoro, P.	Packer	Army
Porter, R.	Apprentice	Army
Powers, J.	Tester	Army
Provost, A.	Assembler	Army
Purnell, S.	Assembler	O. R. C.
Quathrociock, P.	Painter	Army
Ransay, E.	Apprentice	Navy
Ransay, W.	Machinist	Army
Reed, L.	Apprentice	O. R. C.
Reynolds, J.	Machinist	Navy
Rice, L.	Laboratory Work	Army
Riley, T.	Operator of Saws	Army
Rixon, F.	Clerk	N. G.
Roulier, C.	Moulder	Army
Rudin, J.	Helper	N. G.
Ruggie, L.	Tester	Army
Russell, E.	Inspector	Army
St. John, E.	Repairman	Army
Sala, R.	Lathe Hand	Army
Sandow, D.	Draftsman	Army
Scarbo, J.	Operator	Army
Scholz, A.	Machinist	Army
Scholz, P.	Machine Oper.	Army
Schultz, R.	Clerk	Army
Scott, T.	Drill Press Hand	N. G.
Servis, J.	Machine Oper	N. G.
Shea, M.	Tester	N. G.
Shepard, D.	Packer	Army
Shriver, H	Tester	O. R. C.
Sibolski, J.	Coal Passer	Army
Sitzer, E.	Clerk	Army
Smith, A.	Assembler	Navy
Smith, E.	Clerk	Army
Smith, G.	Designer	N. G.
Smith, J.	Coal Passer	Army
Smith, L.	Wireman	Navy
Smith, O.	Electrician	Navy
Spearman, E.	Clerk	Army
Spears, E.	Lathe Oper.	Army
Stojda, W.	Assembler	N. G.
Sutton, J.	Winder	Navy
Tabor, A.	Winder	Army
Tarantino, L.	Laborer	Army
Taylor, J.	Winder	Army
Teehan, F.	Bench Hand	N. R.
Teggi, T.	Punch Press Oper.	Army
Thompson, C.	Tester	Army
Thorpe, H.	Clerk	O. R. C.
Ticknor, W.	Winder	Army
Tillette, H.	Calculator	O. R. C.
Tilley, M.	Assembler	Army
Tilton, O.	Calculator	Army
Tisdell, F.	Machinist	Navy

N.G., National Guard. N.M., Naval Militia. N.R., Naval Reserve. O.R.C., Officers' Reserve Corps.
O.T.C., Officers' Training Camp.

Name	Occupation	Branch of Service
Treat, C.	Electrician	N. G.
Trynor, H.	Labeler	Army
Van Horn, R.	Student	Army
Van Marter, G.	Tester	N. G.
Varno, H.	Helper	Army
Vaughn, C.	Engineer	O. T. C.
Vecellio, S.	Clerk	Army
Vincent, F.	Clerk	Army
Vito, D.	Stacker	Army
Volin, L.	Drill Press Hand	Army
Volin, T.	Helper	Navy
Walcott, S.	Drill Press Hand	N. G.
Welch, J.	Wire Operator	Army
Welch, R.	Apprentice	Navy
Wells, R.	Grinder	N. G.
White, R.	Apprentice	O. R. C.
Williams, S.	Clerk	Army
Wilner, E.	Machine Hand	Army
Wood, E.	Machine Hand	Army
Wood, H.	Die Setter	N. G.
Wood, M.	Tester	Army
Wright, A.	Machine Hand	Army
Wright, W.	Tester	O. R. C.
Wring, J.	Tool Maker	Army
Zellmer, P.	Assembler	N. G.
Zuffalsata, G.	Sheet Iron Worker	Army

ERIE WORKS

Name	Occupation	Branch of Service
Adams, W. G.	Craneman	Navy
Anderson, R. A.		
Andrews, H. W.	Clerk	O. R. C.
Barber, C. C.		
Bauer, F. W.	Lathe Oper.	Army
Baumeister, F.		
Britton, C. G.		
Cairns, J. D.		
Carlson, O. H.	Shaper	Army
Crane, D.	Inspector	Navy
Dearing, G.		
Demond, A.		
Doyle, H.		
Doyle, H. J.	Machinist	Navy
Gill, P. L.		
Gillis, M. D.		
Gorgon, J.	Molder	Army
Hall, L. D.		
Hartley, H. A.	Clerk	O. R. C.
Hoskins, D. H.		
Hurley, A.		
Hurley, J. A.	Clerk	Army
Jacobsen, J. H.		
Johnston, A.		
Kinnear, F. D.	Inspector	Navy
Landrette, J. T.		
Lemp, H.		
McCarthy, C.	Inspector	Navy
McDamon, I.	Craneman	Navy
McLean, A. H.		
McMitchael, J. H.	Clerk	Army
Maffett, T.	Clerk	Army
Maffett, T. V.		
Miller, P.	Craneman	Army
Momeyer, K. W.		
Mook, P.	Oiler	N. G.
Nelwon, E. W.		
Patten, L. M.		
Pratt, A.	Lathe Oper.	Navy
Renshaw, A. E.		
Schmelzer, E.		
Smith, D.	Clerk	N. G.
Stover, R.	Wireman	Navy
Thompson, C. H.		
Wallace, W. L.	Repairman	N. G.
Yeager, E. W.		

(Complete List for Erie Works not received at time of printing.)

FORT WAYNE WORKS

Name	Occupation	Branch of Service
Adams, F.	Motor Repairer	N. G.
Allen, L.	Clerk	Army
Armiston, R.	Tool Dept.	Army
Asher, V.	Apprentice	N. G.
Baker, E.	Helper	Army
Barrowsm, I.	Packer	N. G.
Bauer, G.	Clerk	N. R.
Bengs, E.	Tester	N. G.
Beuchel, H.	Stockkeeper	N. G.
Biltz, C.		N. G.
Bird, J.	Stock Room	Army
Blake, V.	Soldering	Army
Board, W.	Helper	Army
Boroff, H.	Stock Room	Army
Bradley, D.	Tester	Army
Brooks, H.	Clerk	Army
Brown, M.	Tester	Army
Brown, L.	Apprentice	Army
Chancy, H.	Drill Press Oper.	Army
Coverstone, A.	Helper	N. G.
Dailey, G.	Wireman	Army
Delagrange, C.	Meter Assembler	Army
Dennison, H.	Motor Assembler	N. G.
Dohern, C.	Machinist	Navy
Edwards, L.	Inspector	N. R.
Ehremfort, W.	Mach. Oper.	Navy
Elder, L.	Toolmaker	Army
Erickson, E.	Inspector	Army

N G., National Guard. N.M., Naval Militia. N.R., Naval Reserve. O.R.C., Officers' Reserve Corps.
O.T.C., Officers' Training Camp.

Fort Wayne Works

NAME	OCCUPATION	BRANCH OF SERVICE
Firehammer, P.	Electrician	N. R.
Fosnough, H.	Clerk	Army
Fox, C.	Inspector	Army
Frank, C.	Apprentice	O. R. C.
Frazier, E.	Wireman	N. G.
Gail, A.	Meter Test	Army
Gehrig, T.	Screw Mach. Oper.	Army
Gillert, C.	Foundry Helper	N. G.
Golillet, C.	Winder	Army
Grabner, W.	Wireman	N. G.
Greider, E.	Bench Hand	Army
Haag, H.	Bench Worker	Army
Hall, L. H.	Scrap Hauler	Navy
Hart, J.	Cleaner	Army
Hembrock, C.	Stockkeeper	Army
Higgins, O.	Machine Hand	Army
Hills, C.	Wireman	N. G.
Hirth, R	Bench Hand	O. R. C.
Hlava, A.	Student	N. G.
Hoppe, E	Inspector	O. R. C.
Horn, B.	Tool Room Keeper	Army
Horn, O.	Stockkeeper	Navy
Houck, J.	Clerk	Army
Huggles, A.	Helper	Navy
Huty, H.	Machinist	Army
Jolly, J.	Repairman	N. G.
Kelly, R.	Tester	Army
Kensy, A.	Finisher	O. R. C.
King, W. C.	Repairman	Army
Kleint, H.	Apprentice	Army
Kreager, D.	Helper	Army
Kreigh, E.	Cleaner	Army
Larson, C.	Bench Hand	Army
Lash, E.	Helper	Army
Locke, C. D.	Blacksmith	Army
Maxson, R.	Spray Operator	N. G.
McMaken, J.	Wireman	Army
McNutt, C.	Inspector	Army
Metcalfe, H.	Insulator	Army
Meyer, P.	Clerk	Army

NAME	OCCUPATION	BRANCH OF SERVICE
Myers, D.	Clerk	Army
Miller, W. R.	Bench Hand	Army
Miles, F.	Helper	Navy
Minnich, C.	Tool Maker	Navy
Mischo, V.	Clerk	Army
Mugg, C.	Motorman	N. G.
Morrow, W.	Grinder	Army
Niemeyer, W.	Bench Hand	Army
Ostein, I.	Stacker	Army
Parnin, R.	Tester	Army
Parisot, R.	Small Motor Prod.	Army
Plummer, F.	Inspector	Army
Rosencrance, J.	Apprentice	Army
Schmidt, C. W.	Guardsman	Army
Schreiber, E. J.	Machinist	N. G.
Schwarts, H.	Winder	Army
Sheehan, C.	Machinist	Army
Sheets, C.	Roller	Army
Shondell, H.	Stamping Tags	Army
Sihler, O. F.	Tester	N. G.
Smith, C. C.	Clerk	Army
Southern, W. R.	Machinist	Navy
Sowers, W.	Tester	Army
Spradlin, K.	Blacksmith	Navy
Stanton, J.	Machine Hand	Army
Stanger, G.	Helper	Navy
Stephenson, H.	Draftsman	N. G.
Stine, D.	Helper	Navy
Streider, O.	Factory Eng. Dept.	O. T. C.
Thieme, G.	Grinder	Army
Vanzant, H.	Tester	Army
Walt, M. W.	Punch Press Oper.	N. G.
Weber, C.	Meter Dept.	Army
Woods, C.	Trans. Dept.	Army
Woodward, E.	Helper	Navy
Williams, R.	Clerk	Navy
Walker, F.	Helper	N. G.
Woltz, H.	Motor Repairman	Navy
Zacharias, J.	Power Cutter	N. G.

EDISON LAMP WORKS

HARRISON

NAME	OCCUPATION	BRANCH OF SERVICE
Adams, G.	Gen. Work	N. G.
Bachmura, S.	Gen. Work	N. G.
Barden, F.	Machinist	Navy
Beger, J.	Salesman	N. G.
Bender, W.	Exhausting Lamps	Army
Benjamin, F.	Clerk	N. G.
Bettcher, C. W.	Engineer	O. T. C.
Bloodgood, E.	Exp. Work	Navy
Bray, W. J.	Clerk	Army
Brox, F.	Wire Drawer	Marines
Bruce, T. H.	Exp. Work	N. G.
Bruno, S.	Lamp Exhauster	N. R.
Calabrese, A.	Machinist	Army
Carson, W. D.	Electrician	N. M
Carter, C.	Wireman	N. G.
Casey, J.	Clerk	N. G.
Casey, M.	Clerk	N. G.
Cincia, P.	Dragger	Army

NAME	OCCUPATION	BRANCH OF SERVICE
Cusick, T.	Wire Drawing	N. G.
Donaghey, B.	Helper	N. G.
Donnelly, C.	Machinist	N. G.
Duffy, B.	Draftsman	O. R. C.
Duffey, V.	Wireman	N. G.
Englander, M.	Shrinkage Man	Army
Fagan, L.	Clerk	N. R.
Erickson, E.	Apprentice	Navy
Flynn, J.	Fitter	Navy
Goetchius, A.	Machinist	N. G.
Haine, H.	Clerk	Army
Heffern, J.	Exp. Work	N. G.
Henry, J.	Exp. Work	N. G.
Hoffman, H.	Draftsman	O. R. C.
Johnson, R.	Repairing	Army
Kaspereen, F.	Blasting	N. R.
Knox, F.	Anchor Machine Oper.	Army
Krotyk, T.	Leader	Army

N.G., National Guard. N.M., Naval Militia. N.R., Naval Reserve. O.R.C., Officers' Reserve Corps. O.T.C., Officers' Training Camp.

NAME	OCCUPATION	BRANCH OF SERVICE
Lansing, C.	Furnace Work	N. R.
Leighton, A.	Reaming	Army
Logan, J.	Exhausting Lamps	N. G.
Mead, D.	Exp. Work	Navy
Meyer, H.	Apprentice	N. G.
Miller, R.	Machinist	N. G.
Muir, D.	Clerk	Army
Neilson, E.	Machinist	Army
Nicholas, R.	Wireman	Army
Oliver, D.	Apprentice	N. G.
Pendleburg, J.	Tungsten Swaging	N. G.
Platner, J.	Clerk	N. G.
Rackett, W.	Clerk	N. G.
Rainbow, E.	Watchman	N. G.
Ritchie, T.	Experimental	Army
Segner, F.	Apprentice	Navy
Shields, H.	Inspector	Army
Smith, A.	Machinist	Army
Smith, J.	Passer	N. G.
Snyder, L.	Foreman	Army
Sommer, E.	Exp. Work	N. G.
Travis, R.	Polishing	N. G.
Truxton, J.	Draftsman	Army
Tyman, H.	Ass't Foreman	N. G.
Victor, W.	Passer	N. G.
Williams, C.	Assistant Inspector	N. G.
Zirkelbach, J.	Gen. Work	N. G.

EAST BOSTON

NAME	OCCUPATION	BRANCH OF SERVICE
Aitken, R.	Packing	Army
Berman, I.	Dragger	N. G.
Bowden, E.	Helper	N. G.
Burke, J.	Foreman	N. G.
Conry, W.	Foreman	Army
McLaughlin, W.	Packing	N. R.
McQuire, D.	Helper	Navy

NEWARK

NAME	OCCUPATION	BRANCH OF SERVICE
Goldmand, L. B.	Electrician	N. R.
James, H.	Marker	N. G.
Lord, R.	Clerk	Army
Motz, F.	Foreman	N. G.
Pullin, C.	Machinist	Navy
Robert, C.	Clerk	N. R.
Vice, L. L.	Reclaimer	N. G.
Waters, H.	Clerk	N. G.

NATIONAL LAMP WORKS

NAME	OCCUPATION	BRANCH OF SERVICE
Anderson, H.	Mold Shutter	N. G.
Ashdown, G. J	Clerk	N. G.
Ashford, F.	Nurse	Army
Baker, R. F.	Engineer	N. G.
Baldauf, H.	Bulb Blower	Army
Ballou, L. C.	Salesman	Army
Bard, R. T.	Clerk	N. G.
Barker, A. T.	Clerk	N. G.
Boiles, F.	Glass Worker	Marines
Brannan, E.	Elevator Man	Army
Brooks, E.	Gatherer	Army
Brooks, G.	Gatherer	Army
Brown, R.	Repairer	N. G.
Brundage, A.	Helper	Navy
Caswell, C. C.	Salesman	Army
Coburn, C.	Gatherer	Army
Cook, H. N.	Bookkeeper	N. R.
Coughlin, R. T.	Metal Reduction	Army
Debasky, A.	Laborer	Army
Davies, J. L.	Machinist	Navy
Derry, E. N.	Attendant	N. G.
Devaney, A.	Inspector	N. G.
Devlin, R.	Operator	N. G.
Doane, L. C.	Engineer	Army
Eddy, J.	Painter	Army
Evans, G. A.	Clerk	Army
Forrest, A. W.	Machinist	Navy
Gerlach, I. H.	Accountant	Army
Goetz, J.	Oiler	Army
Gregory, F. S.	Inspector	N. G.
Hardin, L. G.	Engineer	Army
Hayman, G. B.	Clerk	N. G.
Herman, C.	Mach. Adjuster	Navy
Hitch, H. M.	Clerk	Army
Holm, C. L.	Engineer	Army
Holt, P. A.	Asst. Foreman	Army
Hull, E. J.	Foreman	Army
Kavanaugh, W. J.	Mail Clerk	Army
Kays, E. A.	Gatherer	Army
Kays, R. P.	Gatherer	Army
Kearney, F.	Gatherer	Army
Kelley, W. B.	Inspector	N. G.
Khoury, N.	Mounting	Army
Kois, S.	Mold Shutter	Army
Larkman, R. W.	Machinist	Army
Larramore, F.	Coverer	Army
Herbert, L.	Gen. Work	N. G.
Lincoln, R. D.	Gatherer	Army
Lindsay, J. C.	Supt. Employment	Army
McFarland, E. J.	Mach. Adjuster	Navy
Mahoney, C.	Gatherer	Navy
Malloy, T., Jr.	Gen. Work	N. G.
Marks, D. W.	Gatherer	Army
Marshall, F. C.	Clerk	Army
Marshall, H.	Machinist	Army
Martin, E. T.	Office Mgr.	Army
Martin, W. F.	Assembling Orders	N. G.
Mattern, W. R.	Painter	Army
Merrick, J.	Glass Worker	N. G.
Moredock, A.	Clerk	N. R.
Morrison, C. B.	Foreman	Army
Murray, J. C.	Stockman	Army
Neiss, G.	Blower	Army
O'Donnel, M.	Laborer	Army
Parmalee, L.	Chaser	Army
Parry, J.	Asst. Foreman	Army

N.G., National Guard. N.M., Naval Militia. N.R., Naval Reserve. O.R.C., Officers' Reserve Corps.
O.T.C., Officers' Training Camp,

Name	Occupation	Branch of Service
Parchall, R. W.	Experimenter	Marines
Peffer, H.	Gatherer	Army
Perry, R.	Salesman	Army
Petosky, N.	Gatherer	Army
Pettit, M.	Clerk	N. G.
Price, W.	Gatherer	Army
Reisinger, J. C.	Technical Asst.	Army
Riser, A. J.	Gatherer	Army
Rodgers, D.	Gen. Work	Army
Roseborough, W.	Branch Mgr.	O. R. C.
Ross, G. J.	Machinist	Army
Ross, W., Jr.	Clerk	N. G.
Rossington, L.	Clerk	Canadian Army
Rossington, W.	Stenographer	Canadian Army
Rust, L. J.	Engineer	Navy
Santoro, E.	Truckman	N. G.
Savage, C. E.	Clerk	N. G.
Skebe, M.	Tube Shop Work	Army
Smith, A.	Swager	N. G.
Smith, R. W.	Gen. Work	Army
Smith, U. M.	Asst. Foreman	Army
Snee, B.	Operator	N. G.
Sorel, L.	Mold Shutter	N. G.
Stambler, D.	Exhausting Lamps	N. G.
Stephan, S.	Packer	N. G.
Strang, J. J.	Warehouse Man	Army

Name	Occupation	Branch of Service
Streng, E. C.	Engineer	Army
Svec, J.	Painter	Army
Swartz, R. I.	Watchman	N. G.
Tefft, J. L.	Clerk	N. G.
Thom, V.	Gatherer	Army
Thornberg, C.	Gatherer	Army
Thornton, L. M.	Asst. Supt.	Navy
Trittipo, W. E.	Salesman	Army
Vaughn, D.	Operator	N. G.
Vise, J. A.	Blower	Army
Walsh, J. A.	Stenographer	Army
Weaver, A. J.	Inspector	N. G.
Webb, H. L.	Clerk	Canadian Army
Wentworth, P.	Mach. Operator	N. G.
Whipple, H.	Laborer	Marines
Whiteman, H.	Gatherer	Army
Williams, J.	Gatherer	Navy
Windenburg, E. L.	Experimenter	Navy
Wise, P.	Packer	Army
Wolfford, L. P.	Office Mgr.	Army
Wolkersdorger, C.	Clerk	N. G.
Wood, D. M.	Draftsman	Army
Woodman, C.	Sorting Lamps	N. G.
Wright, D. B.	Asst. Mica. Dept.	N. G.
Wright, E. L.	Glass Cutter	Army

SPRAGUE ELECTRIC WORKS

Name	Occupation	Branch of Service
Kennedy, W. J.	Clerk	N. G.
Kline, N.	Assembler	N. G.
Larrison, W.	Punch Press Helper	N. G.
Lieberwirth, G. W.	Winder	N. G.

Name	Occupation	Branch of Service
Meier, A. L.	Winder	N. G.
Neville, R. J.	Bench Hand	Navy
Reich, G. J.	Armature Connector	N. G.

DISTRICT AND LOCAL OFFICES

ATLANTA

Name	Occupation	Branch of Service
Anderson, T.	Clerk	N. R.
Bridges, P. A.	Clerk	N. G.
Brown, G. N.	Salesman	O. R. C.
Burel, J. A.		
Casey, H. J.		
Coleman, A. S.		
Doriocourt, C. D.	Clerk	N. R.
Dunn, S. F.		
Fincher, W. B.		
Glover, C. V. C.	Salesman	O. R. C.
Le Conte, W. L.	Clerk	O. R. C.
Loftis, W. T.		
Murphy, W. G.	Clerk	O. R. C.
Pearce, E. F.	Salesman	O. R. C.
Summer, H. N.	Salesman	O. R. C.
Whitten, L. H.		
Yarborough, W. W.	Clerk	N. G.

BALTIMORE

Name	Occupation	Branch of Service
Darby, G. W.	Clerk	Army
Wheeler, E.	Salesman	Army
Woods, R. S.		Navy

BOSTON

Name	Occupation	Branch of Service
Anderson, A. E.	Clerk	N. G.
Barry, T. A.		
Chambers, E. M.	Filing	N. G.
Clapp, E. M.		
Gibbs, F.	Solicitor	Army
Harding, J. W.	Clerk	Army
Knight, R. M.		
Melavin, J. J.		
Morrill, L. B.		
Newington, J.	Solicitor	Army
Price, M. S.	Clerk	Army
Richardson, O. E.	Salesman	Army

N.G., National Guard. N.M., Naval Militia. N.R., Naval Reserve. O.R.C., Officers' Reserve Corps.
O.T.C., Officers' Training Camp.

NAME	OCCUPATION	BRANCH OF SERVICE
Robbins, R. R.		
Stewart, G. A.	Office Work	Army
Stiles, R. A.	Clerk	Army

CHARLESTON

Bolden	Clerk	Army
Ricketts, P. S.	Clerk	Army

CHARLOTTE

Davis, H. E.		
Rowland, G. T.	Salesman	O. T. C.

CHICAGO

Alverson, F.	Helper	N. R.
Allen, E. W.	Asst. Dist. Mgr.	O. R. C.
Colman, G. W.	Cashier	Army
Curtin, P. J.	Chauffeur	N. G.
Duncan, R.	Clerk	Canadian Army
Duwe, J. F.	Helper	Army
Fawcett, W.	Solicitor	Recruiting Office
Fiske, G.	Specialist	O. R. C.
Gallagher, B. F.	Helper	Army
Gardner, J.	Salesman	O. R. C.
Gordon, J. D.	Solicitor	N. G.
Head, H. G.	Solicitor	O. R. C.
Kirkman, J.	Specialist	O. R. C.
Lee, R. E.	Clerk	O. T. C.
Lewin, W.	Helper	N. R.
Logan, H.	Specialist	Army
McSpaden, L.	Foreman	Army
Lombardi, A.	Clerk	N. R.
McMunn, W.	Clerk	N. R.
Mendonsa, R.	Clerk	N. R.
Kirkman, J.	Specialist	O. R. C.
Maier, J.	Clerk	N. R.
Martin, J.	Office Asst.	N. G.
Murphy, W.	Laborer	Army
Peterson, H.	Clerk	Army
Quennell, A. W.	Salesman	O. T. C.
Rowland, R. A.	Specialist	O. R. C.
Shand, W.	Clerk	Canadian Army
Spring, H. E.	Salesman	O. R. C.
Taussig, W. S.	Specialist	O. R. C.
Taylor, E.	Engineer	N. R.

CINCINNATI

Bechtold, G.	Salesman	Army
Drew, V.	Salesman	Army
Freedman, S. S.		
Jaquith, M. L.	Salesman	Army
Ledbetter, R. H.		
Reardon, H. B.	Specialist	O. R. C.
Silva, A. D.		

DALLAS

Bowman, G.	Customer's Index	Army
Kirkpatrick, G.	Clerk	N. G.
Lange, F.	Clerk	Navy
Lowery, M. A.	Clerk	N. G.
McBroom, L. R.	Salesman	Navy
Mason, V. B.	Salesman	N. M.

NAME	OCCUPATION	BRANCH OF SERVICE
Mugford, E.	Clerk	N. G.
Parker, J. G.	Clerk	Army
Sydnor, E. B.	Counter	N. M.

DETROIT

Harvey, T.	Salesman	Army
McLaughlin, R. G.	Salesman	Army
Pond, F.	Asst. Salesman	Army
Shorrock, E.	Asst. Salesman	Army

MILWAUKEE

Logan, H.		Army
Spring, H. E.		O. R. C.

NEW HAVEN

Hall, T. B.	Office Boy	N. G.
Kenworthy, A.	Clerk	Army
Middleton, A. C.	Foreman	O. T. C.
Stevens, E. G.	Clerk	Army

NEW YORK

Allen, O. F.	Salesman	Army
Benton, H.	Clerk	N. G.
Bradley, E.	Rep. Shop Man	Army
Bush, H. B.	Clerk	Army
Cadsman, B. J.	Mechanic	Army
Carroll, P. H.	Construction	N. G.
Clarks, A. V.	Clerk	Army
Clifford, C. S.	Salesman	N. G.
Costello, E. A.	Accounting	Army
Dollet, H.	Rep. Shop Hand	Army
Douglass, S. A.	Clerk	O. R. C.
Fisher, H. L.	Clerk	Army
Graham, R. W.	Clerk	N. R.
Granberg, A. E.	Clerk	N. G.
Harrison, L.	Salesman	N. R.
Hennessey, J. M.	Clerk	N. M.
Hill, E. D.	Clerk	N. R.
Williams, M.	Clerk	Army
Monteith, H. L.	Rep. Shop Man	Army
Muhlmeyer, G.	Rep. Shop Hand	Marines
Ovington, H. D.	Clerk	Army
Purcell, T. E.	Engineer	N. G.
Quinn, J. M.	Rep. Shop Hand	Navy
Rockwell, G. S.	Salesman	Army
Schwab, I.	Clerk	N. R.
Schwartz, G. L.	Electrician	Army
Shelby, J. B.	Salesman	N. G.
Solomon, A.	Clerk	Army
Springett, J. D.	Clerk	N. G.
Robinson, D. B.	Clerk	Army
Taylor, J.	Salesman	Army
Willoschat, W. G.	Clerk	N. G.
Wolfe, F. D.	Clerk	N. G.

PHILADELPHIA

Baer, C. A.	Salesman	O. R. C.
Brady, J. T.	Salesman	Army
Bolden, J. C.	Clerk	Army
Cobb, P. M.	Helper	Navy

N.G., National Guard. N.M., Naval Militia. N.R., Naval Reserve. O.R.C., Officers' Reserve Corps.
O.T.C., Officers' Training Camp.

NAME	OCCUPATION	BRANCH OF SERVICE
Dalby, T.	Clerk	Army
Hefner, W. J.	Foreman	Army
Holden, N. C.	Clerk	Army
Horn, A. F. E.	Salesman	O. T. C.
Knopple, W. A.	Clerk	Navy
Little, J. H.	Salesman	O. T. C.
Livergood, H.	Foreman	Army
Withington, W.	Clerk	N. G.
Yoder, G. A.	Clerk	Navy

PITTSBURGH

NAME	OCCUPATION	BRANCH OF SERVICE
Calverley, J. G.	Salesman	Army
Huber, L. S.	Salesman	Army
Mundo, C. J.	Salesman	O. R. C.

PORTLAND

NAME	OCCUPATION	BRANCH OF SERVICE
Bay, C. L.	Clerk	N. G.
Hayes, F.	Clerk	N. G.
Reinke, J. F.	Clerk	N. G.
Soreghan, F.	Clerk	N. G.
Neil, T.	Clerk	Army

ST. LOUIS

NAME	OCCUPATION	BRANCH OF SERVICE
Bailey, P. B.	Engineer	O. R. C.
Moran, R. H.	Specialist	Army
Stokes, J. W.	Engineer	O. T. C.
Purinton, R. B.	Engineer	Army
Waugh, T. L.	Accountant	Army

SAN FRANCISCO

NAME	OCCUPATION	BRANCH OF SERVICE
Matson, F. S.	Electrician	Army
Stock, R. F.	Electrician	O. R. C.

SYRACUSE

NAME	OCCUPATION	BRANCH OF SERVICE
Carlotte, L. H.		
Grover, H. H.		

WASHINGTON, D. C.

NAME	OCCUPATION	BRANCH OF SERVICE
Warner, R. A.	Patent Dept.	O. R. C.

N.G., National Guard, N.M., Naval Militia. N.R., Naval Reserve. O.R.C., Officers' Reserve Corps. O.T.C., Officers' Training Camp.

We have included in this list the names of all employees of the General Electric Company who have entered the military service of the United States, as reported to us up to the time of going to press. If any errors or omissions have been made, please report the fact to the Editor, General Electric Review, Schenectady, N. Y.

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GENERAL ELECTRIC REVIEW

VOL. XX, No. 12

Published by
General Electric Company's Publication Bureau
Schenectady, N. Y.

DECEMBER, 1917

THE PATH OF GOLD

Ornamental Lighting of Market Street, San Francisco, Cal., with Luminous Arc Lamps Mounted on Three-unit Standards

Street Lighting with Modern Electric Illuminants

Page 945

POSITIVE DRIVES

THERE can be no slip in the Link-Belt Silent Chain Drive—the chain meshes into the gear, engaging more teeth than in a gear drive, as may be seen by the illustration. All the power of the drive reaches the driven wheel, pulling the load with unyielding, yet resilient force.

LINK-BELT
SILENT CHAIN DRIVES

are operating every conceivable kind of machinery. The drive is Flexible as a Belt—Positive as a Gear—More Efficient than Either. The success of Link-Belt Silent Chain is due to its patented Pin-Bushed-Joint construction—a round pin and two case-hardened semi-circular bushings—found in no other chain. Write for 128-page price list Data Book No. 125.

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Acme-Evans Company
Indianapolis, Indiana

April 20, 1916.

Link-Belt Company,
Indianapolis, Indiana

Gentlemen:—Regarding the results we are receiving from our Link-Belt Silent Chain Drive, will say we have been running the 20-inch chain on a 300 H. P. motor for about 10 months. Up to this time, we are pleased to say the drive has given us entire satisfaction, not even a moment's delay. We also have an 8-inch chain running on a 50 H. P. motor. This chain is also satisfactory.

Yours very truly,
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(Signed)
Jas. E. Nichols, Supt.

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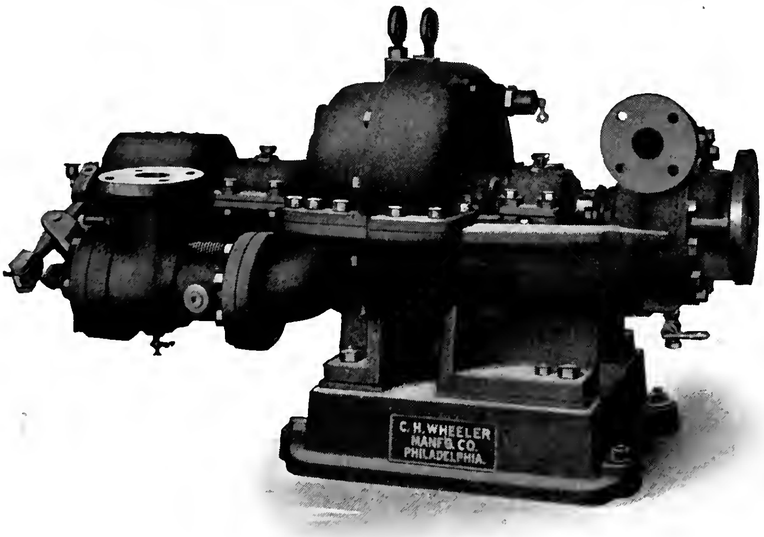

Marine Type Condensate Pump used in connection with "RADOJET" Air Pumps

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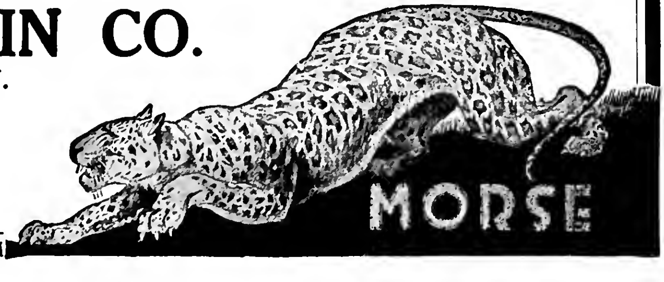
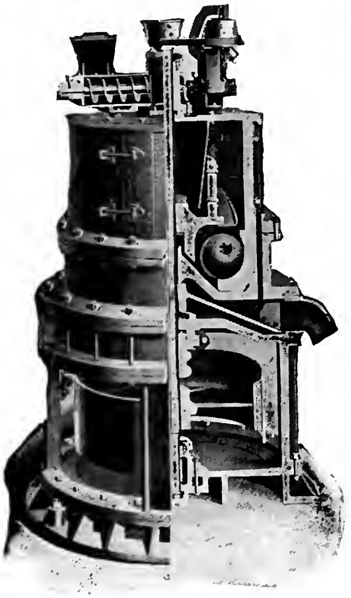

MORSE

Pulverized Coal Equipment

Among some of the plants using our Pulverized Coal Equipment for heating Industrial Furnaces are the following:



American Iron & Steel Co., Open Hearth, Puddling and Heating Furnaces.
American Locomotive Works, Steam Boilers.
Amer. Smelt. & Refining Co., Reverberatory Furnaces.
American Steel & Wire Co., Open Hearth Furnaces.
American Steel & Wire Co., Heating Furnaces.
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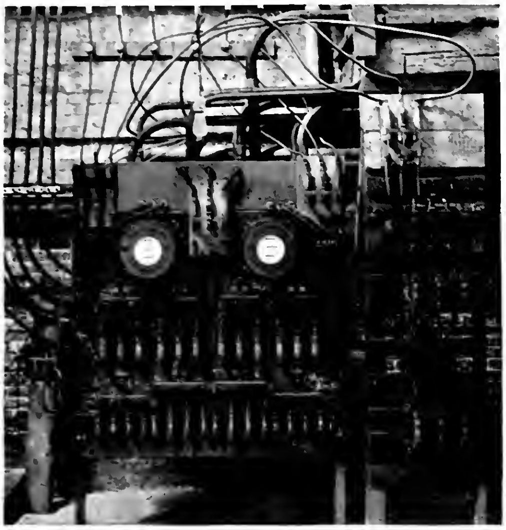
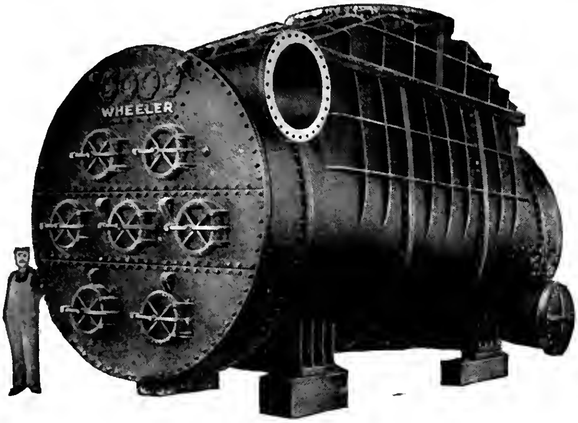


Old Switchboard

New Switchboard

The board at the left no longer exists. It was evidently inefficient, dangerous, and liable to breakdown. It was replaced by the board on the right —modern, safe, and reliable. The important thing is that the change was made *without interfering with service.*

WHEELER CONDENSERS



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The filling slot reduces the load capacity of the race, and for this reason most manufacturers prefer to have the races only about two-thirds full of balls rather than use a filling slot. It is only in the Gurney Bearings that you can secure the full complement of balls without the filling slot.

Another reason for the high capacity of Gurney Bearings is the high accuracy of the race contours, which is made possible by the use of special machinery developed by our Mr. Gurney. By making the contour of the raceway an *accurate* curve which follows closely the curvature of the ball, we greatly increase the area of contact between ball and race.

The increased area of contact makes it possible for a ball rolling in a Gurney raceway to safely carry twenty-six times as much load as the same ball could carry rolling on a flat surface.

These are the reasons for the large load capacity of Gurney Ball Bearings, and this large load capacity is the reason why Gurney Bearings are used by such companies as General Electric, Westinghouse, Allis Chalmers, J. G. Brill, Otis Elevator, Lodge & Shipley, Pratt & Whitney, Brown & Sharpe, and many others almost as well known.

Our Service Engineering Department makes a specialty of solving difficult bearing problems. If you have any such problems our engineers will be glad to give you the benefit of their wide experience.

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Largest bearing is 19.685 in. diameter and has a load capacity of 64,500 lbs.

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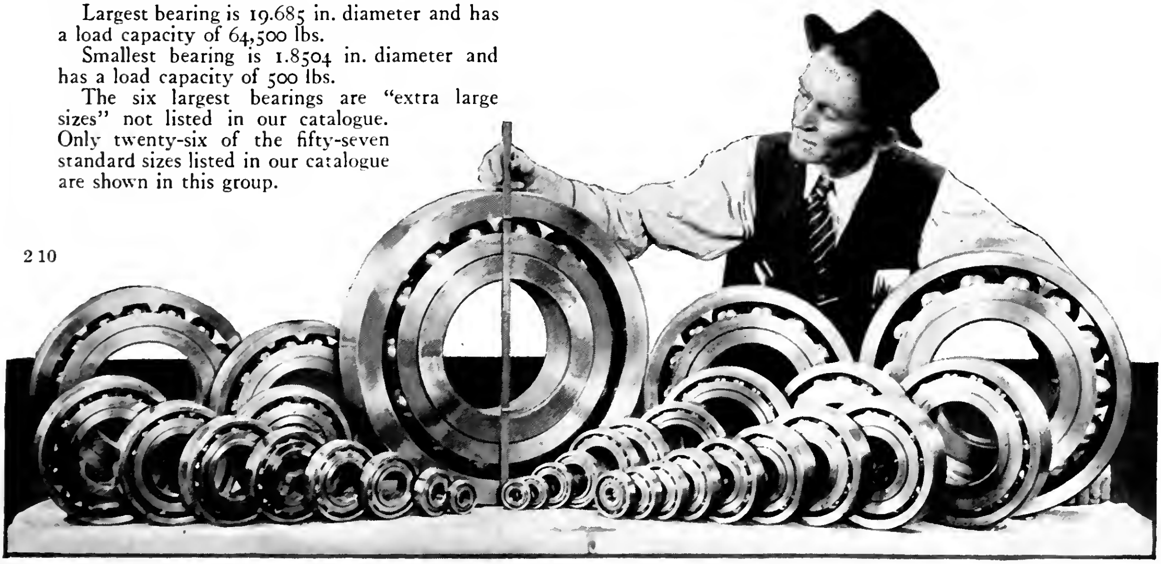

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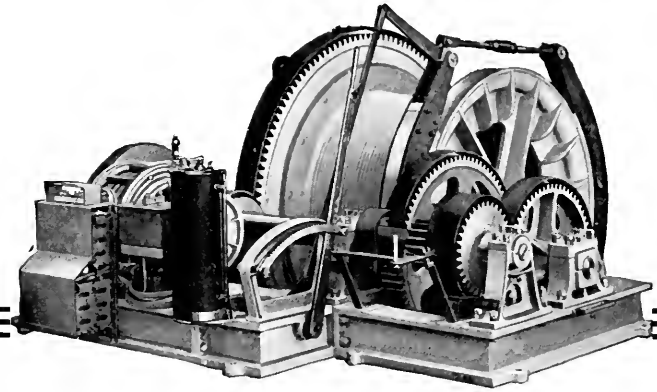

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We build Electric Hoists for every character of service, and in any size.

Illustration shows a two-speed hoist handling 20,000 lbs. loads at 60 f.p.m. and 5,500 lbs. loads at 160 f.p.m. Long experience in hoisting work has enabled us not only to develop a complete line of standard styles and sizes for contracting and mining work, but it enables us to properly design and construct hoists for special duties.

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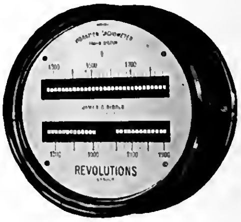

Frahm Tachometer with Two Rows of Reeds

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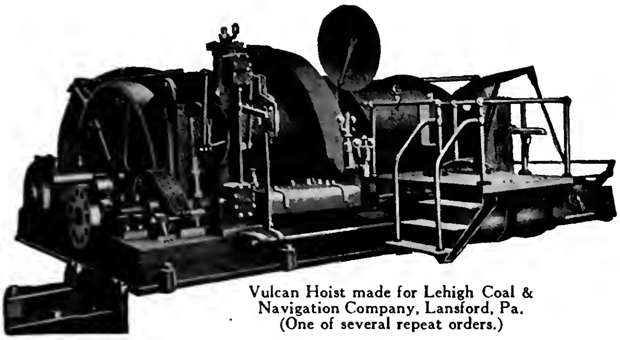

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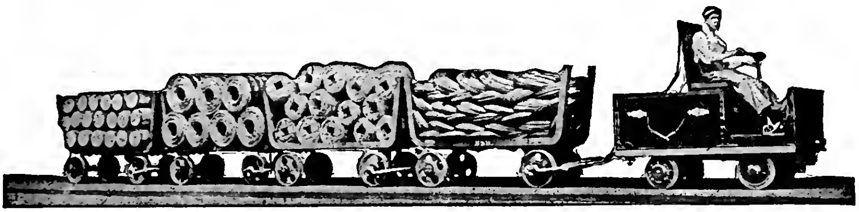

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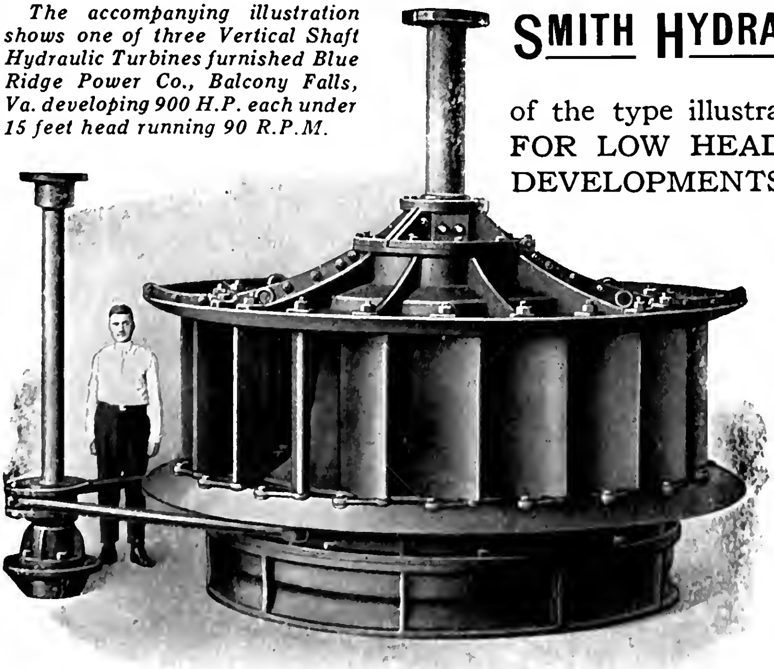

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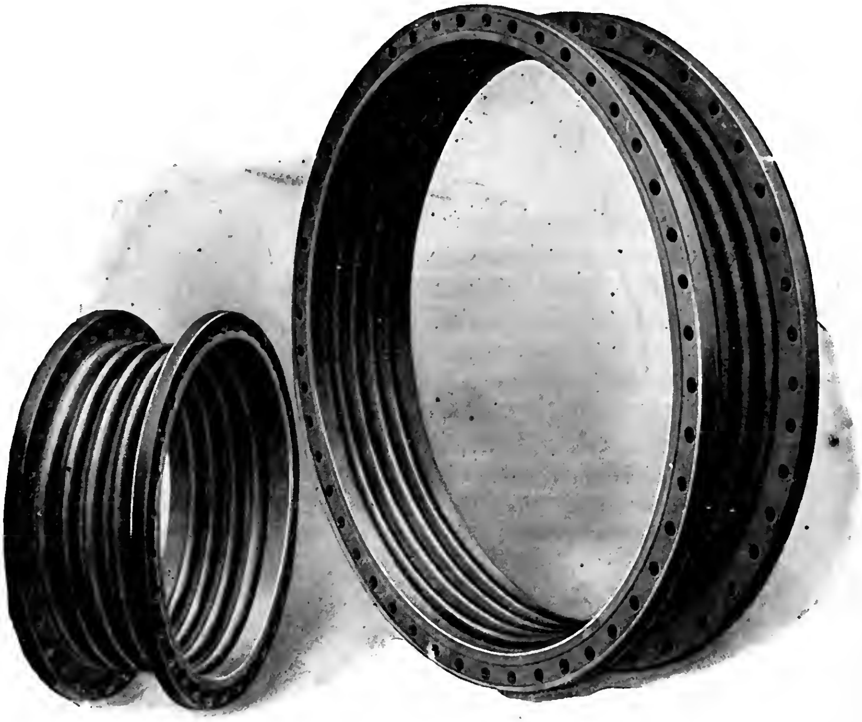

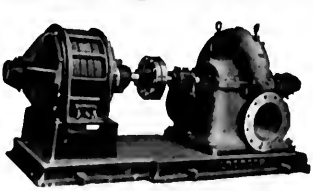

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Seventeen lines of **STANDARD UNIT PANELS** are indexed and described in this bulletin. They range from a one kilowatt wall-mounted combination generator and feeder panel, to "Dead Front" and "Safety First" Truck Type Panels.

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The number of the Index
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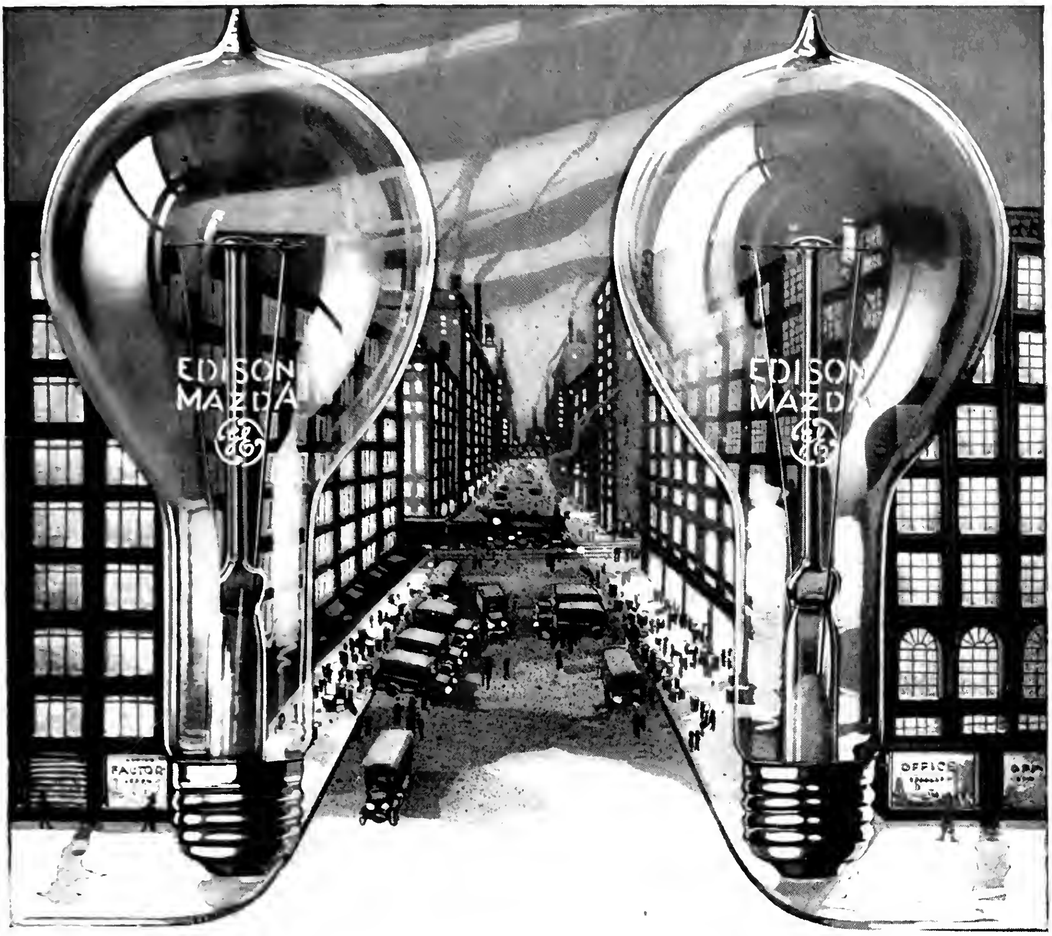

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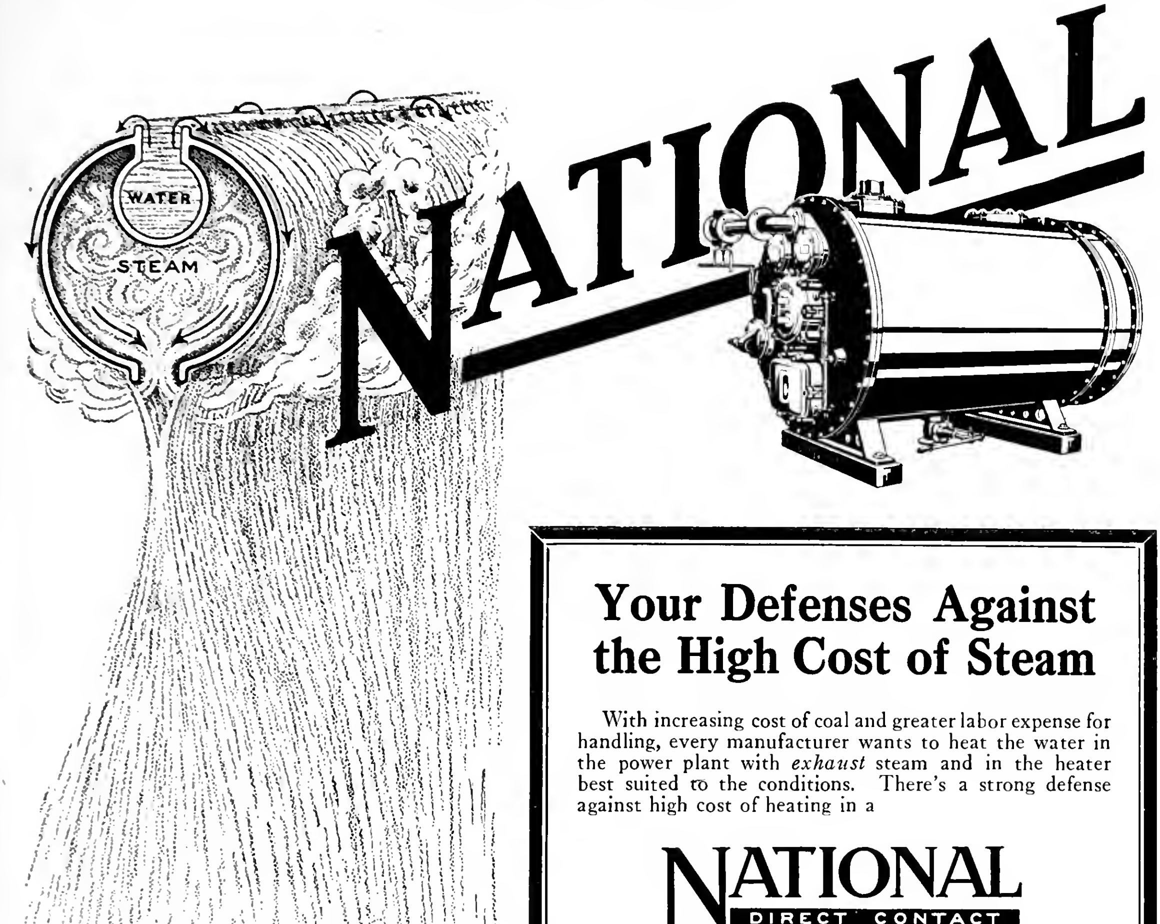

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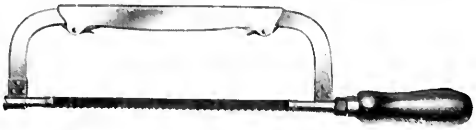

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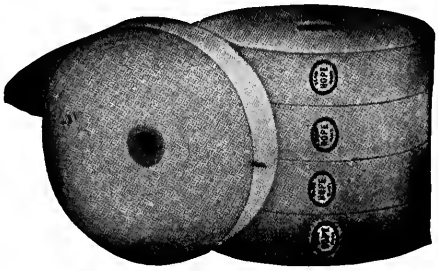

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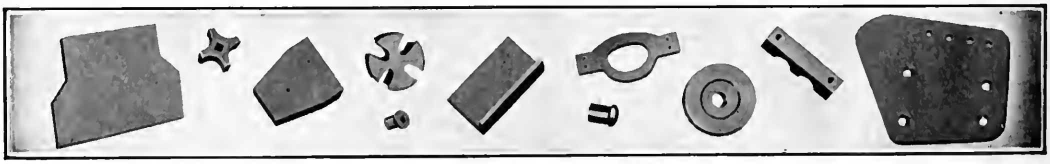

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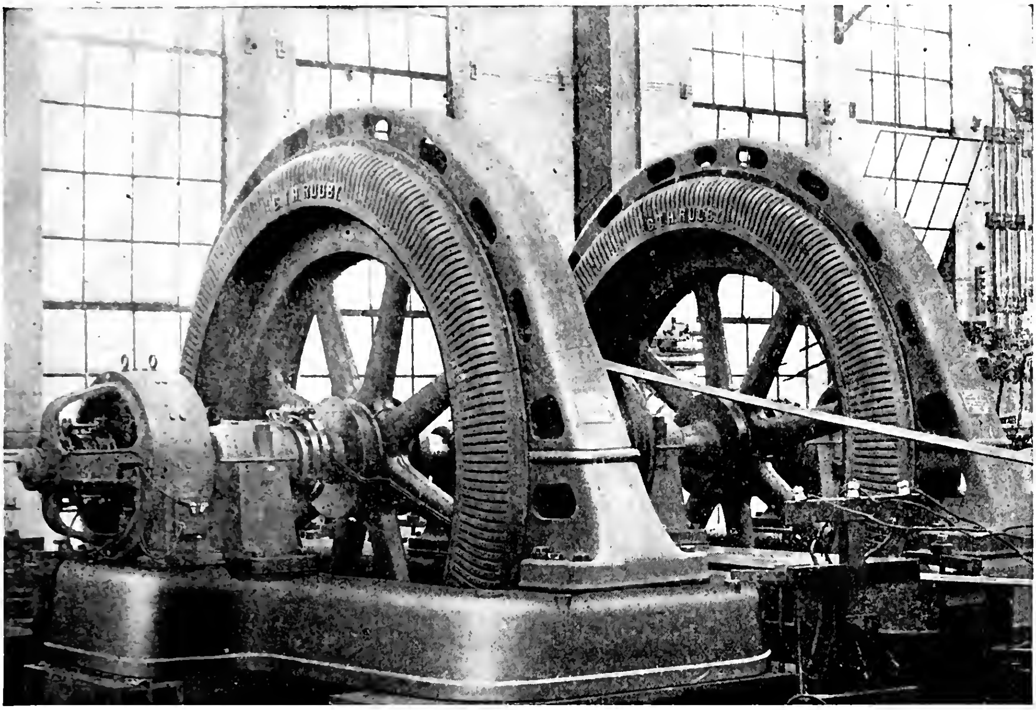

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