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GENERAL ELECTRIC REVIEW

A MONTHLY MAGAZINE FOR ENGINEERS

Manager, M. P. RICE
Editor, J. R. HEWETT
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In Charge of [illegible]

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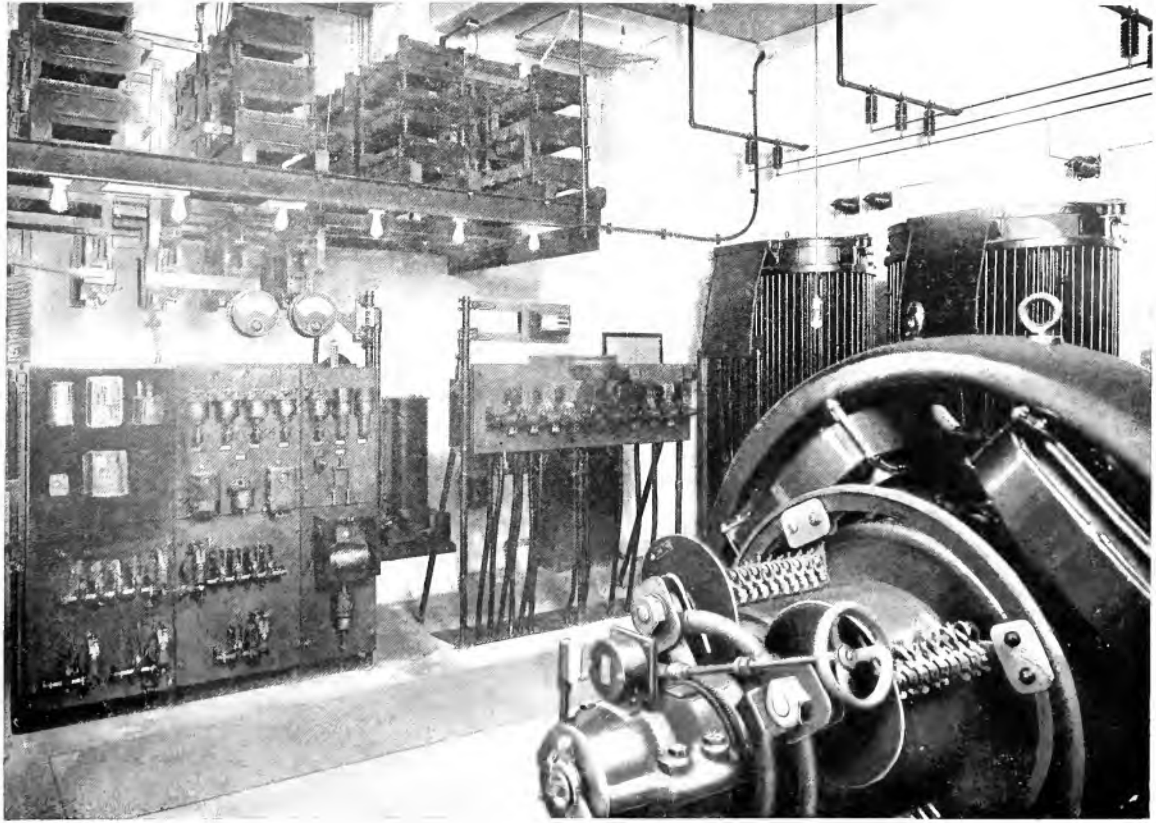

Interior of a Typical Automatic Railway Substation showing the Control Panels at the Left, the Drum Controller on the Wall, the Current-limiting Resistors Overhead, and the Transformers and Converter at the Right. On page 552 of this issue appears a record of a year's operation of such a substation

GENERAL ELECTRIC
REVIEW

A TRIUMPH FOR INDUSTRY

When America declared war on Germany in April, 1917, most of us were deploring the unpreparedness of the country. It would be easy to write criticisms on this score, as it is true we were lamentably unprepared; but it is useless crying over the past, the only reasonable thing to do is to learn from past mistakes and profit by them in our future actions.

The record, after America became a participant in the great world tragedy up to the signing of the armistice, is one of which all may justly be proud. During the last three months of the war for every minute of the night and day seven American soldiers with all equipment and maintenance arrived in France. The Navy, always better prepared for war than many realized, had grown till the personnel amounted to 600,000 officers and men and comprised about 2000 armed vessels and transports. These were wonderful achievements. The efforts of the country were not confined to the raising of an army of millions, transporting 2,000,000 men over 3000 miles of sea, the expansion of the navy to an unprecedented extent, and the building of a mighty merchant marine, but included a prodigious industrial effort and financial task that hitherto would have been thought impossible. Such a record, when thrown against the background of unpreparedness, is nothing short of marvelous and engenders a natural pride in the spirit that accomplished it.

The National undertakings were of such magnitude that the figures we use in measuring them became almost meaningless, because the human mind has little power of discriminating between one huge sum total and another when they climb from millions to billions and beyond. It would be wearisome to recite some of the huge totals, but it is interesting to try to get some mental impression of their proportion. To take one example, the Fourth Liberty Loan amounted to \$6,000,000,000. Would it make much difference to our mental conception of this huge total if we were to add or subtract a cipher or two? We need a new measuring stick. This sum amounts to \$6 for every minute since the birth of Christ up to Christmas, 1919. The American National debt during the period of the war increased by \$20 for every minute of the entire Christian era. The total National debts of the larger belligerent countries mounted up to \$194 for every minute of this era of "Peace on Earth, Good Will Toward Men," and all this vast sum, except a minute fraction, was spent in prosecuting the world war so that future eras might still be called Christian.

The preparations that America made between the time she entered the conflict and the signing of the armistice are so prodigious that it is hard to comprehend them. Had the war continued they would have astonished the whole world.

How was it that a country so totally unprepared was capable of obtaining such results? There is only one logical answer; America had a huge patriotic army thoroughly organized, well generaled, and working with wonderful efficiency. It was not a fighting army, it was an army of peace, the army that had given America her prosperity—the Great Industrial Army of the United States.

The full story of what this army did during the war will never be told—it is too big to tell—but one thing ought to be known and appreciated by the country at large, namely, that except for the fact that this army was loyal, well organized and ably generaled by big patriotic citizens, the story of her part in the war would have been very different.

It is very hard to appreciate the size of America's industrial army. Taking the figures of the Department of Labor for 1918 we find that there were just about 38,000,000 men and women enlisted in the ranks, about 7,000,000 women and the rest men, fighting the industrial battles of the country. The railroads alone employed over a million and three-quarters, over a million and a half were in the building trades, no less than twelve millions were following the pursuits of agriculture and forestry and three-quarters of a million were employed in our coal mines and so on, till by the time we have recorded all those mining metals, our fishermen, our merchant marine, our power houses, our quarries, our street railways and the great host of over seven millions employed in general manufacture, we reach our grand total of nearly thirty-eight million soldiers of industry.

The big spirit, truly American, that led this army from the paths of peace into paths of war is a National asset that must never be forgotten. Any government action would have been sterile without the hearty co-operation of the great captains of industry and the great army of workers who put their shoulders to the wheel and did the job irrespective of party, creed, or any other affiliations. The large organizations of industry in America, sometimes called trusts, proved their national value when the great crisis hung over the country.

It would be absolutely impossible to recite the accomplishments of organized industry during this trying period—it is altogether too fabulously great—but it seems profitable as well as interesting to try to point out what one great American corporation did as its share in the great National undertaking and leave it to the imagination of the reader to draw his own deductions of the burdens that were shouldered by the great corporations throughout the country. Accordingly, in this and subsequent issues of the REVIEW we shall attempt to outline some of the work that the General Electric Company did to help win the war.—J. R. H.

Third Liberty Loan Parade, Schenectady Works. "A Tank to the Attack"

The General Electric Company in the Great World War

By John R. Hewett

Editor General Electric Review

It is difficult to give our readers anything like an adequate idea of the work done by the General Electric Company during the great world war. However, the present article is the first of a series in which we attempt to outline the Company's war activities. This first installment tells of some of the Company's activities in directions other than research and manufacture, and will perhaps be of less interest to a large [illegible] of our readers than some of the other installments. In subsequent issues we shall deal with the research, including submarine detection, X-ray work, radio, electric welding and other research work. Following this the enormous amount of work that the Company did in building cargo boat equipment for the Emergency Fleet Corporation and other ship-propulsion equipment, will be told. The huge gun-shrinking and electric heat-treating furnaces, and the work done on searchlights, will then be dealt with. The last installment will cover "Other War Work," and will tell of some of the Company's activities in helping the industries of the country to "do their bit." The text and illustrations of this installment refer principally to the Schenectady Works, but similar activities transpired at the other factories of the Company.—Editor.

The value of the large industrial corporation as a national asset, during times of both peace and war, is seldom recognized. Is it not the large organized industries that have given America her prosperity in peace and her protection in war?

When America declared war on Germany in April, 1917, Mr. E. W. Rice, Jr., President of the General Electric Company, immediately wired to President Wilson offering the entire facilities of the Company to the Government for the prosecution of the war. There were many other Captains in the great industrial army of the United States who took similar action, and thus, as if by magic, the country's enormous resources were turned from the pursuit of peace to the sterner duty of helping to win the great world war.

This single telegram from Mr. Rice put at the disposal of the Government an army of over 60,000 workers and enlisted in their ranks were some of the most highly trained experts in the world. It gave the Government over fifty factories throughout the country with a combined floor space of over 15,000,000 square feet for the production of war material.

The amount and variety of war work done by the Company defies anything like a complete description, so we shall attempt to describe only a few of the more notable examples. Some small appreciation of the extent of this work can be gathered from the fact that, at the time the armistice was signed, the Company had approximately 19,000,000 square feet of floor space and were employing an army of over 65,000 men. To put this in terms of other values it may be stated that in September, 1918, the Company was doing business at the rate of $255,880,000 per year and that 95 per cent. of this vast production was either directly or indirectly war work.

What the Company was able to do toward helping to win the war was by no means confined to manufacture. The full resources of the Company were at the disposal of the Government and certainly one of their greatest resources was their men. These were lent freely to help in any capacity where the call was urgent. Some of the highest officials of the Company spent many months in helping the Government Departments at Washington, and the service of our scientists, engineers and experts were lent in such various localities and for such a variety of work that it is impracti-

War and Navy Departments

United States of America

This Certifies that

have assured the War and Navy Departments that they will gladly reemploy everybody who formerly worked with them, and left to serve in the Army or Navy during the Great War.

Secretary of War

Arthur Woods Josephus Daniels

Secretary of the Navy

Fig. 1. A Certificate

cable to record them. The expert knowledge and advice of these men was called on freely by the Government and was given freely by the Company. A large number of the Company's experts served on Government committees; but this phase of the Company's contributions is so widespread that an account of it would soon become tedious to read.

The Company's research facilities, which are unequaled by any single organization in the country, were devoted entirely to the solution of war problems, all their scientists and technical experts immediately devoting their entire energies to such special war problems as submarine detection, X-ray outfits for army surgical service, the fixation of nitrogen, wireless telegraph and telephone outfits, and the finding of war substitutes for materials which conditions made it hard or impossible to procure.

Fig. 2. Ambulance Presented to Base Hospital No. 33 by Schenectady Employees of General Electric Company

The assemblage of so large a number of men in one organization and the spirit which controlled it enabled the Company to render conspicuously useful service to the Government in such matters as filling important Government positions with suitable men, assisting the Government's Agent in such matters as the Selective Draft, Liberty Bond Campaigns and the Red Cross Drives. In fact, every national activity that was designed to help win the war received the active and aggresive aid of the Company; they had their own problems to face, but the officials and others were never too busy to help in the broader scope of national activities. A great deal of good work was done in putting the issues of the war before the personnel in the offices and shops by inviting men of national and international reputation to address the men and show them how their interests were truly at stake.

The following paragraphs will give the reader some general idea of a few of the various ways, other than in manufacture and research, that the Company and its employees helped the Government to carry out its many-sided war program.

The Selective Service Law passed by Congress required the registration of all men between the ages of 18 and 45 for military service and each registrant was required to file a questionnaire with his Local Board. The Company appointed a special committee, which represented every entity in its organization, to determine which of its employees were necessary to carry on its war work and which could be spared, or for whom substitutes could be found. Most of the men were required in the industry; therefore all applicants were classified according to whether they were essential to the work to be performed, their training, and their experience. The work of classification was carried out by Associate Legal Advisory Boards which were organized by the Company's Industrial Service Department. The members of these Boards assisted each registrant in making out the industrial section of his questionnaire and in the completion of the necessary affidavits. It is interesting to note that in one of the Company's plants alone 12,000 of the employees registered for military service, and about 7000 questionnaires were investigated. Also that 2552 of these registrants received deferred classification. But it should also be noted that the Company only claimed deferred classification for 2766 of the employees in this plant.

The Company co-operated with the Local and Industrial Boards in every way possible, and it is gratifying to state that the methods worked out by the Company and the way in which they handled this arduous duty was spoken of most highly by Government officials. Indeed, in one instance the Company's work in this direction was held up as an example to other industries.

The "Emergency Fleet Classification" was particularly helpful in the fulfillment of Government contracts. Registrants under the Selective Service Registration who were classified as being in classes 1, 2 and 3, and who were particularly skillful in mechanical or technical operations could be inducted into military service irrespective of their order of service. But any registrant who was employed on contracts for the Navy Department or for the Emergency Fleet Corporation could be granted Emergency Fleet classification which prevented their being called for military service. All such men were assigned definitely to Naval and Emergency Fleet contracts by the Navy Department upon application being made by the Company through the resident Naval Inspector. The draft law was rigidly enforced by the Government and obeyed by the Company, but the spirit of confidence and mutual trust which existed between the Government and the Company is shown well by the fact that only two applications were made, which included 276 of the Company's employees, and that this Emergency Fleet classification was granted to every man on the list. Can the reader appreciate what endless confusion and hindrance to work such co-operation avoided?

Industrial furloughs were granted in a few exceptional cases where highly skilled classes of labor had been drafted. In such cases application was made to the Navy Department through the resident Naval Inspector. It reflects credit on all those responsible for the vast amount of work this registration and classification involved, to tell that the Company made only four requests for the return of previous employees, all of which were granted by the Navy Department.

Fig. 5. Secretary of the Navy Daniels Awaiting to be Introduced to Employees of the Schenectady Works

The Industrial Service Department was kept busy all through these trying times, as the organization work necessary in changing an army of so many thousand workers from a peace to a war basis entailed an enormous amount of work, which is often lost sight of amid some of the more spectacular undertakings. By virtue of the President's proclamation all German aliens were required to carry a permit to continue work and to come within one half mile of the Company's plant during the period of the war. Therefore, all alien Germans employed by the Company were required to register in the Industrial Service Department, giving their name, address, check number, occupation, department employed in, length of service with the Company, and stating whether he was a declarant. Applications were then made for Government permits for each alien enemy. All this classification work was carried out in conjunction with the Department of Justice and the United States Marshall.

All non-English speaking minors between the ages of 16 and 21 were, by law, required to attend school until they had acquired the intelligence of a fifth grade grammar student. In order to determine which of the Company's employees should attend evening school it was necessary for them to pass an examination furnished by the City Board of Education. Thousands of employees were interviewed and many examined and classified. But a small percentage of those examined failed to pass and were therefore required to attend classes furnished by the City Board of Education. This is but one phase of "Americanization Work," of which so much was done during the war and which will be continued after the war.

Another task that fell to the lot of the Industrial Service Department was the registration of all boys between the ages of 16 and 18 for military drill in accordance with the military training law. Under certain conditions of employment boys could be exempted from drill and in order that the Military Training Commission could decide which should be excused, two Field Secretaries of the Commission visited the Works. This training proved to be most beneficial to the boys, improving their general makeup and attitude toward life; in fact, it showed every promise of making better American citizens.

Fig. 6. Third Liberty Loan Parade, Schenectady Works

During the war emergency the Company made a comprehensive survey of "Women in Industry," which resulted in the conclusion being reached that it was not advisable to employ women on as large a scale as many concerns were doing. Only on a few occasions did the Company employ women on occupations previously performed by men.

Unfortunately, there was an entirely different class of activity which made calls on the energies of the Industrial Service Department—a watchful eye had constantly to be kept to avoid anti-military activities, deserters, draft evaders, and propagandists. The Company did much work in these directions which was of much benefit to the Government and to the country as a whole.

The anti-military activities which had to be guarded against were largely the spreading of false rumors, the putting of ground glass in food, and small endeavors to obstruct the production of important military necessities. Such activities were under the guiding hand of enemy sympathizers, if not agents. The Company rendered considerable assistance to the authorities in connection with desertions and draft evasions. Each man applying for employment was asked for his classification card and if this card could not be produced he was held until the United States Commissioner could be informed as to his status. A number of delinquents were apprehended. Records of deserters were posted by the Draft Boards and also from lists received by the Adjutant General of the State of New York showing deserters from various parts of the country. The Industrial Service Department rendered assistance in apprehending deserters from the States of Washington, New Mexico, Arizona, Alabama, Georgia, Louisiana, New Hampshire, Maine, Massachusetts, South Carolina, and New York.

Fig. 7. Mass Meeting of Employees at the Schenectady Works During the Visit of English Labor Delegates

To turn to a different class of activity which was undertaken by the Company for the War Department, the Industrial Service Department did a considerable amount of work in assisting "The Committee on Classification of Personnel in the Army," whose function was to standardize industrial occupations and devise key questions to determine a man's ability in his occupation. This Committee developed various methods of testing the trade knowledge, skill, and general intelligence of men who were drafted into the army.

In August, 1918, the United States Employment Service opened an office in Schenectady and the Company gave considerable assistance in the organization and starting of this work and close co-operation has been maintained at all times. The purpose of this service was to act as a clearing-house for labor, and, as a war emergency to try to remedy an unequal distribution of labor throughout the country, as well as to switch labor for non-essential occupations to essential war work. Since the war this service has assisted in sending discharged soldiers back to their original employment.

To turn again to an entirely different class of work: what the Company did in connection with war gardens, which were so essential throughout the country to relieve the food situation, should be mentioned. To help in this good work, during the last two years the Company at the Schenectady Works made available for gardening purposes the land between the old Erie Canal and the Mohawk River. This land was plowed, harrowed, and staked off in lots 75 feet by 25 feet wide. Application for these garden lots was made by employees of the Company and the gardens were assigned in the order of application. Rules were drawn up to secure a uniform working of all the gardens. Approximately 1000 gardens were cultivated each year and a large amount of corn, potatoes, cabbage, carrots, tomatoes, beans and onions were raised.

LIBERTY LOANS

	SUBSCRIPTIONS	AMOUNT
FIRST	13309	$1.057.400
SECOND	20905	$1.515.600
THIRD	21869	$1.646.600
FOURTH	23326	$2.557.350
VICTORY	20316	$2.014.300
TOTALS	99725	$8.791.250

VICTORY LOAN

GOAL $1.250.000

	SUBSCRIPTIONS	AMOUNT	TOTAL
WEDNESDAY	3030	$ 275.000	$ 275.000
THURSDAY	7814	$ 752.050	$1.027.050
FRIDAY	5076	$ 492.550	$1.519.600
SATURDAY	4396	$ 494.700	$2.014.300
TOTALS	20316	$2.014.300	$2.014.300

Fig. 8. Official War Service Record of the Schenectady Works

The reader will naturally be interested to know the number of men who left the Company to serve their country in the army. From the Schenectady Works alone, over 3200 men entered the service, and the number of the entire organization mounted up to 8329. Already 1074 men have returned to the Schenectady Works, and 2310 have rerutned to the Company's employ throughout the organization. Thirty-five of the Company's employees from Schenectady and 97 from the entire organization gave their lives in the service of their country during the great World War.

The Company has issued definite instructions to the heads of all departments concerning rehabilitation of men returning from service. Every man who served his country and receives an honorable discharge from the army will be re-employed in his former work if possible, and if not will receive employment with the Company at the current rate for the class of work he is performing. The Company has gone to considerable trouble in arranging for the employment of disabled soldiers and sailors, having made out a rehabilitation questionnaire and circulated it to the superintendent and department [illegible] are glad to say that up to [illegible] we have learned of only [illegible] former employees being disabled.

The Company tried to keep [illegible] man in service all the time, and at [illegible] each received a Christmas card [illegible] President of the Company.

Fig. 9. Third Liberty Loan, Official Record, Schenectady Works

LIBERTY LOANS

The raising of Government Loans was a vital national undertaking upon which the Government's war program depended. The organized industries of the country did distinguished service in this connection and the officials and employees of the Company spared no pains to stimulate the energy of local organizations in the various plants to facilitate everyone doing his bit.

These activities came under the auspices of the Welfare Department; the table on page 504 gives the statistical data of the results achieved, which should be gratifying to those loyal workers whose patriotic efforts led to such notable accomplishments. Quite an interesting story could be written of these activities, but we must confine our remarks to a few paragraphs.

	CONTRIBUTORS	AMOUNT	TOTAL
TUESDAY	2518	$28808	$28808
WEDNESDAY	5303	$44947	$73755
THURSDAY	5345	$43256	$117.011
FRIDAY	4028	$29428	$146.439
SATURDAY	3417	$24.369	$170.808
TOTALS	20.611	$170.808	$170.808

Fig. 10. Official Record of Second Red Cross War Fund Campaign, Schenectady Works

When the Government issued its first call to the country to buy Liberty Bonds both the officials and employees of the Company took active steps to form a campaign organization. A committee of 600 was formed to canvass the Schenectady shops. The quota for the Schenectady Works was $1,000,000 and this was oversubscribed. It is interesting to note that the form of organization and the sales methods employed were widely adopted by others and became a model for subsequent campaigns; indeed, the Company's methods proved so effective that they were adopted by the War Council and issued to the country at large when it was proposed to raise $100,000,000 for the American Red Cross. When the Second Liberty Loan had to be raised the Committee of 600 was expanded to the "Committee of One Thousand," by which name it has since been known. The scope of the Committee embraced all L[illegible] Campaigns, War Relief Work [illegible] sub-committees. Departmental A[illegible]tions were formed to look after the [illegible] of soldiers and sailors.

Fig. 11. Roll of Honor, Schenectady Works

An interesting incident occurred at the Schenectady Works on October [illegible], the completion of the Second Liberty Loan Campaign, which should be recorded. Perhaps up to this date there had not been a sufficient realization in the public mind of each individual's personal responsibility to take his share in the war, but the employees of the Schenectady Works certainly declared war on this date. This declaration was an interesting example of crowd psychology, as it was just as unexpected as it was spectacular. The Committee of One Thousand was announcing the final results of their Second Liberty Loan Campaign from the

Fig. 12. Committee of One Thousand Under Whose Auspices the Second and Subsequent Liberty Loan Campaigns were Carried Out at the Schenectady Works

Fig. 13 Bird's-eye View of Employees' War Garden Plots, Schenectady Works

bandstand—$1,000,000 was asked and a million and a half had been subscribed. The enthusiasm of the employees knew no bounds; an enormous parade formed spontaneously; banners appeared as if by magic; and a celebration such as has seldom been seen before began. In an increditably short time the whole Schenectady Works was in line to march, and when the noon whistle blew to return to the shops the workers were passing out of the main gate on their way to parade the city. Protests were unavailing, work was entirely forgotten, and with a patriotic enthusiam this parade carried a war message to the city of Schenectady such as few cities have ever received. After two hours, in which the orderly formation of the parade was never broken for a minute, the marchers returned to work and took up their jobs as if nothing unusual had happened. Mr. G. E. Emmons, Vice-President of the Company, in charge of manufacturing, said: "This is the first time in my manufacturing experience of one quarter of a century that I have ever seen with any pleasure the men leave their work during shop hours."

The effect of this demonstration upon the employees themselves and upon the city was very pronounced. All later work was easier. It had often been said that the war would be won in the work shops of the world, and this demonstration certainly did its mite in the fulfillment of this prophecy.

During the Third Liberty Loan Campaign history repeated itself in the high percentage of employees subscribing. For the Fourth Liberty Loan all previous records were eclipsed when the 23,000 employees of the Schenectady Works subscribed two and one half million dollars. Up to May, 1919, at the conclusion of the Victory Liberty Loan Campaign the employees of the General Electric Company had invested over $21,250,000 in Government Bonds; 255,128 separate subscriptions had been made in a group of about 70,000 industrial workers. To this good record must also be added what these same workers did in the many other phases of war relief work. The Schenectady workers alone contributed to such organizations as the Red Cross, United War Work campaign and to others gifts totaling $350,000.

These figures show better than any long-winded argument the spirit of the shop. The spirit of the office and the spirits of the shops was the same—put your shoulder to the wheel and do whatever job Uncle Sam wants of you—do it quickly—do it well.

LIBERTY LOAN SUBSCRIPTIONS BY GENERAL ELECTRIC COMPANY EMPLOYEES

	FIRST LOAN		SECOND LOAN		THIRD LOAN		FOURTH LOAN		FIFTH LOAN		ALL LOANS	
	Number Subscribers	Amount	Number Subscribers	Amount	Number Subscribers	Amount	Number Subscribers	Amount	Number Subscribers	Amount	Number Subscribers	Amount
Schenectady Works, including General Office	13,309	$1,057,400	20,905	$1,497,600	21,869	$1,646,600	23,205	$2,563,200	20,093	$2,074,700	99,381	$8,839,500
Philadelphia Works					240	14,550	318	29,100	342	28,600	900	72,250
Lynn Works	8,737	559,800	9,111	555,000	8,819	561,400	9,603	811,500	8,430	653,150	44,700	3,140,850
Pittsfield Works	4,145	287,400	4,413	289,050	4,978	326,200	5,802	433,100	4,454	361,300	23,792	1,697,050
Erie Works	2,384	177,450	2,360	160,050	4,468	355,450	5,893	628,150	3,500	208,400	18,605	1,529,500
Fort Wayne Works	2,129	152,050	2,922	196,600	3,413	245,750	3,538	277,250	2,549	212,950	14,551	1,084,600
Edison Lamp Works	3,212	213,650	3,387	200,250	1,293*	86,800*	5,039	310,600	2,305	151,050	15,236	962,350
Sprague Electric Works	802	57,850	594	56,450	1,482	116,850	2,046	215,900	2,137	170,950	7,061	618,000
National Lamp Works	3,389	278,200	2,908	250,400	6,079	437,100	7,270	770,000	†	†	19,646	1,735,700
District Offices	1,748	219,050	1,717	224,100	2,610	329,250	2,702	494,450	2,497	307,700	11,256	1,574,550
Totals	39,855	$3,002,850	48,317	$3,429,500	55,251	$4,119,950	65,416	$6,533,250	46,289	$4,168,800	255,128	$21,254,350
Average individual subscription	$75.00		$71.00		$75.00		$100.00		$90.00			
Increase over first loan-												
Number of subscribers			21%		39%		64%		27%‡			
Amount of subscriptions			14%		37%		117%		53%‡			
Percentage of subscribers to total employees	57%		67%		76%		90%		78%			

* Subscriptions not solicited from employees receiving less than $1000 per annum on account of previous War Savings Stamp Campaign.
† No Company campaign made. Subscriptions taken by house to house canvass and total not available.
‡ Exclusive of National Lamp Works.

The Arrangement of Electrons in Atoms and Molecules*

PART I

By Irving Langmuir

Research Laboratory, General Electric Company

In the following article the author has set forth a new theory of atomic structure which [illegible] a great deal of appreciation from scientists in this country. The main assumption in this theory [illegible] electrons are stationary and situated in concentrated shells. By means of this theory the writer found that it is possible to explain the periodic properties of the elements, and also succeeded in evolving a new view of valency which bids fair to replace all the older views on this subject.—Editor.

The problem of the structure of atoms has been attacked mainly by physicists who have given little consideration to the chemical properties which must ultimately be explained by a theory of atomic structure. The vast store of knowledge of chemical properties and relationships, such as is summarized by the Periodic Table, should serve as a better foundation for a theory of atomic structure than the relatively meager experimental data along purely physical lines.

Kossel† and Lewis‡ have had marked success in attacking the problem in this way. The present paper aims to develop and somewhat modify these theories. Lewis, rejecting the physical data, as being insufficient or inconclusive, reasons from chemical facts that the electrons in atoms are normally stationary in position. These electrons arrange themselves in a series of concentric shells, the first shell containing two electrons, while all other shells tend to hold eight. The outermost shell, however, may hold two, four or six, instead of eight. The eight electrons in a shell are supposed to be placed symmetrically at the corners of a cube or in pairs at the corners of a regular tetrahedron. When atoms combine they usually hold some of their outer electrons in common, two electrons being thus held for each chemical bond. These electrons may form parts of both atomic shells of eight electrons. By means of these postulates Lewis is able to give an extraordinarily satisfactory explanation of the periodic arrangement of the elements and to explain in detail most of their chemical properties. He confines his attention, however, exclusively to the inert gases, the alkali and the alkaline earth metals, the halogens, *B*, *Al*, *Sc*, *C*, *Si*, *N*, *P*, *As*, *Sb*, *Bi*, *O*, *S*, *Se* and *Te*—a total of 35 out of the 88 known elements. The theory in its present form does not apply at all satisfactorily to any of the other elements.

Kossel's theory has many points of similarity. He conceives of the electrons as located in a plane in concentric rings, rotating in orbits about the nucleus. Certain arrangements, corresponding to those of the inert gases, are supposed to be of unusual stability and all the other atoms, in forming compounds tend to give up or take up electrons so that their electrons may become arranged like those of the inert gases. Kossel considers only the elements up to cerium, a total of 57. His theory does not satisfactorily account for the properties of the elements from *V* to *Zn* or from *Cb* to *Ag* and is only partially satisfactory for any of the elements above *V*. In other words, its main success is limited to the first 23 elements. The theory does not lend itself nearly as well as that of Lewis to the detailed explanation of the properties of elements and their compounds.

A rather thorough review and discussion of these and other recent theories of atomic structure has been published by S. Dushman (General Electric Review, 20, 186, 397, 1917).

There is much chemical evidence, especially in the field of stereochemistry, that the primary valence forces between atoms act in directions nearly fixed with respect to each other. This can only be satisfactorily accounted for and explained by electrons arranged in three dimensions.

Kossel attempts to explain the tetrahedral arrangement of the carbon valences by arguing that four spheres drawn in by strong forces towards a central atom must arrange themselves as a tetrahedron and that if the

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* Published simultaneously in the Journal of the American Chemical Society, 41, 868 (1919).

† N. Kossel, Amer. Physik., 49, 229 (1916).

‡ G. N. Lewis, Jour. Amer. Chem. Soc., 38, 762 (1916).

forces are great enough they will not be able to shift their positions. It is evident that even this structure would not have the requisite symmetry for the carbon atom, when the plane of the electron orbit is taken into account. But there is, moreover, conclusive evidence, even when carbon atoms are surrounded by less than four other atoms, that the forces act in definite directions. For example, if wood is carbonized under certain conditions a charcoal is obtained having about the same volume as the wood. This is notably true when such a substance as finely divided WO_3 is reduced in very dry hydrogen. The volumes occupied are in some cases 20 or 25 times as great as that of the corresponding solid in crystalline form. The whole behavior of such bodies, especially in regard to the sintering at higher temperatures indicates that the atoms are arranged in branching chains in which most atoms are surrounded by only two or three others. Since the bodies are definitely solid it must follow that the atoms are not able to shift their relative positions except when acted on by strong external forces. Such structures are inconceivable if atoms contain only electrons revolving in orbits about their nuclei.

Further evidence for the stationary electrons has been obtained by Hull who finds that the intensities of the lines in the X-ray spectra of crystals are best accounted for on the theory that the electrons occupy definite positions in the crystal lattice.

In attempting to determine the arrangement of electrons in atoms we must be guided by the numbers of electrons which make up the atoms of the inert gases; in other words, by the atomic numbers of these elements, namely, helium two, neon 10, argon 18, krypton 36, xenon 54 and niton 86.

Rydberg* has pointed out that these numbers are obtained from the series

$$N = 2\ (1 + 2^2 + 2^2 + 3^2 + 3^2 + 4^2 +)$$

The factor two suggests a fundamental two-fold symmetry for all stable atoms. By a consideration of this equation and principles of symmetry and by constant checking against the Periodic Table and the specific properties of elements I have been led to the postulates given below. Some of these may seem in themselves to be very improbable and will undoubtedly need to be modified as more facts are acquired. But it is felt that all contain a fundamental basis of truth and that, although future modifications may make them take rather different forms, their application in predicting properties of elements will not be greatly altered.

The first postulate is concerned particularly with the structure of the stable atoms of the inert gases.

Postulate 1. The electrons in the atoms of the inert gases are arranged about the nucleus in pairs symmetrically placed with respect to a plane passing through the nucleus which we may call the equatorial plane. The atoms are symmetrical with respect to a polar axis perpendicular to the plane and passing through the nucleus. They have also four secondary planes of symmetry passing through the polar axis and making angles of 45 deg. with each other. The symmetry thus corresponds to that of a tetragonal crystal. Since the electrons must occur in pairs symmetrical to the equational plane there are no electrons in this plane.

Postulate 2. The electrons in the atoms are distributed through a series of concentric spherical† shells. All the shells in a given atom are of equal thickness. If the mean of the inner and outer radii be considered to be the effective radius of the shell then the radii of the different shells stand in the ratio 1:2:3:4, and the effective surfaces of the shells are in the ratio $1:2^2:3^2:4^2$.

Postulate 3. Each spherical shell is divided into a number of cellular spaces each of which may contain one or two electrons. The thickness of these cells measured in a radial direction is equal to the thickness of the shell and is therefore the same (Postulate 2) for all the cells in the atom. In any given atom the cells occupy equal areas in their respective shells. All the cells in an atom have therefore equal volumes. The first postulate, regarding symmetry, applies also to the location of the cells. The first shell therefore contains two cells obtained by dividing the shell into two equal parts by the equatorial plane. The second shell having four times the surface (Postulate 2) must contain eight cells. The third shell thus contains 18 while the

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* Phil. Mag. 28, 144 (1914).

† In accordance with Postulate 1, it is probable that the surfaces of the shells are ellipsoids of revolution rather than spheres. In the present argument this distinction is immaterial.

fourth contains 32 cells. Or if we consider only one hemisphere the numbers in the successive shells are 1, 4, 9 and 16.

Postulate 4. Each of the two innermost cells can contain only one electron* but each of the other cells is capable of holding two. There can be no electrons in the outside shell until all the inner shells contain their maximum numbers of electrons. In the outside shell two electrons can occupy a single cell only when all other cells contain at least one electron. We may assume that two electrons occupying the same cell are at different distances from the nucleus. Each shell, containing its full quota of electrons, thus consists of two "layers." We will find it convenient to refer to these layers of electrons by the symbols I, IIa, IIb, IIIa, IIIb and IVa where the Roman numerals denote the shell containing the layer. Helium, neon, argon, krypton or xenon contains respectively the first 1, 2, 3, 4 or 5 of these layers, while niton contains all six.

The two-fold symmetry assumed in postulate 1 is derived from the factor 2 which occurs in Rydberg's equation. The four-fold symmetry is derived from the remarkable numerical relation brought out in the following table:

Shell	Radius	*n*	No. of Cells in Axis	In Zones
I	1	1	1	0
II	2	4	0	4
III	3	9	1	8
IV	4	16	0	16

Here *n* represents the number of cells in one of the hemispheres of the shell. If this number is odd one of the cells must lie along the polar axis; all other cells must be distributed in zones about this axis.

We see from this table that the number of cells which must be arranged in zones is always a multiple of four. We can therefore assume tetragonal symmetry for the atoms of the inert gases.

Postulates 2 and 3 offer perhaps the simplest possible explanation of the occurrence of the terms 1, 2^2, 3^2 and 4^2, in Rydberg's relation. There are some reasons for believing that the shells close to the nucleus would be closer together. These reasons are based mainly on the assumption that Coulomb's inverse square law holds even at short distances, and for this assumption there is little experimental evidence, except in the case of forces between two positive nuclei (Rutherford's scattering experiments). It is probable that the law of force is quite different for electrons bound in an atom and for positive or negative particles passing through the atom.

The assumption of the existence of cells independent of the electrons in them, seems to be needed to account for the properties of elements above the rare earths. It is, however, closely related to Bohr's assumption of the existence of stationary states. The passage of an electron from one cell to another probably causes the emission of a spectrum line. It should be noted that the numbers 1, 2^2, 3^2, 4^2, etc., also occur in Bohr's theory in the determination of the location of the stationary orbits. It is probable that a common explanation will be found for both theories.

Postulate 4 seems necessary to take into account that the terms 2^2, 3^2, etc., in Rydberg's series occur twice. It seems to denote a remarkable tendency like that suggested by Postulate 1 for the electrons to form pairs.

From the steady progression in the properties of the different inert gases, however, we must conclude that the two electrons in a single cell do not exert very strong forces on each other.

The first four postulates give us a definite conception of the arrangement of the electrons in the atoms of the inert gases. Helium consists of two electrons symmetrically placed with respect to the nucleus. This same pair exists (as Shell I) in the atoms of all the other inert gases and determines the position of the polar axis. Neon contains a second shell (IIa) containing eight electrons arranged at the corners of two squares placed symmetrically with respect to the equatorial plane and parallel to it. These positions probably correspond fairly closely to the corners of a cube, but the effect of the two electrons in the first shell should be to shorten the cube in the direction of the polar axis. Argon is just like neon, except that there is a second layer of eight electrons (IIb) in the second shell. The two inner shells of krypton are like the two shells of argon, but in addition it has a third shell containing 18 electrons. Two of these electrons are located at the ends of the

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* If, as Rydberg believes, there are two undiscovered elements of atomic weights less than that of hydrogen, then this exception in the case of the innermost cells may be avoided.

polar axis while the other sixteen are placed symmetrically to the axis and to the equatorial plane and to the electrons in the inner shells. In all probability four of the eight electrons in each hemisphere are located in the same plane as those in the second shell, while the other four are in planes making an angle of 45 deg. with these.

Xenon is like krypton except for the addition of another layer (IIIb) of electrons in the third shell.

Niton has in addition to the three shells of xenon a fourth shell containing 32 electrons, 16 for each hemisphere. We have no data by which to determine the exact arrangement of these, but it is obvious that the 16 can be arranged with a high degree of symmetry with respect to the underlying layer of eight electrons (in each hemisphere).

The following postulate deals with the forces and tendencies which govern the arrangement of electrons in the outside layer of atoms other than those of the inert gases.

Postulate 5. It is assumed that electrons contained in the same cell are nearly without effect on each other. But the electrons in the outside layer tend to line themselves up (in a radial direction) with those of the underlying shell, because of a magnetic field, probably always to be associated with electrons bound in atoms (Parson's magneton theory.) This attraction may be more or less counteracted by the electro-static repulsion between the outside electrons and those in the underlying shell. The electrons in the ourside layer also repel each other and thus tend to distribute themselves among the available cells so as to be as far apart as possible. The actual positions of equilibrium depend on a balance between these three sets of forces together with the attractive force exerted by the nucleus.

Postulate 6. When the number of electrons in the outside layer is small, the magnetic attraction exerted by the electrons of the inner shells tends to predominate over the electrostatic repulsion, but when the atomic number and the number of electrons in the outside layer increase, the electrostatic forces become the controlling factor. As a result, when there are few electrons in the outer layer these arrange themselves in the cells over those of the underlying shell, but where the outside layer begins to approach its full quota of electrons the cells over the underlying electrons tend to remain empty.

Postulate 7. The properties of the atoms are determined by the number and arrangement of electrons in the outside layer and the ease with which they are able to revert to more stable forms by giving up or taking up electrons, or by sharing their outside electrons with the atoms with which they combine. The tendencies to revert to the forms represented by the atoms of the inert gases are the strongest, but there are a few other forms of high symmetry such as those corresponding to certain possible forms of *Ni*, *Pd*, *Er* and *Pt* atoms towards which atoms have a weaker tendency to revert (by giving up electrons only).

We may now apply these seven postulates to derive the properties of the chemical elements. We will first go through the list of elements dealing only with broad features and will later consider the properties of certain elements in more detail. At present we will confine our attention to the properties of the elements in atomic condition. We shall discuss only their tendencies to take up or give up electrons. The properties of the elements in solid or liquid form, or in their compounds, involve forces acting between different atoms, and, therefore, can be best considered after we have discussed the formation of molecules. The properties of the atoms up to argon fit in well with even the older arrangements of the periodic table. In fact, the present theory and Lewis' theory resemble each other very closely as far as their application to these first 18 elements is concerned.

Table I to which it will be convenient to refer frequently during the following discussion, contains a list of all the elements, arranged in order of their atomic numbers. The table is designed to show the way in which the electrons are arranged in the different shells. The numbers forming the first horizontal line denote the number of electrons in the outside layer of the atom. The first vertical column gives the index number of this outside layer. Thus boron has three electrons in the IIa layer, chromium has six in the IIIa layer.

Hydrogen ($N = 1$) has a single electron. It is therefore (Post. 1 and 7) unsaturated and tends to take up an electron in order to assume the symmetrical form characteristic of helium. The valency of hydrogen is therefore unity.

With helium ($N = 2$) the first shell is completed. Beyond this point any additional electrons must go into the first layer of the second shell (IIa). There are eight cells in this layer (Postulate 3) so that eight electrons can be added before the atoms again acquire the stability of an inert gas. In lithium ($N = 3$) the single electron in the second shell is easily detached so that the atom reverts to the stable form that corresponds to helium, thus forming a univalent cation. In Fig. 1 the positive and negative valences of the elements are plotted against their atomic numbers.* It is seen that up to $N = 17$ the maximum positive valency increases regularly up to the halogens (with the exception of oxygen and fluorine). This maximum valency is determined by the number of electrons which are given up when the atom reverts to that of the next lower inert gas.

In beryllium and boron the properties are determined largely by the ability of the atom to revert to the form corresponding to helium. The actual arrangement of the electrons in the atoms of these elements is thus of little significance. In carbon the four electrons in the second shell tend to arrange themselves (Postulate 5) at the corners of a tetrahedron for in this way they can get as far apart as possible. With nitrogen no symmetrical arrangement of the five electrons is possible. We shall see that this leads nitrogen to form a series of very unusual compounds. Whereas the properties of the elements from lithium up to carbon vary in a rather regular progression, the properties of carbon and nitrogen form a very sharp discontinuity. The constant valency of carbon—the variable valency of nitrogen; the high melting point of carbon; the low melting point of nitrogen, the very great inertness and stability of most carbon compounds; the very great activity and often explosive properties of nitrogen compounds—all these illustrate this fundament break in properties. We shall see that a somewhat similar break occurs in each case where the atom becomes equally unsymmetrical, namely, in the fifth element of each succeeding shell, thus the breaks occur at nitrogen IIa, phosphorus (IIb), vanadium (IIIa), columbium (IIIb), praseodymium (IVa).

FIRST LONG PERIOD

Beyond argon we soon come [illegible] where most periodic relations be[illegible]. It will therefore be well to examine the [illegible] theory rather critically.

With potassium we begin to form [illegible] shell, the third. There are now cells enough to hold nine electrons in each hemisphere (Postulate 3.) The first few electrons arrange themselves in much the same way as in the first two periods. Thus *K*, *Ca*, *Sc* have properties closely related to those of *Na*, *Mg* and *Al*. In the first two periods the properties of the atoms just beyond *C* and *Si* were electronegative in character, because their atoms tended to assume the stable forms corresponding to *Ne* and *Ar* by taking up electrons. But in the third period the conditions are quite different. Thus in the atoms of the eighth element of this period, *Fe*, only four out of the nine outside cells in each hemisphere contain electrons. This atom therefore does not have the stability of those of the inert gases and there is thus little tendency for the elements of lower atomic number to take up electrons. The elements *Ti*, *V*, *Cr*, *Mn*, have therefore predominantly electropositive character. In Table I the differences between the properties of these elements and those of the corresponding elements in the earlier periods is indicated by the heavy lines enclosing these elements. These lines also express the mutual resemblance between the elements.

We can go much further in predicting the properties. The maximum valency of the elements is determined by the ability of their atoms to revert to *Ar*, thus *V* has a valency of five, *Cr* six, and *Mn* seven. It will be shown that in the formation of acid radicals with high valencies the electrons, although they are given up to oxygen atoms, yet remain within the field of force of the original atom. In other words, the acid forming atoms share their electrons with oxygen atoms but do not lose them completely. In compounds in which these high valencies occur the properties are like those of the corresponding elements of the previous period. Thus vanadates resemble phosphates, chromates resemble sulphates and permanganates are like perchlorates. But when these elements have other valencies their properties do not show such relationships.

The electropositive character of *K*, *Ca* and *Sc* is determined by the ease with which the atoms of these elements revert to *Ar*. Elements like *V*, *Cr* and *Mn*, however, cannot form positive

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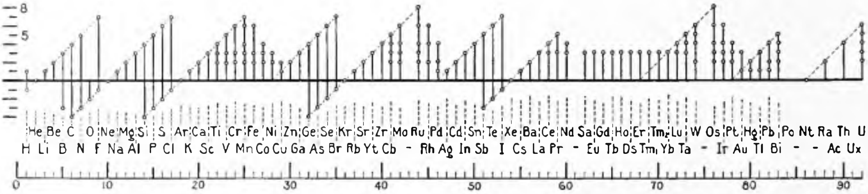
* This figure is taken with some modifications from I. W. D. Hackh. This Journal, 40, 1024 (1918).

ions by reverting to *Ar* for they would have to give up completely five, six and seven electrons respectively. The large electrostatic forces involved prevents the formation of ions with such large charges. The electropositive character of these elements must manifest itself, therefore, by the formation of ions with fewer charges. The tendency to give up electrons is dependent on the presence of electronegative elements capable of taking up the electrons.* In general, we may suppose that the atoms in a metal are held to each other by very strong forces as indicated for example by the high heats of evaporation. If the metal goes into solution a large amount of energy must be expended in separating these atoms and in removing some of their electrons. This energy is supplied by the energy of combination of the electronegative elements with the electrons separated from the atoms when they go into solution in the form of ions. Now, if a metal forms divalent ions, more energy can be supplied than if it forms univalent ions. On the other hand, it will be more difficult to separate two electrons than one electron from an atom. Thus we may suppose in a given case that univalent ions will not form because the energy supplied by the combination of a single electron with the electronegative atom is not sufficient to separate the metal atom from the others. On the other hand, quadrivalent ions may not form because the energy necessary to separate four electrons from the atom may be greater than that which can be supplied by the combination of the four electrons with the electronegative element.† It may happen, however, that both divalent and tervalent ions can form with about equal ease.



As a matter of fact, if we examine Fig. 1 we see that the elements *V*, *Cr*, *Mn*, *Fe*, all form divalent and tervalent cations, but form no univalent or quadrivalent ions in solution. The fact that they all form ions of the same valency with so nearly the same ease shows that the stability of these electrons in these atoms is very nearly the same. But this is just what our theory would lead us to expect.

For the elements under consideration only five to eight out of the 18 cells in the third shell are filled with electrons. Furthermore, the tendency of the electrons to line up (Postulate 6) with the underlying electrons of the second shell is gradually being weakened by the mutual electrostatic repulsion. Therefore, the tendencies of these elements to give up electrons do not differ greatly. The lack of definite forces to determine the distribution of the electrons among the cells renders these elements (according to a theory of Lewis)‡ capable of absorbing light in the visible spectrum. We thus find that they all form colored salts. To quote from Lewis: "The difficulty * * * * * * lies in the fact that the kernel of these atoms is not uniquely and permanently defined. It seems probable that in these elements there is a possibility of the

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* The form sometimes given to Nernst's theory by which the tendency to form ions is due to a solution pressure cannot correspond to the true mechanism of ionization. The real tendency of such a substance as potassium to give off electrons is measured by the Richardson work function as determined from the electron emission in high vacuum. The tendency for single atoms of potassium to give off electrons is measured by the ionizing potential. In both cases an energy must be expended to separate electrons from potassium which corresponds to a difference of potential of a couple of volts. I have previously discussed at some length the general theory underlying this statement (Langmuir, Trans. Amer. Electrochem. Soc., *29*, 125 (1916).

† It should be kept in mind that the work which must be done to separate electrons from an atom increases rapidly with the number removed. Thus if 1 represents the work done to remove one electron, the work done to remove the second is 2, the third 3 and the fourth 4. To remove four electrons the total work is thus 10 times that needed to remove one. The energy supplied by the formation of the anions increases, however, in direct proportion to the number of electrons removed. To take a concrete example let us assume that in terms of the energy units chosen above the formation of each anion supplies 2.7 units while the separation of the metal atoms from each other requires the expenditure of 2 units per atom. Then the free energy supply and consumption for the differently charged cations are

Number of electrons	0	1	2	3	4	5
Energy supplied........	0	2.7	5.4	8.1	10.8	13.5
Energy consumed........	2.0	3.0	5.0	8.0	12.0	17.0

In this case, therefore, there is sufficient energy to form the divalent or tervalent ion but not sufficient to form the univalent, quadrivalent or quinquivalent ion.

‡ See also Bichowsky, Jour. Amer. Chem. Soc., *40*, 500 (1918).

transfer of electrons either from one part of the kernel to another, or between the kernel and the outer shell, or possibly between two separate outer shells of the same atom and that electrons which are suspended midway between two such stages are responsible for this absorption of light in these cases." According to the present theory the absorption is caused by the transfer of electrons between different parts of the same outside shell or is possibly due to the ease with which an electron is gained or lost by the outside shell. There is no necessity for, and in fact every probability against, the kernel (*i.e.*, the inner shells) being concerned in this process.

In the atoms of iron there are eight electrons in the third shell, or four in each hemisphere. According to Postulate 6 the magnetic forces will make these electrons take positions as close as possible to those of the underlying shell. We may therefore picture the structure of the iron atom as follows. Close to the nucleus are two electrons. The 24 remaining electrons arrange themselves in three layers at the corners of three concentric cubes (slightly flattened) whose diagonals coincide. Although this atom possesses about as high a degree of symmetry as that of argon it differs radically from the latter in that the outer shell is not saturated, only four of the nine cells in each hemisphere being occupied by electrons (Postulate 3). Furthermore, the number of electrons in the outside shell is beginning to be so great that the electrostatic repulsion (Postulate 6) tends to decrease the stability of this arrangement. These are the fundamental reasons why the elements of smaller atomic number like *Cr* and *Mn* do not exhibit the electronegative properties of *S* and *Cl*.

In cobalt and nickel, whose atomic numbers are respectively one and two units larger than that of iron, the extra electrons can no longer be arranged over those in the underlying shell. Let us consider the way that the electrons in nickel arrange themselves. In the outside shell there are five electrons in each hemisphere and these tend to arrange themselves over the underlying four electrons (IIb). The only position of reasonable symmetry which the extra electron can take is directly over the center of the square formed by the four electrons of the second shell. In other words, the electron goes into the polar axis of the atom. In cobalt there is an electron at one end of the polar axis but not at the other.

The present theory thus explains in a perfectly satisfactory way the anomalous position of *Fe*, *Co* and *Ni* in the periodic table. We shall see that it also accounts for their unusual magnetic properties.

The ordinary chemical properties of these three elements resemble those of *Cr* and *Mn* except that they have lost most of the acid forming properties because they are so far removed from *Ar* that they cannot revert to it. Thus these three elements never show valencies of eight, nine and ten and do not form acids corresponding to chromates and permanganates. They form predominantly salts in which they exist as divalent or trivalent cations and for the same reasons as those discussed in connection with *V*, *Cr* and *Mn*. The colors of their salts is even more marked than those of the chromium and manganese cations which indicates that their electrons are even more loosely bound. With nickel the number of electrons is so great that the electrostatic forces seriously oppose the magnetic forces (Postulate 6). The introduction of the electrons in the polar axis also tends to force the other electrons away from their positions over the underlying electrons and thus still further weakens the magnetic forces. The effect is thus to bring about a rearrangement of the electrons so that the square containing the four electrons in each hemisphere, tends to revolve 45 deg. about the polar axis. This arrangement, which we may call the β form, has a higher degree of symmetry than the α form previously considered, in that all the electrons in the β form are as far from the underlying ones as possible, while in the α form one electron was far from, and the other four were close to, the inner ones.

According to Post. 3 we should look upon the transformation from the α to the β form as involving the passage of electrons between different cells in the outside layer. It is perhaps best to imagine that it is the empty cells which arrange themselves over the underlying electrons in the β form.

The β form of the *Ni* atom has a symmetry which exceeds that of any other atom between *Ar* and *Kr*, with the possible exception of *Fe*. Thus the atoms of the elements above *Ni* in giving up electrons tend to revert to either *Ni* or *Fe*. But by the time we get to elements above *Ni* the large nuclear charge causes the electrostatic forces to predominate over the magnetic so that the tendency to revert to iron is eliminated.

As a matter of fact, by referring to Fig. 1, we find that copper (cuprous) has a valency of one, zinc has two, gallium three, etc., right up to selenium six. These elements therefore all tend to give up electrons in such a way that their atoms revert back to the symmetrical β form of the nickel atom. It must be remembered that after these atoms have given up their extra electrons their outside layers contain the same number of electrons as the nickel atoms but they differ from the latter in that the charge on the nucleus is greater and therefore there is a much greater tendency for the β form to be the more stable form.

The tendency of the elements above nickel to revert to the β form of nickel is expressed in Table I by placing *Ni* β in the same vertical column as the inert gases. The horizontal lines enclosing these elements indicate the distinction between the structure of *Ni* β and atoms of the inert gases.

In the case of copper we find that the ability to form an ion having an α form is not wholly lost. Thus copper forms divalent ions. The cupric ions form a continuation of the family of similar elements which extend from *V* to *Ni*, but the cuprous salts form a radical departure from this series. The electrons are given up in the formation of cupric ions not because there is any inherent stability in the *Co* atom to which it reverts but for the same reason that *Cr*, *Mn*, *Fe*, *Ni* and *Co* form divalent ions. It is interesting to note that the cupric salts are highly colored and in many ways resemble nickel salts. The cuprous salts on the other hand resemble those of no element thus far considered. It is true the atoms have the same valency as those of the alkali metals and that the ions are colorless in both cases showing that all electrons are firmly held. But the solubilities of the salts are very radically different. Now this is just the kind of difference we should expect from the difference between the structure of *Ni* β and the atoms of the inert gases. The atoms of these gases are characterized by weak secondary valence forces (low boiling points, etc.), whereas atoms having only about half of the cells in the outside shell filled have strong residual fields of force. The properties of the alkali metals are therefore determined almost wholly by the electrostatic charges on their ions, but with ions like that of univalent copper there is in addition the residual field of force due to the large number of unsaturated electrons. The cuprous ion thus tends to form insoluble solid salts and many addition products while the alkali metals do neither.

With zinc we have completely broken away from the tendency to variable valence. The salts are now all colorless. The tendency to form molecular compounds (secondary valence) still distinguishes this element from the more purely electropositive metal, like *Ca*.

Germanium is interesting because it begins to acquire an electronegative character because of its ability to assume the form of *Kr* by taking up four electrons. It thus resembles *C* and *Si* in forming a volatile hydride whereas such a tendency is absent in case of *Ti*.

In *As*, *Se* and *Br* because of the proximity of *Kr*, the electronegative character predominates and these elements thus closely resemble *P*, *S* and *Cl*. But their tendency to form insoluble secondary valence products distinguishes them from these other elements.

Magnetic Properties[*]

Before proceeding with the discussion of the elements beyond *Kr* let us consider the magnetic properties of the elements of the first long period. We have seen that the structures of the atoms of *Fe*, *Co* and *Ni* differ from that of all the elements so far considered in that there are 24 electrons arranged at the corners of three concentric cubes. Furthermore, our theory leads us to believe that they are held in these positions by magnetic forces. It is significant also that Parson[†] was led to assume that the magnetic properties of iron were conditioned by the existence of four concentric shells of eight electrons each and that these electrons exerted magnetic forces on each other. Hull[‡] in a study of the crystal structure of iron by the X-ray method found that the atoms of iron are arranged according to a centered cubic lattice, that is, each atom is surrounded by eight others in directions corresponding to the diagonals of a cube. Hull also found that the intensities of the lines in the X-ray spectrum were best accounted for on the assumption "that eight of the 26 electrons in each atom are arranged along the cube diagonals at a distance from the center equal to one-fourth the distance to the nearest atom. * * * * * * If all the electrons are displaced from the center of the atom along the cube diagonals in four groups of 2, 8, 8, 8 at distances $\frac{1}{32}$, $\frac{1}{16}$, $\frac{1}{8}$, and

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[*] Most of the data used in the following pages have been taken from the excellent review of "Theories of Magnetism" by S. Dushman (GENERAL ELECTRIC REVIEW, May, August, September, October and December, 1916).

[†] Smithsonian Miscel. Collections, Vol. 65, No. 11 (1915).

[‡] *Physical Review*, 9, 84 (1917).

¼ respectively of the distance to the nearest atom, all the observed facts are accounted for within the limit of experimental error." The structure thus proposed by Hull is identical with that to which we are led by our present theory, except that we should expect the radii of the electron shells to be more uniform than the values given by Hull. However, this is a point of smaller significance. It is possible that the thermal agitation of the outside electrons which are not under as strong constants as the others may somewhat modify Hull's results. It should be noted that Hull (*Physical Review 10*, 691 (1917) has found that nickel atoms arrange themselves in a crystal in a similar way to those of iron. He has not, however, determined the probable positions of the electrons.

The ferromagnetic properties of *Fe*, *Co* and *Ni* undoubtedly depend not only on the arrangement of the electrons in the atom but also on the arrangement of the atoms with respect to each other. Hull's results indicate that there are six electrons in a line between the centers (nuclei) of each pair of adjacent iron atoms. The two which correspond to the outside layer of electrons in the atoms are held by weak constraints, but the inner ones are probably held at least as firmly as those in argon. The fact that the ferromagnetic properties of the metals disappear when these are heated above certain critical temperatures, even without change in crystalline form, indicates that the outside electrons are subject to thermal agitation which destroys the regular structure necessary for the development of ferromagnetism.

It is suggestive that the next most strongly ferromagnetic substances, besides those considered, are the Heusler alloys which consist of manganese and copper together with smaller amounts of aluminum, arsenic, etc. Copper having too many electrons to give a ferromagnetic metal may supply enough electrons to the manganese atoms to make them take a structure like that of iron. Other elements than copper such as *P* or *N* also give ferromagnetic alloys with manganese. Similarly *Cr* or *V*, although to a lesser degree, may form magnetic alloys when combined with other elements. In all these cases it is probable not only that the outer shell of the *Mn*, *Cr* or *V* atom takes up electrons to revert to *Fe*, but that the atoms arrange themselves in a crystal structure which helps to bring out their magnetic properties (perhaps always the centered cubic lattice).

When *Fe*, *Co* and *Ni* have been heated above their critical temperatures (900 deg. for *Fe*, 1075 deg. for *Co* and 340 deg. for *Ni*) they lose their ferromagnetic properties and become paramagnetic and thus resemble the metals of lower atomic number. The magnetic susceptibility of the elements of the first long period varies in a remarkable manner as the atomic number of the elements increases.* Argon is very strongly diamagnetic, *K* is already slightly paramagnetic, and the succeeding elements *Ca*, *Ti*, *V*, *Cr* and *Mn* show a very rapid but steady rise in paramagnetism until we come to the strongly ferromagnetic metals *Fe*, *Co*, *Ni*. Beyond *Ni* there is a sharp discontinuity for the next element copper, is slightly diamagnetic. The rest of the elements up to *Br* have about the same susceptibility as copper, that is, all are slightly diamagnetic.

The sharp break in the curve between *Ni* and *Cu* is just what our theory would lead us to expect and it affords striking indications of the correctness of the viewpoint. Still more striking confirmation is to be had in the fact that cupric salts are rather strongly paramagnetic, while cuprous salts are diamagnetic. We have already seen that in the cuprous ion the atom reverts to the β form of *Ni*, while in the cupric salts it has properties which correspond closely with those of the divalent ions of *Fe*, *Co* and *Ni*. In other words, in metallic copper and in cuprous salts the electrostatic forces predominate, as we have already seen, in determining the positions of the electrons while in cupric salts the magnetic forces still play an important part.

It may be asked why argon which contains electrons arranged at the corners of cubes, does not resemble iron in its magnetic properties. According to Langevin's theory of diamagnetism and paramagnetism, the presence of electronic orbits in an atom does not in general cause paramagnetism. If the orbits are so arranged in the atom that they have a resultant magnetic moment equal to zero, then the effect of an increase in the external field is to increase the diameters of some of the orbits and decrease others in such a way that diamagnetism results. It is only when the external field is able to change the direction of the axis of rotation that paramagnetism can occur. In the atoms of the inert gases the electrons (or magnetons

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* A curve giving the susceptibility of all the elements as a function of the atomic number has been published by Harkins and Hall. Jour. Amer. Chem. Soc., 38, 169 (1916).

since we assume they have a magnetic field of their own) being under very large constraints, arrange themselves so that the magnetic field of the atoms is nearly wholly internal, in other words, so that the magnetic moment is zero. Such atoms are diamagnetic. It is only where the electrons are under much weaker constraints, but yet are held by magnetic rather than by electrostatic forces that we should expect paramagnetism.

Second Long Period

Beyond *Kr* the second layer in the third shell begins to be filled. The first of the 18 electrons needed to complete this layer (Postulates 3 and 4) arrange themselves with respect to the eight electrons in the second shell (Postulate 5), just as in the first long period, so that *Ru* has a structure analogous to *Fe*. The 18 electrons in the first layer of the third shell, however, make the symmetry much less perfect than it was in the case of *Fe*. The properties of these elements are more complicated than those of the first long period and there is a greater tendency to form insoluble salts and secondary valence compounds. The elements up to *Ru* are slightly diamagnetic or slightly paramagnetic, but from *Ru* to *Pd* there is a large increase in susceptibility. This reaches a sharp maximum with *Pd* and then drops suddenly to a negative value for *Ag*. There is thus the same marked discontinuity as was observed between nickel and copper. But the susceptibility of *Pd* is only about equal to that of *Mn* and thus of quite a different order of magnitude from that of *Fe*, *Co* or *Ni*.

According to our theory there can be no doubt but that the extra two electrons in *Pd* arrange themselves in the polar axis. In the elements beyond this point the electrons around the polar axis seek positions as far as possible from the electrons in the second shell, so that the atoms tend to revert to a β form of the *Pd* atom. Thus *Ag* forms colorless univalent ions, *Cd* divalent, etc. These properties and their explanation are so nearly like those of the first long period that we need not consider them in more detail.

The "Rare Earth" Period

After xenon the fourth shell begins. There are 32 cells to be filled by electrons before the atom again reaches the stability of an inert gas (niton). The first three or four elements have predominantly electropositive character and form positive ions whose valency increases by steps of one due to the tendency to revert to xenon. As more electrons are added they will tend, according to Postulate 6, to arrange themselves over the 18 of the underlying third shell, just as in the first long period the electrons arranged themselves over the eight underlying ones in the second shell. This process yields a series of similar elements having about the same valency, just as we found among the elements from *Ti* to *Ni*. By referring to Table I we see that this family of elements corresponds exactly with the rare earth elements. The eighteenth element from xenon is lutecium, and this marks definitely the last of the rare earths.

Since the forces holding these 18 electrons are predominantly magnetic and since the constraints are not of the rigid kind characteristic of the inert gases, we should expect these elements to be paramagnetic. As a matter of fact, the rare earths are the most strongly paramagnetic of any of the elements except those from *Mn* to *Ni*. Even *Ba* begins to show a perceptible paramagnetism (*Sr* is diamagnetic). The susceptibility of only a few of these metals have been determined but the atomic susceptibilities of cerium, praseodymium, neodymium and erbium are respectively 2, 7, 11 and 7 times that of manganese. Gadolinium sulphate lies between ferric sulphate and manganese chloride in magnetic properties.

It seems probable that the most marked magnetic properties occur with the elements samarium, europium and gadolinium for these are the eighth, ninth and tenth elements from xenon and thus should correspond most closely in their structures to *Fe*, *Ni* and *Co*. In samarium there is probably a slight tendency for the eight electrons in the outside layer to arrange themselves at the corners of a cube, while in gadolinium the two extra electrons are in the polar axis. But in other properties these three elements should not differ radically from the other rare earths.

By the time the 18 electrons have been added the electrostatic forces have begun to oppose the magnetic attraction to a marked degree. Therefore, when in tantalum an additional electron is added, the whole outside shell tends to rearrange itself so that the empty cells come opposite the electrons of the underlying shell. The most symmetrical arrangement of this kind will occur when there are 18 empty cells opposite the 18 underlying electrons. The atomic number of niton in which the fourth shell is complete is 86—therefore, an element having 18 empty spaces in the fourth shell will have an atomic number 68 corresponding to erbium. The structure of this β form of erbium has the same kind of stability for large nuclear charges that we found in the cases of β-nickel and β-palladium. We may therefore expect that the atoms beyond lutecium will show a marked tendency to revert to β-erbium. Thus tantallum with an atomic number 73 tends to lose five electrons and tungsten to lose six. The properties of *Ta* and *W* thus resemble those of columbium and molybdenum, but because of the complexity of the atom to which they revert, and in general because of the large numbers of electrons in their outside shells, their secondary valence forces are more highly developed.

In accordance with the marked change in the electron arrangement beyond lutecium we find that the paramagnetism is practically absent in the elements tantalum and tungsten.

The β form of the erbium [illegible] 18 empty cell arranged over the [illegible] the third shell. When electrons are [illegible] we pass to elements of larger [illegible] the first eight of them naturally [illegible] arrange themselves at the corners [illegible] because of the magnetic attraction [illegible] eight electrons in the second shell. The two electrons for reason of symmetry [illegible] arrange themselves in the polar axis. We thus have the three "eighth group" elements osmium, iridium and platinum. Because of the weakness of the forces acting between the fourth and the second shell we should not expect strongly developed magnetic properties in these elements. As a matter of fact osmium and iridium have susceptibilities nearly equal to zero, but there is a small but sharp rise at platinum making this element about one-fourth as paramagnetic as palladium. The next elements gold, mercury, etc.,

TABLE I

TABLE OF THE ELEMENTS ACCORDING TO THE ARRANGEMENT OF THEIR ELECTRONS

Outside Layer	N	E = 0	1	2	3	4	5	6	7	8	9	10
I			*H*	*He*								
IIa	2	*He*	*Li*	*Be*	*B*	*C*	*N*	*O*	*F*	*Ne*		
IIb	10	*Ne*	*Na*	*Mg*	*Al*	*Si*	*P*	*S*	*Cl*	*A*		
IIIa	18	*A*	*K*	*Ca*	*Sc*	*Ti*	*V*	*Cr*	*Mn*	*Fe*	*Co*	*Ni*
			11	12	13	14	15	16	17	18		
IIIa	28	*Niβ*	*Cu*	*Zn*	*Ga*	*Ge*	*As*	*Se*	*Br*	*Kr*		
IIIb	36	*Kr*	*Rb*	*Sr*	*Y*	*Zr*	*Cb*	*Mo*	43	*Ru*	*Rh*	*Pd*
			11	12	13	14	15	16	17	18		
IIIb	46	*Pdβ*	*Ag*	*Cd*	*In*	*Sn*	*Sb*	*Te*	*I*	*Xe*		
IVa	54	*Xe*	*Cs*	*Ba*	*La*	*Ce*	*Pr*	*Nd*	61	*Sa*	*Eu*	*Gd*
			11	12	13	14	15	16	17	18		
IVa			*Tb*	*Ho*	*Dy*	*Er*	*Tm*	*Tm$_2$*	*Yb*	*Lu*		
		14	15	16	17	18	19	20	21	22	23	24
IVa	68	*Erβ*	*Tmβ*	*Tm$_2$β*	*Ybβ*	*Luβ*	*Ta*	*W*	75	*Os*	*Ir*	*Pt*
			25	26	27	28	29	30	31	32		
IVa	78	*Ptβ*	*Au*	*Hg*	*Tl*	*Pb*	*Bi*	*RaF*	85	*Nt*		
IVb	86	*Nt*	87	*Ra*	*Ac*	*Th*	*Ux$_2$*	*U*				

are distinctly diamagnetic. The same sharp break occurs here as we found between *Ni* and *Cu*, *Pd* and *Ag*, *Lu* and *Ta*, although its magnitude is much less. We may therefore assume that beyond platinum the electrons tend to rearrange themselves in a β form in which the ten electrons which have been added since erbium endeavor to get further away from those of the underlying electrons. The eight empty cells tend to take symmetrical positions in the atom probably at corners of a cube, and the cells containing electrons space themselves as best they can. The fact that an arrangement of this kind does not have nearly the symmetry which we found for the β form of the nickel atom is probably the explanation of the fact that the tendency of the succeeding elements to revert to this β form of *Pt* is much less marked than we observed in the cases of reversion to nickel, palladium and erbium. Thus we find that gold and mercury have variable valency differing in this respect from silver and cadmium. Thallium forms univalent and tervalent ions whereas indium forms only tervalent. Lead only exceptionally is quadrivalent, while this seems to be the normal condition of tin compounds. Thus stannous salts are strong reducing agents but divalent lead salts are not. Bismuth is normally tervalent and forms only a few very unstable compounds in which it is quinquivalent. Antimony on the other hand has about equal tendencies to be tervalent or quinquivalent.

There is an interesting sudden break in the susceptibility curve between lead and bismuth. Gold, mercury and thallium are very slightly diamagnetic, but bismuth is the most strongly diamagnetic element with the exception of the inert gases. In all of the elements between gold and niton the positions of the electrons are determined mainly by electrostatic forces (Postulate 6). But magnetic forces still tend to cause the electrons to arrange themselves in the eight available cells (in platinum) so that they will be placed as symmetrically as possible with respect to the underlying electrons. Now the four additional electrons (in lead) can arrange themselves in the eight spaces with reasonable symmetry, but the five electrons in bismuth cannot do so. The extra electron displaces the others and thus weakens the magnetic forces and strengthens the electrostatic. In agreement with this theory we find that there is a similar, although smaller, minimum in susceptibility at phosphorus, arsenic and antimony, the elements which also have atomic numbers three less than those of the following inert gases. We also find distinct maxima at germanium, tin and lead which have four electrons less than the inert gases which follow them.

The Uranium Period

With niton the first layer of electrons in the fourth shell is completed. As we add more electrons we should expect to go through the same cycle as that of the rare earth period. The properties of the first two or three elements are determined primarily by the ease with which they give up electrons. Thus radium very closely resembles barium, differing from it in chemical properties only by its slightly greater secondary valence which manifests itself here by slightly decreased solubility of its salts.

Thorium resembles cerium and zirconium, the elements of similar constitution.

Beyond thorium we might expect another series of elements analogous to the rare earths up to an atomic number of 104 if the nuclei of such elements were stable enough to exist under ordinary conditions. However, the properties of uranium do not bear out this supposition. Uranium is not closely related in its properties to neodymium, nor in fact does it closely resemble any other element. It would seem therefore, that it is not safe from our present knowledge to make definite predictions as to the properties of other possible elements of this period.

(To be Continued)

Methods for More Efficiently Utilizing Our Fuel Resources

PART XXIX. THE COAL RESOURCES AND TRANSPORTATION FACILITIES IN ALASKA

By F. P. Coffin

Research Laboratory, General Electric Company

The Alaskan coal fields contain the only accessible deposits of high grade steam, bituminous coal on the shores of the Pacific Ocean; as well as extensive deposits of lignite. Their development has been delayed by unsatisfactory land laws and by the lack of railways. Congress has passed new laws and transportation facilities are now available. The coal mining industry is being developed to supply the local requirements. If coal can be produced economically it can ultimately be shipped south to supply the Pacific Coast market.—Editor.

[1] Alaskan coal is of great value, but its extent and character have been much exaggerated. There are great quantities of lignite and low-grade bituminous coal in several parts of the Territory, but there are only two fields of accessible high-grade coal known in Alaska. Their location is shown on the map accompanying this article. The Bering River field is near Controller Bay. The Matanuska field is larger and may prove to be the more important. Both of these fields contain anthracite and high-grade bituminous coals.[1]

The development of these fields has been delayed by the lack of railways for transporting the coal over the relatively short distance to the coast. A branch of the new government railroad now taps the Matanuska coal field and several mines are now producing coal on a small scale. Another railroad is under construction which will tap the Bering River field.

MINING LAND LAWS

Former Unsatisfactory Laws

Development has also been delayed by the unsatisfactory state of the mining laws pertaining to the coal lands of Alaska prior to the year 1914.

[2] The first act, passed June 6, 1900, simply extended to Alaska the provisions of the coal-land laws in the United States. This law was ineffective, for it provided that only subdivided lands could be taken up, and there were then no land surveys in Alaska. The matter was rectified by the act of April 28, 1904, which permitted unsurveyed lands to be entered and the surveys to be made at the expense of the entrymen. Unfortunately, the law provided that only tracts of 160 acres could be taken up, and no recognition was given to the fact that it was impracticable to develop an isolated coal field requiring the expenditure of a large amount of money by such small units. Many claims were staked however, and surveys were made for patents. It was recognized by everybody familiar with the conditions that after patent was obtained these claims would be combined in tracts large enough to assure successful mining operations. No one experienced in mining would, of course, consider it feasible to open a coal field on the basis of single 160-acre tracts. The claims for the most part were handled in groups, for which one agent represented the several different owners. Unfortunately, a strict interpretation of the statute raised the question whether even a tacit understanding between claim owners to combine after patents had been obtained was not illegal. Remedial legislation was sought and enacted in the statute of May 28, 1908. This law permitted the consolidation of claims staked previous to November 12, 1906,* in tracts of 2560 acres. One clause of this law invalidated the title if any individual or corporation at any time in the future owned any interest whatsoever, directly or indirectly, in more than one tract. The purpose of this clause was to prevent the monopolization of coal fields; its immediate effect was to discourage capital. It was felt by many that this clause might lead to forfeiture of title through the accidents of inheritance or might even be used by the unscrupulous in blackmailing. It would appear that land taken up under this law might at any time be forfeited to the government through the action of any individual who, innocently or otherwise, obtained interest in more than one coal company. Such a title was felt to be too insecure to warrant

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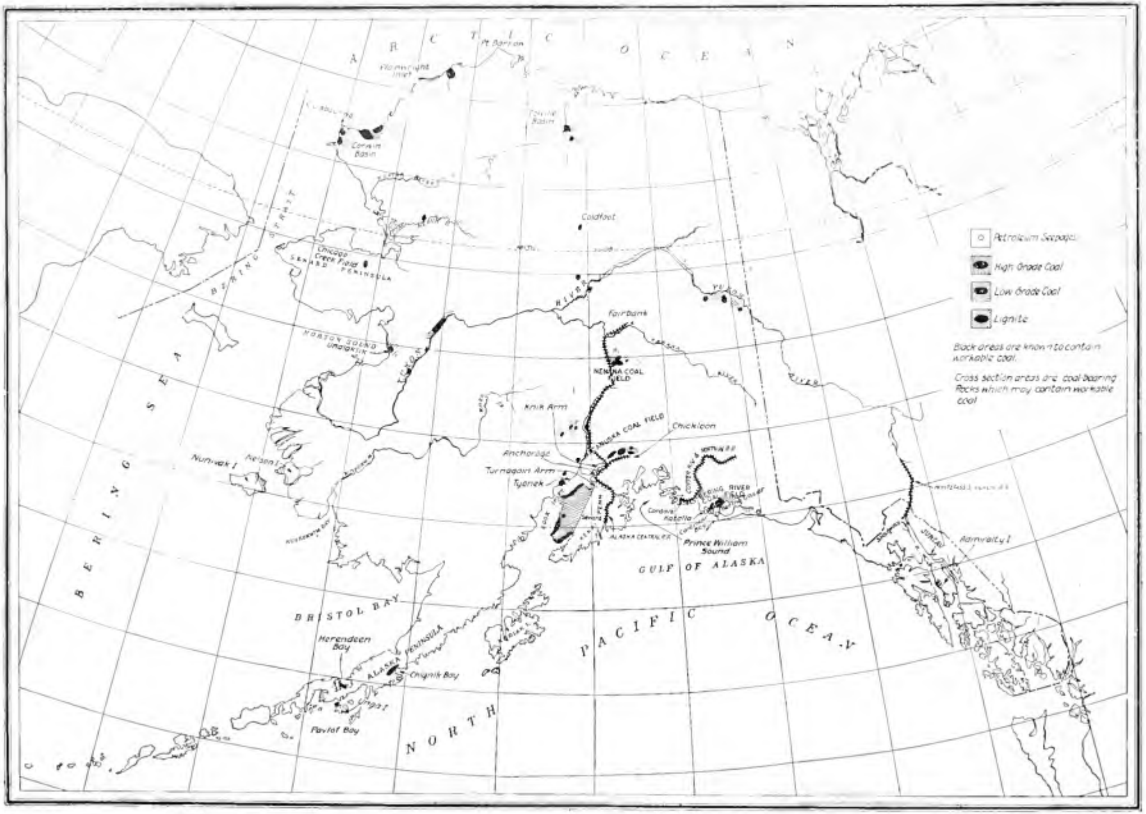
* All coal lands of Alaska were withdrawn from location and entry on November 12, 1906.


ARCTIC OCEAN
Pt Barrow
Wainwright Inlet
Corwin Basin
Colville Basin
Coldfoot
Chicago Creek Field
SEWARD PENINSULA
BERING STRAIT
NORTON SOUND
Unalaklik
YUKON RIVER
Fairbank
NENANA COAL FIELD
TANANA RIVER
Knik Arm
MATANUSKA COAL FIELD
Chickaloon
Anchorage
Turnagain Arm
Tyonek
COOK INLET
Seward
KENAI PENINSULA
ALASKA CENTRAL R.R.
COPPER RIV. & NORTHW. R.R.
BERING RIVER COAL FIELD
Cordova
Katalla
Controller Bay
Prince William Sound
GULF OF ALASKA
WHITE PASS & YUKON R.R.
Skagway
JUNEAU
Admiralty I
Nunivak I
Nelson I
BERING SEA
BRISTOL BAY
Herendeen Bay
ALASKA PENINSULA
Chignik Bay
Unga I
Pavlof Bay
NORTH PACIFIC OCEAN
○ Petroleum Seepage
High Grade Coal
Low Grade Coal
Lignite
Black areas are known to contain workable coal.
Cross section areas are coal bearing Rocks which may contain workable coal

the large investments needed for mining developments.

[3] The net result of all this is that no titles to coal lands were passed. Meanwhile, a popular clamor was raised indiscriminately against all Alaskan coal claimants. The practice of locating coal lands through power of attorney, which is strictly legal and universally accepted in all mining law, was confused with the so-called "dummy entryman" practice, which was illegal. It is true that many of the coal-land claimants were non-residents, yet this was necessarily so, for the man who had the means necessary to provide for a survey, payments to the government, and the development work on a claim required before patent was issued usually did not follow the vocation of a prospector. The difference between the mining of coal and the mining of placer gold has not always been recognized. A placer claim may yield a profit to the prospector who has but a supply of provisions and a few simple tools, but as a necessary preliminary to coal mining at least several thousand dollars must be expended on each claim. Even after the money necessary to patent has been spent, no profit from mining can accrue until sufficient capital has been invested to provide equipment and transportation facilities. These explanations, obvious to every coal miner, are made because an idea seems prevalent that any individual prospector, after staking a coal claim, can proceed to develop it at a profit as he might a gold placer.[2]

[3] During 1914 Congress passed two laws—the Alaska Railroad Act and the Coal Leasing Act—that will mean much to the development of the resources of the territory. Under the Railroad Act, provisions were made for the construction of a railroad extending from Seward, on Resurrection Bay, inland to Fairbanks, a distance of 471 miles. The route selected is through the Susitna and Matanuska Valleys and taps the known coal fields that are situated in both these valleys. Work on this railroad has been pushed forward as rapidly as conditions would warrant, and there is now completed and in operation 255 miles of railroad. Transportation facilities are now available for coal mines situated at Matanuska and Chickaloon to Anchorage, a deep water port on Cook Inlet.[3]

Leasing of Coal Lands

[3] Under the Coal Leasing Act, provisions were made for the survey of coal deposits in Alaska and the leasing of coal units after the survey has been made. The law permits the leasing of coal areas in tracts not to exceed 2560 acres in extent, the lessor paying to the Government a royalty of not less than two cents per ton for all coal mined. It also provides for the granting of Free Use Permits, on tracts of ten acres or less, for the mining of coal for local use and for prospecting purposes. This allows the pioneer prospector to enter the field and ascertain to some degree the value and extent of his findings.

[3] A portion of the coal bearing lands in Alaska has already been surveyed and the leasing units made ready for entry. Twenty such units have now been laid out in the Matanuska field, on six of which coal mines are now being operated and producing coal. Before there can be any large producing mines, a great deal of prospecting, drilling and other development work must be performed. There is nothing to prevent the quick development of smaller mines that will be able to supply the local demands for fuel at the present, but the opening of coal mines on a large scale will require the expanding of the workings to a point where there is room for the miners to produce a large tonnage, all of which takes considerable time.

[3] The Government is operating and developing mines on three of the units in the Matanuska fields, the coal produced being used for the operation of the railroad and for fuel for construction equipment.[3]

[4] The President of the United States is required by the leasing act to "designate and reserve from use, or disposition, not exceeding 5120 acres of coal-bearing land in the Bering River field, and not exceeding 7680 acres of coal-bearing land in the Matanuska field," before opening the fields under the provisions of the act.

[4] It is recognized that if the government were to reserve the total acreage allowed by law and were to select those areas that are believed to be best suited for profitable mining, the result might be effectually to prevent coal mining in Alaska until such time as the government itself might undertake mine development and operation. The intention of Congress in passing the Alaskan coal-leasing law is believed to have been the promotion of the mining of coal in the Territory as early as possible to meet the demands of the government railroad, the Navy, and Alaskan consumers. The legal provision for government reservation furnishes a means for safeguarding the public interest in the future, when lack of compe-

tition or other exigency may necessitate government operation. The tracts now selected for reservation, in accord with this policy, are therefore such as are believed to possess the average rather than the highest value.[4]

Competition from California Oil

The third reason for the delayed development of the Alaskan coal fields has been the rapid development of the California oil industry and the consequent abundance of fuel oil on the Pacific coast.

Oil has supplanted coal in many fields and possesses advantages in economy and in convenience of handling. For example, it has supplanted coal on many of the western railroads and on the railroads in Alaska. It is used on most of the steamships in the Pacific coastwise service as well as on the steamers navigating the Yukon river. In the latter case, it supplanted Alaskan coal which was formerly mined from the local coal deposits along the Yukon.

The present high price of oil on the Pacific coast now puts the situation in a different light.

THE COAL FIELDS

Geologic Distribution of Coal

[2] The oldest coals known in Alaska are some which are of a high-grade bituminous character and occur near and south of Cape Lisburne, on the Arctic Ocean.[2] These were formed in the early part of the carboniferous age, which was the earliest period in which extensive coal deposits were formed anywhere. It was at this period in the earth's history that terrestrial vegetation became sufficiently developed to form extensvie peat deposits. Fossil plants collected at Cape Lisburne indicate that what is now Arctic Alaska has had a more temperate climate in past ages. Table I indicates that the various coal fields range in age all the way from the earliest to the most recent ages at which coal was formed.

Geographic Control of Development of Coal Fields

[2] Two great series of ranges, the Pacific mountain system on the south and west and the Rocky Mountain system on the north and east, traverse Alaska and divide it into three general geographic provinces. The southernmost of these provinces, here called the Pacific slope, is divided from a second province, called the central region, by a series of snow-covered ranges. This central region is separated from the third province, called the Arctic slope, by a second mountain barrier. The Pacific slope province includes the watersheds of all the streams flowing into the Pacific Ocean, and therefore a considerable part of the southern mountain system. The Pacific seaboard, except for the upper part of Cook Inlet, is open to navigation throughout the year. A number of transverse valleys and low passes break the continuity of the southern mountain barrier and thus afford routes of approach to the central region. Yukon and Kuskokwim rivers, which drain the central region, are, together with their tributaries, navigable for thousands of miles, but only for the summer months. The Arctic slope is accessible along its seaboard only for a part of the summer. While the mountains which bound it on the south are broken by many passes, railway connection with an open port on the Pacific will not be commercially practicable under any condi-

TABLE I

STRATIGRAPHIC POSITION OF ALASKA COALS[2]

System	Series	Character of Coal	Principal Distribution
Quarternary	Pleistocene	Lignitic	Yukon Basin and other parts of Alaska
Tertiary	Pliocene	Lignitic	Yakutat Bay and other localities
	Miocene or Eocene	Anthracite and bituminous	Bering River
	Eocene	Chiefly lignitic; also some bituminous and subbituminous	Throughout Alaska, notably on Cook Inlet and in Matanuska Valley, Susitna Valley, and Yukon Basin.
Cretaceous	Upper Cretaceous	Subbituminous and bituminous	Alaska Peninsula, Yukon and Colville Basins
Jurassic		Subbituminous and bituminous	Near Cape Lisburne
Carboniferous	Mississippian	Subbituminous Bituminous	Yukon River, 20 miles south of Cape Lisburne

tions that can now be foreseen. Evidently, then, geographic and climatic conditions have a dominating control of the utilization of Alaska's mineral fuel. In considering the use of Alaska's coal it is therefore necessary to take into account the distribution of the fields with reference to these conditions. By this means it can be determined which coals are available for present use and which are locked up by natural conditions until such time in the future as the price of fuel may make it commercially possible to bring them to market.[2]

Table II gives the distribution of the various coal fields.

Arctic Slope

[2] The coals of the Arctic slope lie north of the Arctic Circle. In areal extent, quantity, and quality of coal the Cape Lisburne field is the most important in northern Alaska. It includes high-grade bituminous coal.

"The scant evidence available points to the conclusion that a survey of the [illegible] region will show very large coal fields in this part of Alaska.[2] In the summer of [illegible] lignite was mined on the Kobuk River and shipped down stream to Kotzebue on the shore of Bering Sea."

[2] A little coal mining for local use has been carried on in the bituminous field near Cape Lisburne and in the lignitic field of Wainwright Inlet, but the region as a whole is practically untouched. It is certain that there will be no extensive mining in this northern field for many generations to come. These coals appear to be too inaccessible to invite exploitation, except for the local use of whalers and natives, under any demands that can now be foreseen. The chief diffi-

TABLE II

THE COAL FIELDS

	AREA SQ. MILES		GRADE OF COAL		Maximum Thickness of Veins in Feet
	Known	Possible	High	Low	
Arctic Slope					
Cape Lisburne Region	200	1200			
Cape Beaufort field	14	Large	B		1.5
Corwin Basin				B	12
Wainwright Inlet			L		
Colville Basin			L		
Kobuk River				L	
Central Province					
Nenana field, Tanana Valley	66	600	L		20–35
Washington & Coal Creek, Upper Yukon			L		
Nulato field, Lower Yukon				B	2–3
Kuskokwim Basin		Large	L		Thick
Kugruk River, Seward Peninsula	Small			L	80
Unalaklik, Bering Sea Coast	Small		L		
Nelson & Nunivak Islands, ditto	Unknown		L		
Pacific Slope					
Cook Inlet Region					
Matanuska field	100	50	A, B, L		5–25
Kenai Peninsula		2565	L		7–60 ft. total veins
Tyonek	Small		L		
Susitna Valley		Large	L		
Southeastern Alaska					
Bearing River field	44	40	A, B		3–25
Copper River Valley	Small		L		
Yakutat Bay	Small			L	
Admiralty and Kupreanoff Islands	Small			L	2–3
Alaska Peninsula	30	150			
Herendeen Bay	(This region only partly		B		
Chignik Bay	surveyed geologically)			B	2–7
Unga Island				L	[illegible]
Pavloff Bay				L	[illegible]
Kodiak Island			L		

* A = anthracite. B = bituminous coal. L = lignite.

culties in attempting to ship out this coal by vessels are, first, the lack of harbors, and, second, the fact that the open season for navigation is less than two months.[2]

Central Province

[2] The central province includes some bituminous and subbituminous coals on the lower Yukon, besides more extensive areas of a lignitic coal-bearing formation in the upper Yukon basin, notably in the Nenana basin and near the coast line of Bering Sea and elsewhere.

Fig. 2. Lignite Outcrop, Nenana Field

[2] Much of the coal of the central province is almost equally unavailable for export under present methods of utilization. It is chiefly lignite and is, therefore, not suitable for transportation to the seaboard, a distance of from 400 to 600 miles. In the absence of extensive forests these coals will in time, however, have great value for local consumption. The extensive peat deposits of the region are also a possible source of fuel.[2]

Yukon Region

[2] The Nulato region of the lower Yukon contains the best coal, but it is in beds from 2 to 3 feet thick, and such comparatively thin seams have not encouraged exploitation, especially as they appear not to have much continuity. Therefore, in spite of the high price of mineral fuel in this central region there has been but a small production, and that chiefly for the use of the Yukon River steamers, many of which now, however, burn California petroleum. The Nenana field is the most extensive and has the thickest beds, and merits a little more detailed description. It lies 20 to 40 miles south of Tanana River, between Nenana and Delta rivers.[2]

[7] The coals, which are all of lignitic character, occur in many beds of different thicknesses, the thickest measuring perhaps 30 or 35 feet, which are distributed rather uniformly through the coal measures. At least 12 coal beds are of workable thickness, and six or more measure over 20 feet.[7] One section on Healy Fork measured 60 feet.

[2] The total area known to be underlain by coal is 66 square miles, but the coal-bearing strata are exposed in an area of 600 square miles and are known to extend eastward into an unsurveyed area. The Nenana field therefore must include a very large amount of coal.[2] [7] It will probably at first be mined by drifts or slopes run from outcrops of coal on the sides of the valleys or by stripping. The abundance of easily accessible coal and the moderate size of the prospective markets make it certain that deep mining will not be necessary for many years.[7]

The government railroad, now under construction from Seward to Fairbanks, will pass by the Nenana coal field.

[7] The coal will probably be used as locomotive fuel, for generating power, and for thawing at the mines in Tanana Valley, as domestic fuel in Tanana Valley, and as fuel on Tanana River boats, and possibly on some of the Yukon steamers. Nenana coal, rather than the better and nearer Matanuska coal, should, if possible, be used on the greater part of the railroad, because the heavy freight traffic will be northbound and the southbound empties will be available for hauling coal.[7]

[2] Some of the lignitic coals of the upper Yukon should eventually find a local market when the scant supply of accessible timber approaches exhaustion. There is a constantly

increasing demand for power in the placer districts, and this can only be met either by developing water powers, which are not extensive, or by utilizing the coals. The low fuel values and the cost of transportation of these coals may lead to their transformation into electric power at the mines, to be transmitted to the placer camps. Some of the lignite fields are near enough to the placer fields to permit such utilization.[2]

Seward Peninsula

[2] The known coal-bearing areas of Seward Peninsula do not exceed a few square miles, and the coal is of a low grade. This coal, however, is important because it can probably be utilized locally to furnish power for mining purposes, instead of the higher grade coals that are now being brought in from outside sources. The important coals are those of Kugruk River, lying in the northeastern part of the peninsula. Here a lignitic coal bed has been opened which is over 80 feet in thickness, with only a few thin partings of bone and shale. Two small coal mines are being operated in this district, and their product is marketed at the near-by placer camps and is competing with higher-grade fuels transported from a distance. In considering the value of this coal it should be noted that most of Seward Peninsula is without timber, and that all mining operations must therefore depend on imported fuels or draw on this local supply of lignite.[2]

In the summer of 1918 lignite was mined at Unalaklik on Norton Sound and shipped by barges to Nome on the south coast of Seward Peninsula and to St. Michael near the mouth of the Yukon.[11]

A hydro-electric plant has recently been planned to supply power to the placer mining districts in the vicinity of Nome.

Pacific Slope

[2] It is evident that the coals of the Pacific slope province are at present of most importance. These include the lignitic or bituminous coals of southeastern Alaska, Cook Inlet, the Susitna basin, and the Alaska Peninsula, as well as the high-grade fuels of the Bering River and Matanuska fields. About 40 per cent both of the area known to be underlain by coal and of the estimated area of the total coal fields of the Territory falls in this province. It includes also at least 90 per cent of the known accessible bituminous and higher grade coals of the Territory. In considering this percentage of total coal area it should be noted that [illegible] part of Alaska, and there is [illegible] likelihood of future discoveries of coal [illegible] province than in the less explored [illegible] of central and northern Alaska. [illegible] as over 50 per cent of this province is geologically almost unknown, there is [illegible] reason to believe that future surveys [illegible] lead to the discovery of other coal-bearing areas.

Fig. 3. Lignite Outcrop, Nenana Field

[2] The known coal lands within these fields contain, according to the estimates, over 6,000,000,000 tons of coal of which 3,500,000,000 tons is of high grade. If the same ratio between tonnage and area holds in the unsurveyed fields, these figures should be multiplied by 10. It is probably safe to say that these fields contain 50 to 60 billion tons of coal and possibly much more.

[2] The Cook Inlet fields, as well as those of the Alaska Peninsula, lie on or close to tide-water

and, indeed, for the most part have good harbors, which are ice free throughout the year. These fields are admirably located as regards transportation; but unfortunately their coal is for the most part not of a quality to assure successful competition with other coals tributary to the Pacific Ocean.

[2] On the other hand, the Bering River and Matanuska fields furnish the only known source of high-grade fuels near either the eastern or the western shore of the Pacific Ocean, unless such fuels may be had from the inland coal fields of China. They have, therefore, a great importance to industries of the Pacific coast. From them must come the high-grade steaming and coking coals and anthracite needed by the growing population of the Pacific seaboard states. Unless they are utilized the manufacturing and smelting industries and the navy must depend largely on foregin coal when oil is not available. Alaska's own need for high-grade coal can be supplied only from these two fields, unless it is furnished by such foreign fuel as is transported for a thousand miles or more from such fields as those of Vancouver Island, New South Wales, and Japan.

[2] Coal mining in the fields of the Pacific slope of Alaska presents no problems which have not been solved elsewhere. The question of placing Alaskan coal on the market in competition with that from other fields depends on the relative cost of production.

[2] The initial expense of installation of mining plants will be large as compared with similar enterprises in the coal fields of the Western States.

[2] In spite of their northern latitude, the climate* in these fields is no more severe than in some of the productive fields in the States. In fact, it can be definitely stated that mining operations will be but little hampered

TABLE III

ANALYSES OF ALASKA COAL[2]

District and Kind of Coal	Moisture	Volatile Matter	Fixed Carbon	Ash	Sulphur
Anthracite					
Bering River, average of 7 analyses	7.88	6.15	78.23	7.74	1.30
Matanuska River, 1 analysis	2.55	7.08	84.32	6.05	0.57
Semi-anthracite					
Bering River, average of 11 analyses	5.80	8.87	76.06	9.27	1.08
Semi-bituminous					
Bearing River, coking coal, average of 28 analyses	4.18	14.00	72.42	9.39	1.73
Cape Lisburne, average of 3 analyses	3.66	17.47	75.95	2.92	0.96
Matanuska River, coking coal, average of 16 analyses	2.71	20.23	65.39	11.60	0.57
Bituminous					
Lower Yukon, average of 11 analyses	4.68	31.14	56.62	7.56	0.48
Sub-bituminous					
Matanuska River, average of 4 analyses	6.56	35.43	49.44	8.57	0.37
Chignik Bay, Alaska Peninsula, Average of 4 analyses	6.98	30.89	42.88	19.29	1.50
Herendeen Bay, Alaska Peninsula, average of 2 analyses	7.75	32.83	50.06	9.26	0.36
Lignite					
Admiralty Island, Southeastern Alaska, average of 5 analyses	1.97	37.84	35.18	24.23	0.57
Port Graham, Cook Inlet, average of 2 analyses	18.41	38.10	35.79	7.69	0.40
Kachemak Bay, Cook Inlet, average of 10 analyses	20.46	38.77	35.56	10.25	0.35
Tyonek and Beluga River, Cook Inlet, average of 5 analyses	21.50	37.28	30.60	10.63	0.57
Nenana River, Tanana Basin, 1 analysis	13.02	48.81	32.40	5.77	0.16
Chicago Creek, Seward Peninsula, average of 9 analyses	37.73	24.14	29.27	8.86	....

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* The annual precipitation in the Bering River field is probably between 120 and 140 inches; in the Matanuska field, about 25 to 40 inches. In the Bering River field the average temperature during the three winter months is about 30 deg. F.; during the summer months, about 51 deg. F. The records in the Matanuska field are very imperfect, but the summer temperature is higher and the winter temperature lower than in the Bering River field.

by the climatic conditions. It is possible, however, that snowslides may have to be guarded against in some localities, and the excessive rainfall of the Bering River field may interfere somewhat with outdoor work. The operating costs of the railways tapping these two fields will be enhanced by the heavy snows in and along the front of the coastal ranges, which probably average 8 to 12 feet annually.[2]

Bering River Field

[2] One of the two Alaskan fields containing the largest known amount of high-grade coal lies about 25 miles northeast of the indentation of the southern shore line of Alaska called Controller Bay. The field is drained by Bering River, from which it received its name.[2]

[5] The extent of the coal bearing formation in the area that has been mapped is about 41 square miles, of which 15.5 square miles is in the area of the high-grade semi-bituminous coal, about 7 square miles is in the area of the semianthracite coal, and 22.5 square miles is in the area of the anthracite coal. An additional area of 38.7 square miles is possibly underlain by the same formation at greater or less depth, but overlying rocks, gravels, and glaciers cause considerable uncertainty as to its precise position, if not as to its actual presence.

[5] The workable coal beds in this field are 3 to 25 feet thick, but through local swellings the maximum thickness is much greater. In quality the coals range from anthracite to semi-bituminous. Analyses are given in Table III. The field probably includes some coking coals. Excessive deformation of the strata has led to the crushing of much of the coal, especially the anthracite and semi-anthracite. These occur in the eastern or more closely folded part of the field, and because of their crushed condition are of uncertain value.*[5]

[1] These conditions will add materially to the cost of mining, which will be further increased by the fact that the coal itself can not be relied upon to support the roof of the mine and that resort to timbering will have to be had to an unusual extent. Although the local timber is of poor quality, it will probably answer for ordinary mining purposes, but the cost for labor will be high. Aside from its crushed condition, much of the coal itself is of excellent quality, possessing high thermal value.[1]

[3] The anthracite of the Bering River field is but little below that of Pennsylvania in composition. The coals classed as semianthracite are of about the same composition as the Loyalsock or Bernice basin coals of Pennsylvania.[3]

Cook Inlet

[2] The largest areas of coal-bearing rocks in this field occupy the western part of Kenai Peninsula, and are in part buried under a cover of glacial gravels. It is not impossible that the entire Cook Inlet depression may be underlain by these coal-bearing formations. It seems probable that the coal reserves in the Cook Inlet region are very large, for the area of the coal field is estimated at 2565 square miles.

[2] The best-known part of this field lies adjacent to Kachemak Bay on the north, where 2000 to 3000 feet of coal-bearing rocks are exposed. These rocks probably contain an aggregate thickness of over 60 feet of workable lignitic coal beds, the thickest of which reaches about 7 feet.

[2] Though Kenai Peninsula was the scene of the earliest coal-mining venture in Alaska (1854), yet the product of the industry has amounted to only a few thousand tons. Coal has been mined at Port Graham, on Kachemak Bay, and near Tyonek. The accessibility of the coal to tide-water and the undisturbed condition of the beds make for cheap mining and transportation. With improvement in methods for the utilization of lignites, fuel from this field might yet become a competitor with the fuels of a higher grade.[2]

Matanuska Field

[6] In the present fuel situation in the Territory the Matanuska coal field shares pre-eminence with the Bering River field. It lies northeast of Knik Arm, a northerly embayment of Cook Inlet, and the distance from the nearest coal to Anchorage, the head of steamship navigation on Cook Inlet, is about 50 miles.

[6] The coal-bearing formation has been traced for about 40 miles along the Matanuska Valley, but much of it is buried under a heavy blanket of gravels. The known area is about 96 square miles, and a covered and unsurveyed area of about 52 square miles additional may be underlain by the same formation. The total area that may be underlain by commercial coal consequently aggregates about 148 square miles.

[6] The commercial coals of the Matanuska field range from lignite or subbituminous to

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* Report on coal in Alaska for use in United States Navy, H. R. Doc. No. 876, 63d Congress, 2d session, 1914, 123 pp.

semibituminous. There is also a little anthracite, but it is probably not of commercial importance. The supposedly workable beds range from 5 to 25 feet in thickness.

[6] Throughout the greater part of the Matanuska Valley the structural details are not known, but there is every indication that complex structure is the general condition It is probable that there are areas in which the structure will permit the mining of the coal, but also that there are larger areas in which the structural conditions will make the mining of the coal difficult and expensive, if not impossible. It will probably be found that where the structure is simple the coal is of low grade.[6]

[10] The Matanuska branch of the Government railroad was completed late in the fall of 1917, which rendered the coal available for exploitation. The coal on Chickaloon River is being mined by the Alaskan Engineering Commission.[10]

Alaska Peninsula Region

[2] Coal has been mined for many years at Chignik, and some has been taken out at Herendeen Bay for local use, but the total output of the peninsula does not exceed 20,000 tons. These coal fields are all readily accessible from good harbors and will form one of the early available fuel assets of the Territory when the demand for coals of this grade warrants their exploitation. Possible markets for these coals may be found along the west coast of Alaska.[2]

Area and Tonnage Estimates

[2] Estimates of Alaska's coal resources, expressed in tonnage, are given in Table IV. Although these figures are of some value to the economist, inasmuch as they serve to indicate the minimum quantity of fuel which Alaska can furnish, yet they do not show the ultimate coal resources of the Territory.

[2] Of the 1210 square miles classed as coal land, less than one quarter has been surveyed in sufficient detail to yield any quantitative data whatever. Even where such surveys have been made, a large factor of uncertainty is introduced either by the folded and faulted condition of the coal beds or by the lack of definite knowledge regarding sequence of strata. There must, therefore, be a very large element of uncertainty in the tonnage estimates for even the 300 to 400 square miles of surveyed coal fields. Moreover, in Alaska there are almost no data available from private sources, such as the results of extensive mining or prospecting operations, which form an important element in the estimates made of the coal resources of the States.

[2] The estimates of tonnage in Table IV were made on the following basis:

(1) No beds less than 3 feet thick were assumed to be workable or contributed to the tonnage.

(2) The depth of workability was assumed to be 3000 feet for the highest grade coal (anthracite, semianthracite, semibituminous); 2000 feet for the better bituminous and subbituminous coals, such as those on the lower Yukon, at Cape Lisburne, and on Matanuska River; and 1000 feet for the poorer subbituminous coals and all the lignites.

(3) The tonnage was computed by the formula: Tonnage = area of bed to limit of workability (square miles) × thickness (inches) × specific gravity × 72,600.

(4) The specific gravity was assumed to be 1.30 for lignite, 1.35 for bituminous, and 1.38 for the high-grade coals.[2]

TABLE IV

ESTIMATE OF TONNAGE OF COAL IN ALASKA*

	AREA			AMOUNT OF COAL IN MILLIONS OF SHORT TONS IN THE KNOWN COAL FIELDS					
	Surveyed Geologically Approx. Per Cent	Coal Fields Sq. Miles		Lignite	Subbituminous	Bituminous	Semibituminous	Anthracite and Semianthracite	Total
		Known	Possible						
Arctic Slope..........	10	312	3,060	1,000	3,470	..	66	.....	4,536
Central Province.....	15	440	4,500	10,700	58	15	.....	.....	10,773
Pacific Slope.........	40	458	8,600	2,175	535	2	1,430	2,130	6,272
Totals............	15	1,210	16,160	13,875	4,063	17	1,496	2,130	21,581

* By A. H. Brooks and G. S. Martin, U. S. Geological Survey, 1912.

[2] In none of the fields was the coal assumed to go beyond points where it is shown to exist by reliable information from members of the survey. The areas used in making the last class of estimates are consequently very small and are possibly subject to an immense extension in the light of subsequent information.

[2] In making the estimates the attempt has been made to err on the conservative side, and thus they represent minimum rather than maximum figures in each case. This may account for the fact that they indicate an average of 20,000 tons to the acre on the Alaskan coal lands, as compared with 32,000 tons to the acre in the coal fields of the western public land states. On the other hand, with the same data for any particular area, the coal estimates of the federal geologist will usually exceed those made by the mining engineer for private interests. The reason for this lies in the fact that the geologist includes in his estimate all the coal beds of a certain thickness and to a certain depth, for it is his purpose to present figures which shall approximate at least the ultimate coal resources of the district under examination. The mining engineer, on the other hand, is not interested in the ultimate coal recovery but is charged with the duty of estimating the quantity of coal which is either immediately available or can be mined under conditions that will soon arrive. For example, a number of engineers have roughly approximated the coal of the Bering River field at 500,000,000 tons, and these figures have been widely quoted. This estimate, however, includes only the coal lying above water level which can be mined without hoisting. The tonnage estimate of the Geological Survey is many times this figure, because it includes all the coal lying within 3000 feet of the surface. It should, therefore, be borne in mind that the two classes of estimates are made with very different purposes and do not admit of direct comparison.[2]

The following figures, by Campbell, for the coal reserves of the United States in 1917 were quoted in Parts XX and XXI of this series.*

	Million Tons
United States including Alaska	4,231,352
United States within 6000 feet of surface	4,205,154
Alaska	26,200
Coal production of United States to date	10,000

[2] In considering Table IV it must be remembered that these estimates cover only the 1210 square miles of coal land, namely, that part of the coal field which, with a reasonable degree of certainty, is believed to be underlain by workable coal beds. No allowance whatever is made for the remainder of the 16,000 square miles, which are mapped as coal fields. The possibilities of finding coal in the unsurveyed districts are also ignored. Evidently, therefore, if the same acre tonnage holds throughout the coal fields, these estimates should be multiplied by ten. Again, the discovery of new coal fields will add to the tonnage. It is, therefore, probably safe to say that the minimum estimate of Alaska's coal resources should be placed at 150,000,000,000 tons and that the actual tonnage may be many times that amount.[2]

Petroleum

Some petroleum has been found in Alaska.†

[2] Oil seepages occur on the west shore of Cook Inlet, on the east side of the Alaska Peninsula, and on Controller Bay, all close to tidewater and hence offering possibilities of cheap development.[2]

There are a few wells in the Controller Bay district from each of which six or eight barrels of petroleum are pumped daily. The output is distilled at a small plant at Katalla which supplies gasolene and distillate for the local market on the shores of Prince William Sound and Cook Inlet. The gasolene is in demand for operating launches.[2]

The development of Alaskan petroleum resources, even though they be of very limited extent, may help to supply the local requirements of the territory for fuel oil, kerosene, and gasolene. It will avoid the necessity of shipping oil from California.

TRANSPORTATION AND MARKETS FOR THE COAL

The Consumption of Fuel in Alaska

Though something has been known of Alaskan coal for more than sixty years, the amount of actual mining has been insignificant as is shown in Table V.

In addition to the coal, Alaska is also a large consumer of fuel oil and gasolene as can be seen from Table VI. [2] This oil is shipped to all settled parts of the Territory, including the interior and Seward Peninsula. It is used by many small mining plants in Seward Peninsula, by the Yukon River steamers, and very extensively for launches and small vessels throughout the seaboard.[2]

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* GENERAL ELECTRIC REVIEW, August and September, 1918.

† Martin, G. C., The Petroleum Fields of the Pacific Coast of Alaska: Bulletin U. S. Geological Survey No. 250, 1905; Notes on the Petroleum Fields of Alaska: Bulletin U. S. Geological Survey No. 259, 1905, pp. 128-139; Geology and Mineral Resources of the Controller Bay Region, Alaska: Bulletin, U. S. Geological Survey No. 335, 1908, pp. 112-130.

Some parts of the Territory have abundant supplies of firewood, especially along the coast of southeastern Alaska. This, however, is not the case as one proceeds further north into the interior, and north of the Arctic Circle there are no forests. The forests in the neighborhood of many interior mining districts cannot long stand the drain upon their timber resources.

The principal uses for fuel in Alaska have been for heating, for transportation, and for power used in mining operations, especially placer mining, and in fish canneries along the coast.

[2] Practically no coal is imported into the interior except a little used for blacksmithing purposes, on which the freight alone was $75 a ton (in 1909).[2]

In southeastern Alaska a few hydroelectric plants supply power for mining and other purposes.

Smelting Alaskan Ore

Table VII gives the output of copper ore from the three districts where mines have been developed. The ore is now shipped to smelters in Tacoma, and the figures indicate what a large saving in freight will result from the erection of smelting works in Alaska.

Ore from the Chitina district is shipped to Cordova over the Copper River & Northwestern Railroad, and then by vessels to Tacoma. The other mines are located near tide water. The Bering River coal field is east of this railroad, and a branch line is planned which will tap the western part of this field. It will leave the main line about 33 miles from Cordova, and will bring the coal to that port over a 78 mile rail haul.

Smelters erected near Cordova would be able to take care of the ore brought down over the railroad as well as ore from the mines on the shores of Prince William Sound, just west of Cordova. This arrangement would eliminate the expensive transportation of ore to Tacoma. There are many indications of copper ore throughout this entire district so that there are opportunities for further development in this industry.

TABLE VI[10]

PETROLEUM PRODUCTS SHIPPED TO ALASKA FROM OTHER PARTS OF THE UNITED STATES

Year	1917 Gallons	1905-1917, incl. Gallons
Fuel oil	23,971,114	194,785,913
Crude oil		
Gas oil		
Residuum		
Gasolene, naphtha, etc.	3,256,870	21,511,481
Kerosene	750,238	7,909,276
Lubricating oil	465,693	2,260,417

Another railroad is under construction from Controller Bay to the eastern part of the Bering River coal field. This railroad will be 28 miles long and is being built by the Alaska Petroleum and Coal Co. Coal can be transported in barges to Cordova or other ports along the coast.

[1] Some iron exists in the Pacific states, and there are numerous indications of its presence in Alaska, although commercial development there is as yet practically negligible.[1]

[10] Development of the copper lodes of the Ketchikan district, particularly on the Kasaan Peninsula has led to the uncovering of large bodies of magnetic iron ore at a number of places. This magnetite, which contains in general about 0.5 per cent of copper, has hitherto been regarded only as a low-grade copper ore. Attention has recently been redirected to these ores as a source of iron. Magnetic separation should yield a high-grade

TABLE V*

COAL CONSUMED IN ALASKA IN SHORT TONS

Year	Produced in Alaska	Imports from U. S.†	Imports, Foreign‡	Total Consumed
1888–1914, inclusive	48,527			
1899–1914, inclusive		626,155	1,075,134	1,740,258
1915	1,400	46,329	29,457	77,186
1916	13,073	44,934	53,672	111,679
1917	53,955	58,116	56,589	168,660
1918	75,600	51,520	37,986	165,112

* Compiled from reference (10) with the addition of figures for 1918 from U. S. G. S.

† Principally from Puget Sound.

‡ Principally from British Columbia.

iron ore and a valuable by-product of chalcopyrite to pay for the cost of separation. Plans for utilizing these iron ores are now being considered.[10]

With the improvement of the transportation system there will be opportunities to smelt the iron and other metallic ores in Alaska. [2]Iron smelting has only recently been begun on a large scale on the Pacific coast, but the plant now established on Puget Sound is undoubtedly the forerunner of others to follow. The raw materials are available, for iron occurs in a number of districts, and Alaska can supply the coke. Moreover, the market for iron is growing rapidly. It was estimated ten years ago that the Pacific coast used annually more than a million tons of raw and manufactured iron, nearly all of which was brought from the East or imported. If this iron were smelted on the Pacific seaboard, it would afford a market for, say, 2,000,000 tons of coking coal.[2]

Utilizing Lignite for Smelting Copper

The lignite in the more accessible fields, such as those on Cook Inlet and the Nenana River, is of good quality as can be seen from Table III. The moisture content is not excessive, and it should be possible to burn it on grates or in pulverized form. The latter method should be particularly applicable to the smelting of copper ore. Fine ore is being smelted in reverberatory furnaces fired with pulverized coal at several large plants. Lump ores of copper are usually smelted in blast furnaces with coke. Recently it has been found practicable to reduce the coke added to the charge by one half, and to supply the other half of the required heat by feeding pulverized coal in with the air blast and burning it in the voids of the charge. Where coke is expensive this results in a considerable reduction in the cost of fuel.

If smelters were located at lignite mines on the shores of Cook Inlet the copper ore could be shipped to them in barges from places along the coast. The use of coke could be avoided by crushing lump ore to a size which could be smelted in reverberatory furnaces.

The blast furnace is more efficient, however, and with the advances being made in methods for carbonizing coal and lignite it may be possible to briquet the product as a substitute for coke. The rich by-product gas might be burned in the voids of a blast furnace charge, just as has been done with pulverized coal.

The Yukon Valley

The present outlets from the Yukon Valley are: (1) From St. Michael on Bering Sea, near the mouth of the Yukon, where the river steamers connect with ocean steamers for Seattle, which is distant nearly 2500 nautical miles. (2) From White Horse, Yukon Territory, Canada. This latter is at the head of navigation on a tributary of the Yukon River. Steamers connect there with the White Pass and Yukon Railway, a narrow gauge line to that part of Skagway at the head of the inland passage. The islands along the coast of southeast Alaska and British Columbia provide a sheltered waterway to Puget Sound. The distance from Skagway to Seattle is about 1000 miles. (3) From Fairbanks to Valdez, on Prince William Sound, by government wagon road.

The rivers, of course, are only navigable during the summer season and it is an 1100 mile journey by river steamer from Fairbanks down the Tanana and Yukon Rivers to St. Michael, and nearly 1500 miles up the Yukon to White Horse.

Fairbanks is the center of the most important gold mining district in the interior of Alaska. [9]The development of the mining industry, however, has been greatly retarded by the high price of fuel. Many valuable placer claims along the creeks are simply waiting for cheaper fuel to be extensively developed. The fuel now used is wood, and the annual consumption is about 100,000 cords. Great quantities are used in placer mining, where all gold bearing gravels must be thawed at all seasons. Wood suitable for fuel is rapidly disappearing, and in some localities it costs $16 a cord, owing to the long haul. It is estimated that with cheaper fuel large areas of lower grade placers can be worked to advantage, as well as various lode mines.

[9]Agricultural development in the Tanana Valley, in the vicinity of Fairbanks, is much further advanced than in other parts of Alaska. Owing to the cost of shipping commodities in from the outside, the farmers find a ready market for all the foodstuffs they can raise.[9]

The Government Railroad

Fairbanks will be the inland terminal of the new government railroad from Seward. This line will pass through the edge of the Nenana lignite field, and will make it possible to supply the Tanana Valley with good fuel at a reasonable cost. It is estimated that one ton of this lignite is the equivalent of two cords of

Figs. 4 and 5. Resurrectio

Figs. 6 and 7 Coal Outcrops i

n Bay and the Town of Seward

n River Bluffs, in the Nenana Field

spruce, which means that 50,000 tons will be required to replace the wood fuel annually consumed, and as much more as an expanding market can absorb.

Seward, the ocean terminus of the railroad, is located on Resurrection Bay, which is a large landlocked fiord, as can be seen from Figs. 4 and 5. This line was commenced in 1904 by private capital under the name of the Alaska Central and, later, the Alaska Northern Railroad. It crosses the Kenai Mountains and descends to Turnagain Arm of Cook Inlet. Here it stopped for lack of funds until purchased by the Government in 1916. Table VIII contains information regarding distances, elevations, and the pro[illegible] work.

The Matanuska coal field bra[illegible] operation and can haul coal to Anchorage, where facilities for shipping coal can be provided. Anchorage is located on Knik Arm at the head of navigation on Cook Inlet. It has certain disadvantages as a harbor, in that the tides in Knik Arm have a maximum range of 40 feet giving rise to strong currents. It will be necessary to dredge out a protected basin for loading vessels. During four or five months in winter the tides dislodge ice from the flats at the head of the Arm, and this, drifting in the swift currents, may interfere

TABLE VII*

OUTPUT OF ALASKA COPPER MINES

District	1917			1918		
	Mines	Ore, Tons	Copper, Tons	Mines	Ore, Tons	Copper, Tons
Ketchikan	7	41,060	1,323	6		8,905
Chitina	3	267,541	35,293	4		26,293
Prince William Sound	7	351,356	7,780	4		7,530
Totals	17	659,957	44,396	14	720,000	42,728

TABLE VIII*

DISTANCES AND ELEVATIONS ON THE NEW GOVERNMENT RAILROAD

Place	Distance from Seward in Miles	Elevation in Feet	Progress
Seward	0	20	Operating
First Summit	12	700	Operating
Kenai Lake	18	450	Operating
Second Summit	45	1070	Operating
Twenty Mile River (on Turnagain Arm)	65	40	Operating
Anchorage	114	150	Operating
Summit	119	240	Operating
Matanuska Junction	149	50	Operating
Chicaloon (end of branch to Matanuska coal fields)	187	983	Operating
Main line up Susitna Valley:			
Completed to	220		Operating
Building to	265		Building
Broad Pass	313	3030	Surveyed
Healy Fork (Nenana coal fields)	360	1600	Surveyed
Nenana (on Tanana River)	394	880	Building
Junction with Tanana Valley R. R.	468		Building
Fairbanks	475	500	Operating
Tanana Valley R. R. (3-ft. gauge):	From Main Line		
Chatanika (up north)	35		Operating
Chena (on Tanana River)	5		Operating
Portage Bay Branch:			
Twenty Mile River	0	40	Surveyed
Tunnel 5000 ft. long	6	100	Surveyed
Tunnel 13,000 ft. long	8	170	Surveyed
Portage Bay	12	20	Surveyed

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* Compiled from data in reference (8).

with navigation for periods of several days at a time.

Seward is available as a winter port, but an inspection of Tables VIII and IX shows that it is heavily handicapped by the longer haul which involves crossing two summits in the Kenai Mountains.

An ideal winter port can be developed at Portage Bay, which is at the head of a narrow fiord known as Passage Canal. This opens into Prince William Sound and, together with Turnagain Arm, nearly cuts off the Kenai Peninsula from the mainland. The isthmus is less than ten miles wide, and the two fiords are connected by a valley which cuts through the Kenai Mountains and provides a water grade route over which a branch line can be built. There is one obstacle, however; a glacier flows into the valley from the mountains on the south side, and completely fills it with ice. This will necessitate the construction of two long tunnels through mountain spurs on the north side, and the expense involved will delay this undertaking until the coal traffic warrants it.

The railroad has already provided access to lands having great agricultural possibilities in the Matanuska and Susitna Valleys, and there is considerable timber along the route. There are gold placers and lode ores in the Kenai mountains, and in the foothills of the Alaska range. This range includes some of the highest mountains on the continent, and the railroad crosses it at Broad Pass, 70 miles east of Mt. McKinley, and descends into the Tanana Valley. A local narrow-gauge railroad has been acquired as a feeder to serve mining districts north of Fairbanks. The output of the gold mines in this region is about $2,5000,000 annually. The availability of fuel will encourage the development of the territory along the entire 500 miles of line.

Export Market

[2] The possible markets for Alaskan coal are, first, within the Territory itself, where it can effectually shut out the imported fuels; second, in the Pacific states and territories. It is improbable that, under the estimated cost of mining, Alaskan coal can compete in foreign markets.

[2] The present Alaskan market cannot support the large coal-mining industry which will be necessary to assure economic operations. Consequently Alaska coal will have to invade fields already supplied from other sources and come into direct competition with that which is mined in more accessible and more favored regions.

[2] The west coast is now chiefly supplied from the Washington and British Columbia fields. The fields of California, Oregon, and the Rocky Mountains also supply some coal, as do those of New South Wales, Australia. Anthracite is brought from Pennsylvania, and during the last few years the Pacific fleet has been supplied from the New River and Pocahontas fields of West Virginia. Belgian coal in the form of coke also found its way to

TABLE IX*

HARBORS AVAILABLE FOR EXPORTING COAL

	Distance from Coal Fields in Miles	Ruling Grade Southbound Per Cent	Distance from Seattle, Nautical Miles	Tidal Range in Feet	Character of Harbor	Winter Ice
From Matanuska Field:						
Anchorage, on Knik Arm of of Cook Inlet..........	53–75	0.4	1430	37.2	Tidal channel and excavated basin	Frequent drift ice
Portage Bay, on Prince William Sound............	112–134	0.4	1240	9.6	Deep Fiord	None
Seward, on Resurrection Bay..................	165–187	2.2	1235	11.0	Deep Fiord	None
From Bering River Field:						
Controller Bay, on Pacific Coast.................	28	(Building)	1134	10.0	Tidal channel in mud flats	Occasional drift ice
Cordova, on Orca Inlet....	78	(C. R. & N. W. Ry. & branch line)	1220	13.0	Landlocked bay	None

* Compiled from data in reference (8).

the Pacific coast before the war, and in some years there has been a considerable importation of Japanese and British coals. It would appear at first sight, therefore, that the market is under strong competition, especially in view of the large consumption of fuel oils. As a matter of fact, the price of coal on the coast, except in some portions of the area in proximity to domestic fields, has always been very high. The Washington fields supply not much more than enough for the markets of that state, and the foreign coals formerly dominated the California market.[2]

The map of the coal fields of the United States, in Part XXI* of this series, shows the scarcity of coal resources in California, Oregon, and Nevada.

Table X shows the imports of coal into the Pacific States and Territories, as well as the production of coal in these states in 1911 and 1913. The imports reached their maximum in 1911 and have since declined. The statistics for 1913 indicate the business before shipping was withdrawn for war purposes.

[2] The production of the California oil fields during the last two decades has been the controlling factor in the coal trade of the Pacific seaboard. Coal consumption has increased somewhat [illegible] the ratio of the petroleum [illegible]

Table XI gives a com[illegible] bituminous coal from the Matanuska [illegible] the best coals now available on the Pacific coast. This sample of Matanuska [illegible] representative of a shipment of 800 [illegible] which was used in making steaming tests [illegible] the U.S.S. *Maryland*. It was found to [illegible] excellent coal for naval purposes. [illegible] volatile coal is also preferable for [illegible] boilers on merchant vessels.

[2] The coal consumption of the State of Washington has probably less bearing on the question of markets for Alaskan coal, because in this state there would be very strong competition with the local fields. At the same time, the Alaskan coal is of so much higher grade than the average of that from Washington fields that for some purposes it would dominate the market, provided it could be sold at competitive prices, considering the relative fuel values. This is particularly true of the coal used for ocean vessels.

[2] The California market seems to afford one of the best outlets for Alaskan coal. The California coal so far produced has been entirely lignitic, but there are some bituminous coals in the state which will some time supply, in part at least, the local

TABLE X

CONSUMPTION OF COAL AND COKE ON PACIFIC COAST

Imports by	AMOUNT IN SHORT TONS			
	1911		1913	
	Coal	Coke	Coal	Coke
Alaska	88,500		67,900	
Hawaii	79,200	1,135	127,000	
California	483,000	109,400	279,000	49,500
Oregon	33,200	5,450	3,250	3,130
Washington	100,200	1,175	67,600	670
Total imports	784,100	117,160	544,750	53,300
Coal equivalent to coke (1.51 tons to 1 of coke)	177,000		80,500	
Equivalent imports	961,100		625,250	
Coal brought into California by rail			363,120	
Eastern coal shipped to San Francisco by water	90,000		136,740	In 1912
Coal used by Navy	142,000		142,000	Average per year
Imports from foreign and domestic sources	1,193,100		1,267,110	
Production of coal:				
California	10,750		24,840	
Oregon	46,660		46,060	
Washington	3,572,815		3,877,890	
Total production	3,630,225		3,948,790	

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* GENERAL ELECTRIC REVIEW, September, 1918.

market. The extent of these fields is not such as to lead to the belief that they will afford serious competition with the Alaskan coal. Oregon also has no very extensive coal fields, nor is the coal of a high grade.

[2]It is estimated that California annually consumes 300,000 to 400,000 tons of coal from the Rocky Mountain fields. This comes chiefly from New Mexico and seems to be largely used for domestic fuel. It appears that, because of the long railway haul and the comparatively inferior quality of this coal, it is not likely to stand competition with the Alaskan coal in the coast towns of California.

[2]The consumption of coke forms a very important feature of the possible market for Alaskan coal. As already indicated, both the Matanuska and Bering River fields include a considerable amount of good coking coals. Vancouver Island supplies most of the imported coke, but some metallurgical processes requiring coke of a high grade have used Belgian coke.

[2]The consumption of anthracite has been small, chiefly on account of its high price. This market, at least, there is little question that the Alaskan field will control.

[2]Of the foreign competing fields those of Vancouver Island are nearest and have a higher grade coal than any others. They are, moreover, close to tide-water, and the cost of mining should be less than in the Alaskan fields. The local demand for the Vancouver Island coal will, however, be much greater when the Grand Trunk Pacific Railway* is completed, and it may be that this domestic market will absorb the entire product of these collieries.

[2]The New South Wales coal fields of Australia will probably continue to be competitors in the west coast market, as they were before the war. Some of these fields lie close to tide-water but the quality of the coal is inferior to that of Alaska. With cheap return freight rates offered by vessels carrying wheat to Australia, the New South Wales coal may be able to compete with Alaskan coals in the California market.[2]

When vessels are available coal can be shipped from the Appalachian fields to California, as return cargo, through the Panama Canal. So it also remains to be seen whether coal from the Matanuska or Bering River fields can compete with New River or Pocahontas coals shipped from Hampton Roads.

For steaming purposes, however, there would seem to be a good opportunity for shipping carbonized lignite from mines on the shores of Cook Inlet, for use as powdered fuel on the Pacific coast. The conditions will continue to grow more favorable for this as California petroleum increases in price, and as more economical carbonizing processes are developed. Low-grade Mexican oil, however, may be shipped through the Panama Canal, and this may temporarily delay the

TABLE XI

ANALYSIS OF MATANUSKA COAL, COMPARED WITH OTHER COALS AVAILABLE ON PACIFIC COAST

	Moisture as Received Per Cent	DRY BASIS Per Cent				DRY BASIS
		Vol.	F. C.	Ash	S	B.t.u., Per Lb.
Matanuska (semi-butiminous)	3.0	21.3	68.2	10.4	0.5	13,925
British Columbia:						
High volatile	2.7	40.0	47.5	12.5	1.1	12,790
Low volatile	1.7	24.0	61.1	14.5	0.5	13,125
Washington:						
Pierce County	3.0	40.0	49.0	11.0	0.9	13,350
King County	0.0	41.0	47.0	12.0	0.8	12,400
Australia	2.6	42.1	51.9	6.0	0.8	14,145
Eastern semi-bituminous:						
Pocahontas, Va.	2.5	17	76.5	6.5	0.6	14,700
New River, W. Va.	2.5	19	76.0	5.0	0.6	14,900
Maryland and Pennsylvania	2.5	19	73.0	8.0	1.2	14,350

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* This railway has now been in operation for several years.

substitution of coal until oil from this source, in turn, becomes more valuable for other purposes.

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Developments in Switchboard Apparatus

STANDARD UNIT RELAYS

Plunger Type for Overload Protection

The standard unit plunger type overload relay shown in Figs. 1 to 3 represents in several respects a very distinct advancement in relay design.

The new relay retains all the good features of the older types and has, in addition, many decided improvements. Both mechanical and electrical characteristics are better. The number of parts used has been materially reduced, and these are simple, strong, and interchangeable.

Standardization has been carried to unusual lengths. Instantaneous, inverse time-limit and definite time-limit relays are alike as far as external appearances are concerned. All relays are made from the same general parts, consequently any one of three types can be converted into any one of the other two by adding or omitting the bellows, or by changing the spring in the barrel which carries the moving contact mechanism.

The bellows is of greater diameter than on the older type relay, and the stroke is also slightly greater, so that the amount of air to be displaced in the operation of the relay is considerably increased. This produces better and more nearly uniform results.

Fig. 1. Standard Unit Time Limit Overload Relay, Type PQ

Fig. 2. Standard Unit Time Limit Overload Relay. Type PQ-3

Fig. 3. Standard Unit Instantaneous Overload Relay. Type PQ

The bellows support is tapped and plugged for a separate device which can be furnished in case a quick resetting feature is desired.

The fixed contacts may be adjusted to give simultaneous contact on both sides.

The carbon cone on circuit-closing relays is so held that it cannot get out of adjustment; neither can it be assembled incorrectly as regards adjustment.

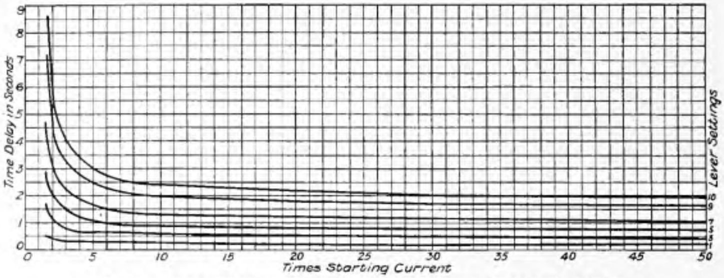


Fig. 4. Time Current Curve, Standard Unit Inverse Time Limit Overload Relay

The fixed contacts can be removed simply by the removal of the two holding screws.

The plunger rod with collars is made in one solid piece which gives strength and assurance of position.

The stop of the plunger rod is adjustable so that the shape of the curve of the definite time limit relay can be altered to a certain extent. This stop also makes it possible to produce a definite minimum time on the time current curve of inverse time limit overload relays.

The relay cover has a large glass window so that casual inspection can be made without removing the cover.

The relay is dustproof, both with respect to the upper portion and to the coil and calibrating details. All slots are filled, and a shutter on the calibrating tube when turned completely prevents the entrance of foreign matter.

The operating coil can be removed without disturbing the upper parts of the relay.

A punched tongue in the calibrating tube which enters a slot in the plunger itself is used to prevent the plunger from turning. This means it is impossible for this piece to come out or interfere with the operation of the device.

The calibration is locked by means of a slotted member which is held in position by a spring. In order to change the calibration it is simply necessary to push up on the calibrating screw and turn it. After the relay is adjusted this locking feature returns automatically to the locked position.

The relays are built single-pole only and for the control of one circuit, circuit-closing and circuit-opening. When two or more circuits are to be controlled, auxiliary relays should be used and connected as shown in Fig. 4.

For a double-pole relay, two standard units are required; for a triple-pole relay, three units, etc.

Accuracy is not affected by commercial variations of frequency.

An Auxiliary Relay for Many Purposes

The possibilities of the recently developed auxiliary relay shown in Fig. 5 are very extensive. In general, it can be used on any direct-current circuit to close or open automatically a direct or alternating-current circuit of small capacity up to 600 volts. When the operating coil is energized the relay contacts close, and when current is cut off

Fig. 5. Auxiliary Relay, Type HG

the coil the armature falls by gravity assisted by the spring action of bronze movable contacts which are under pressure when closed.

A few uses of the auxiliary relay are shown in Figs. 6 to 9.

Fig. 6 shows the auxiliary relay used in connection with an overload relay to relieve the contacts of the latter from making or breaking a comparatively large current. This is the usual connection for the auxiliary relay when used as a control or a signal relay.

Fig. 7 shows three auxiliary relays with the coils in series as used to control the automatic opening and closing of several circuits, depending on the operation of a master relay which may function on overload, reverse power, or other abnormal circuit condition. This is a scheme used when the simultaneous tripping of several breakers is desired.

Fig. 8 shows an auxiliary relay used to seal in a circuit made by another relay so that once current is thrown on the tripping coil of an oil circuit breaker, this current will remain on until the breaker opens and the tripping circuit is opened by an auxiliary switch on the breaker. This is a scheme used in connection with some types of reverse power relays. In this instance the auxiliary relay is mounted in the case and is a part of the reverse power relay.

Fig. 9 shows an auxiliary relay connected in one circuit to control a second circuit. This arrangement differs from that shown in Fig. 8 in that either breaker may be tripped by the protective relay independent of the position of the second breaker. This is accomplished by connecting the auxiliary relay, with its resistance (if the voltage requires the use of the resistance) across the control bus. It will be necessary, in this case, for the protective relay contacts to be capable of breaking the current through the auxiliary relay coil.

The auxiliary relay, as shown in Fig. 5, consists of a cylindrical coil with soft iron core, a magnetic circuit consisting of machine-bent U- and L-shaped pieces of soft iron, brass hinges for the armature contacts, terminals, and insulation.

The coil is machine wound, the frame and armature are machine bent. The contacts, terminals, and insulation are punched parts. The stationary contacts are of comparatively heavy copper. The movable contacts are of spring bronze. The contacts are interchangeable and replaced easily.

The contacts open and close with a wiping motion which keeps them clean. The break is vertical and the contacts when adjusted for maximum travel will open about 10 amperes at 125 volts, [illegible] 250 volts, and at [illegible] voltages. Approximately [illegible] required to operate the relay.

For momentary service [illegible] be connected in [illegible] direct [illegible] 125 [illegible] source. For constant service [illegible]

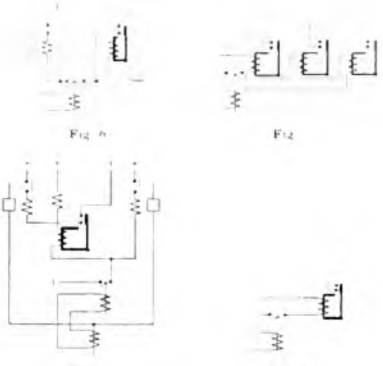


Fig. 6 Fig. 7

Fig. 8 Fig. 9

Diagrams showing Uses of Auxiliary Relays

used in series with the coil and of sufficient value to reduce to about 20 volts the potential across each operating coil.

The auxiliary relay can be mounted by two screws on any flat surface, for example, as shown in Fig. 5 on a punched sheet steel base which constitutes the bottom of an enclosing box. These relays are mounted usually on the back of the switchboard panel usually in the box, and singly or as a multiple unit battery, as desired. When the relays are mounted on the front of the board in addition to the two holes for mounting each unit, a third hole is necessary to take care of coil leads. When the relays are mounted on the back of the board the usual practice is to insert small spacing washers over the attaching screws and between the base of the relay and the panel. In this manner ample clearance for the easy manipulation of the leads is obtained.

As a matter of safety and convenience, it is well to use covers for each individual relay to protect the working parts from dust and dirt, and to eliminate the chance of accidental contacts with the live parts.

The auxiliary relay is approximately three inches high, one and one quarter inches wide, and two and one quarter inches deep. It is an extremely simple, inexpensive, and effective device.

The Construction of a Pumping Station for the Schenectady Works, General Electric Company

By Keith O. Guthrie

Engineering Contractor, Schenectady, N. Y.

A large manufacturing plant, such as the Schenectady Works of the General Electric Company, requires a reliable and at the same time considerable supply of water for power generation and manufacturing purposes, and is of prime consideration in locating the site of large factories. The pumping station described in this article was made necessary by some changes in the normal water level of the Mohawk River to minimize the danger of floods that were common in former years. The method of pouring the concrete sub-structure and lowering it into position as the work progressed was novel and is described in detail.—**Editor.**

After the abandonment of the old Erie Canal the General Electric Company purchased from the State of New York a strip within the "Blue Line," comprising a two-mile level on the west side of Schenectady. This is used as a storage pool for condensing water and in part as supply for manufacturing purposes. Level in this pool was maintained by a pumping station, with its intake on the Binnekill, an arm of the Mohawk River. This station contains two vertical pump units, each with a capacity of 20,000 gallons per minute. The total head under normal conditions is 19 ft.

In 1917 announcement was made by the State Department of Public Works that during the following winter the level of the canalized Mohawk at Schenectady would be drawn down as a measure of protection against the flood conditions, which have been a yearly menace and damage. It was estimated that opening the control gate at Vischer's Ferry Dam—eight miles below Schenectady—would bring the river level to about El. 204 at the Company's plant, or 8 ft. below average summer level.

This meant that the Binnekill on which the old pumping station is located would be dry. Conditions were not favorable for maintaining a deeper channel by dredging on account of the distance from the river—a mile—and the rapid silting up that would take place in such a back channel having slow current. It was therefore decided to build a new pumping station to be located on the river channel, where depth is bound to be maintained for barge canal purposes.

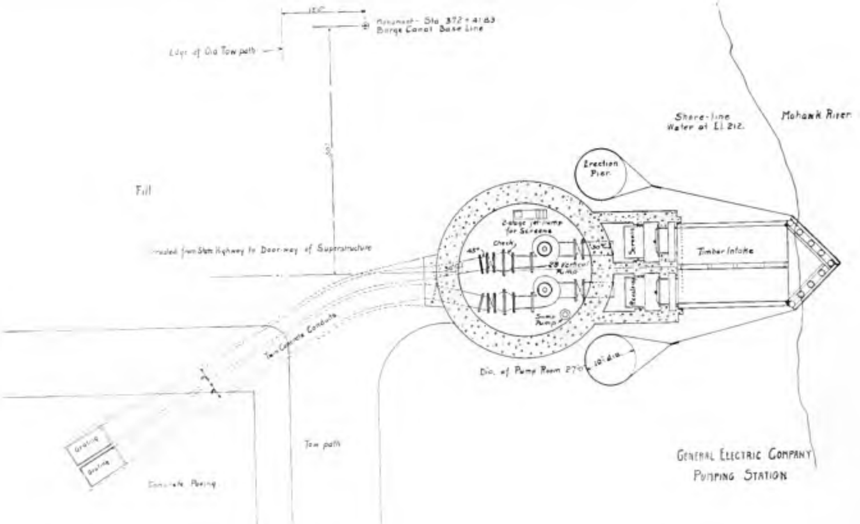


Fig. 1. General Layout of Station, Intake and Discharge Conduits

A suitable location was found just above the head of the Company's pool, where the river bank was only 80 ft. from the tow-path and on the outside of a bend in the river, making it likely that the current would keep the intake free from silt. At this location a short intake 22 ft. long was secured, and short discharge lines 70 ft. from house to center of canal.

Before working out the design the following preliminary decisions were arrived at:

To build the intake flow-line well below any ice that could form at lowest winter level

To construct the plant in duplicate from intake to discharge lines, so that either unit could operate with any part of the other unit out of commission

To use vertical centrifugal pumps placed at such depth that top of pump casings would be below lowest winter level, to obviate the use of priming devices

To place the pump motor bases 2 ft. above record flood level

To screen out floating logs by closely spaced piles in front of intake and remove the smaller refuse with vertical travelling screens inside the house.

Working out the de[illegible] brought the pump-room floor [illegible] below normal summer river level [illegible] 10 ft. below record stage. A circular [illegible] the pump-house proper was the obvious solution of the problem of handling the water pressures at flood level. This form has the further advantage of requiring no interior bracing.

Figs. 1, 2 and 3 show the general arrangement of the development.

Water is taken from the river through a timber intake 16 ft. wide by 6 ft. high inside and 22 ft. long. This intake is back-filled with gravel following the natural slope of the bank. It is held in place against the house by a V-shaped cluster of piles tied to shore with a heavy steel band.

Water after passing through the intake enters the two open screen wells through 48 in. by 60 in. Caldwell-Wilcox sluice gates. Although the pressure is off the seat of these gates they have proved remarkably tight in operation. They are normally wide open and are to be closed only to make inspection or repairs in the screen-wells.

Each well has a vertical traveling screen made by the Chain Belt Co., of Milwaukee, extending

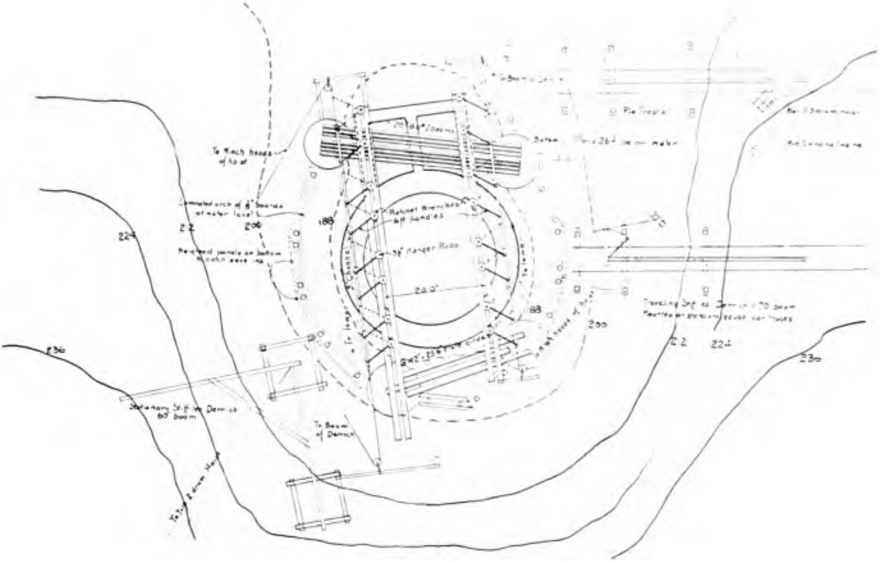


Fig. 2. Diagram showing Equipment for Lowering House Derrick Locations and Excavations Contours

12 ft. above normal river level. Each screen is connected by drive-chain to a W. A. Jones speed reducer located on the operating floor and coupled to a General Electric 5-h.p. synchronous motor. The screens are made up in baskets 6 ft. long, 18 in. wide. The width was determined by the consideration that there should be available cross-section at lowest water to reduce velocity through the screens to one foot per second. The screens travel at about 10 ft per minute, carrying all refuse up and over the top where it falls into a narrow D-shaped trough built of wire lath and cement plaster. To clean the baskets on the way down a 2-in. slotted jet-pipe is installed inside of screen frame about 6 in. above edge of trough. 80 lbs. pressure is maintained in the jet pipes by a 4-in. 2-stage Worthington pump located in the pump-room. The jets, which form a continuous sheet of water, blow the most clinging refuse from the screens into the trough.

Each screen-well can be drained by a 4-in. pipe leading into the pump-pit of the pump room.

The main pumps draw from their individual screen-wells through the circular wall of the pump-room, each 30 in. section having a gate valve just inside the wall. The pumps are Worthington single-stage, volute type, rated at 20,500 gals. per minute, at 28-ft. head. They are driven by 235-h.p., 500-volt, 3-phase induction motors at 400 r.p.m.

All main piping inside the house is 30 in. cast iron flanged. After leaving the house the water is discharged through a twin concrete conduit, each side 36 in. square, which leads up to the bottom of the old canal, the bed and sides of which are protected from wash by concrete paving.

The superstructure of the house is of reinforced concrete following in plan the same outline as the substructure. It contains the static transformers and switching apparatus, pump motors, screen-driving apparatus and sluice-gate stands. All pieces can be handled by chain block on trolley running on a 12-in. I-beam bolted to the ceiling. The operating room is well lighted and ventilated by fenestra sash.

The material at the site is a compact coarse water-bearing gravel, unsuited to any kind of cofferdam. The method of construction consisted, in essence, of excavating to grade, concreting the house above water, and lowering it until it rested on its foundation.

At the start of the work a 2½-yd. dipper dredge made 16 ft. of water over the site of the house and for about 20 ft. around it. The spoil was removed in scows. At the same time stiff-leg derricks were erected on either side of the cut which operated 1¼ yd. clam-shells and completed the excavation to 24 ft. below water level.

When excavation had been roughly completed four piers were built around the location of the house, as shown in Fig. 2. The forms for these piers were round barrels, 10 ft. inside diameter, 30 ft. long, with outside ribs of 2 in. by 10 in. plank lapped and well spiked. To provide a cutting edge and also weight for sinking a reinforced concrete ring was attached to the bottom of each form. The complete form units weighed about 8 tons and were set in place by the derricks and guyed. It was desired to have these piers extend at least 2 ft. below grade of excavation for the house so as to secure the full bearing power of the gravel. The forms were sunk quite readily by excavating inside them with clam-shell. As soon as a form reached grade, nine 45-ft. piles were driven inside with 5-ton steam-hammer to practical refusal, which came at from 15 to 20 ft. penetration. Concrete 1, 2, 4 was then placed by tremie and the piers brought to 9 ft. above water and capped with a grillage of old rails.

The two inshore piers were bridged by three 42-in. plate girders, the two outshore piers by eight 20-in. 80-lb. I-beams. Both the girders and I-beams were girdled with heavy clamps and the space between webs filled with concrete from pier to pier to resist lateral buckling under load. In addition the girders and beams were securely anchored into the pier tops to minimize the danger of any pier leaning.

Seated on the cross-beams and cross-girders mentioned above were two pairs of heavy plate girders, from which hung the suspender rods that carried the house itself. The girders of each pair were spaced with the flanges just far enough apart to pass the connecting sleeve-nuts of the rods. The girder pairs were spaced 20 ft. centers. Pains was taken to give the main girders an evenly distributed bearing, as well as an anchorage to the beams and cross girders on which they were seated. The girders of one pair were 6 ft. deep by 58 ft. long, of the other pair 7 ft. deep by 67 ft. long.

To secure maximum supporting power from the main girders they were cantilevered at the screen-well end for about 12 ft., giving roughly the same bending moment at the outshore piers as at the middle of the long span.

Fig. 3. Start of the Work. Looking up the river towards Lock No. 6.

Fig. 8. Lowering House and Pouring Concrete at the Same Time. Level of fresh concrete was kept about one foot out of water.

Fig. 5. One of the Four Girders from which the House was Lowered:
7 ft. deep, 67 ft. long, weight 14 tons.

Fig. 9. Highest W[illegible]
February 18, 1918.

Eight 3½-in. V-threaded rods were hung from the top flanges of each pair of girders. At each rod the girders were bridged with a pair of 10 in., 30-lb. channels on which rested the washer carrying the lowering nut. To obviate the danger of the nut cutting under a load of at least 30 tons and possibly much more, the washers were made of two 1½-in. plates, 16 in. diameter, with the faces in contact finished, oil-grooved in opposite directions, and packed in light grease.

Fig. 4. Landing Form for One of the Four Supporting Piers. These forms were 10 ft. dia. and 26 ft. long

The lowering nuts were 12 in. long, of standard hexagon section, and were engaged by ratchet wrenches with 6-ft. handles (Fig. 6). The ends of the wrench handles were bolted to 5-in. channels, one on either side of the house. Lines ran from each end of the channels to the derrick hoists, which operated the wrenches back and forth in unison, each movement giving the nuts a one sixth turn. Electric door-switches, engaged by the moving channels, rang bells in the engine-rooms indicating to the hoist-runners the limits of stroke.

Opposite rods supported pairs of 15-in. I-beams which formed a floor under the entire house. As erected, these beams just reached the water. They were tied together with ¾-in. tie-rods, 4 ft. spacing, and separated by a 4-in. wooden floor resting on the bottom flanges. After the first ring of outside forms was set, resting directly on the floor-beams, a sub-floor of concrete was placed covering the top flanges 2 in. and with an 18-in. fillet at the outside form. On this sub-floor and up the outside forms was laid five layers of roofing felt very thoroughly mopped with water-proofing pitch. Rein-

Fig. 7. Operating the Ratchet Lowering Wrenches by Lines Led to the Two Derricks

forcement, inside wall forms and forms for the 30-in. by 48-in. inverted floor-beams were then placed and concreted. The house was lowered at the same time, keeping the level of the concrete about 1 ft. out of water. The best progress in lowering at any time was 15 in. an hour.

The outside forms were built one foot higher than the inside to provide a lap for the water-proofing of the succeeding lift. No difficulty was experienced in lowering fresh concrete into the water. Frequently concrete in the walls an hour old was under water—amply protected by the 5-ply water-proofing.

This water-proofing passed a remarkable test one night when a thaw up the valley caused a sudden rise in the river. Before a gang could be got together from the city and concreting started, the water-level was 20 in. above the concrete in the walls and at one point 3 ft. There was not so much as a drop of leakage through the outside forms, due to the tenacity of the water-proofing pitch. While it has always been customary to place water-proofing against a masonry wall, this was dispensed with on this work to save time and expense. It is believed that the wooden forms—always under water—will prove a permanent protection.

It was felt in advance that the chief danger in this method of lowering a heavy structure lay in the possible settlement of one of the piers. It was conceivable that a material relative settlement of one pier would concentrate the entire weight on a few rods, overloading and even snapping them with consequent disaster. To guard against this possibility a great deal of care was taken with the piling and concreting of each pier; the rods were made heavier than required for even loading; and the sub-floor on which the house proper was built, was made flexible in one direction. The first pour of the house, including floor and a portion of the walls, weighed about 600 tons. This was cast without lowering into the water, with the idea that this entire load would be likely to bring about immediate and maximum settlement, and being fairly flexible up to this point would adjust itself to any relative settlement of the piers. As it developed, however, there was no observable settlement in any pier.

A further fear was entertained that through unequal running off of the lowering nuts some of the rods might be overloaded. Considerable thought was given to the application of strain gauges, but it was soon found that an underloaded rod shifted on its support as the heavy wrench swung back and forth while an overloaded rod groaned. A one sixth turn of the nut—about one twentieth inch on the rod—was usually sufficient to equalize the loading.


Fig. 6. One of the Sixteen Ratchet Wrenches which were Operated in Unison


Fig. 10. Completed Superstructure. Taken from new roadway leading across old Erie Canal

The hanging equipment went through a very severe test in the early part of February. The house had been lowered 16 ft. into the water, a set of forms made ready for a new pour, and the entire structure covered with a board house as protection against the severe cold. A fire—started presumably by a salamander—consumed forms, runways and protection housing to the water's edge. The girder webs were badly buckled and one girder sagged two inches, but after making good the forms, lowering was resumed without any difficulty except in lubricating the lowering nuts.

Work was started in October, 1917, and continued without cessation through the severe winter following, until high water on

February 13th, put an end to all operations for a month.

The method of construction was developed by the writer and the station design was worked out by him in consultation with Mr. A. R. Nisbet, Superintendent of Power, and Mr. C. G. Hulth, Superintendent of Grounds and Buildings, of the General Electric Company.

Mr. W. R. Abbott, Assoc. Mem. Am. Soc. C. E., acted as Construction Engineer and Mr. James J. Fahey as Superintendent.

Voltage Regulation of Distributing Feeders as a Means of Improving Central Station Efficiency

By Frank Hershey

Supply Department, General Electric Company

If voltage regulators served only to improve the customers' service, they might well be considered a luxury. However, their additional usefulness as a means for raising the efficiency of a central-station system, for obtaining a greater return on the invested capital, and for effecting economics in feeder construction make them a necessity for an up-to-date system. The following article Mr. Hershey read a paper before a meeting of the Ohio Electric Light Association in Cleveland, February, 1919.—Editor.

In the design of new power plants, or the remodeling of existing plants, the aim of the designing engineer is to select such equipment as will result in the desired energy being delivered to the busbar at the minimum cost. Many auxiliary devices are included to assist in obtaining a higher conversion of the energy in the coal or waterfall as it passes through the various stages until it is delivered to the bus in the form of electrical energy. Performance guarantees applying to the main units, as well as to the auxiliary devices, are carefully compiled and compared in order that the most efficient combination may be selected. To secure a small fraction of one per cent increase in plant efficiency, the expenditure of additional capital is oftentimes justified for the higher efficiency units.

In laying out the distributing system, however, is the same effort made to carry efficiency through to the consumer—to maintain constant normal voltage at the recording meter—or are the power plant economies being consumed by losses in the distributing feeders? Voltage drop and the corresponding line loss cannot be entirely eliminated, but by analyzing the load conditions to be taken care of on the various feeders and by laying out the distributing system with the same care as is used in the design of the power plant the losses can be reduced and the drop compensated for so that efficiency of operation will not stop at the bus but will be carried through to the consumer.

Electrical appliances used in the household are designed for most efficient operation at a definite predetermined voltage; and operation at a voltage other than normal impairs the service, results in increased cost to the consumer, as well as reduces the revenue to the central stations. For instance, the wattage and candle-power of Mazda lamps vary at the rate of slightly more than 1.5 and 3 per cent, respectively, for each per cent change in voltage from normal. If the voltage applied to the terminals is 3 per cent low, less current will be consumed, reducing the revenue to the central station by 4.5 per cent and the illumination for the consumer by 9 per cent. The life of the lamp will be increased but the reduction in illumination is so great that the cost of light per candle-power-hour is increased. If the voltage is 3 per cent high, the revenue will be increased 4.5 per cent, and the candle-power 9 per cent, but the life of the lamp will be reduced to such an extent that

VARIATION OF WATTAGE AND CANDLE-POWER WITH VOLTAGE FOR MAZDA LAMPS

Per Cent Normal Voltage	Per Cent Candle-power	Per Cent Total Watts
95	83.1	92.2
96	86.3	93.7
97	89.6	95.3
98	93.0	96.9
99	96.4	98.4
100	100.0	100.0
101	103.6	101.6
102	107.4	103.2
103	111.2	104.8
104	115.1	106.4
105	119.0	108.0
110	140.3	116.3

again the cost per candle-power-hour is increased.

Household appliances, such as irons, toasters, percolators, warming pads, broilers, and curling irons are used to a large extent because of their convenience. For satisfactory operation, they require nearly as close regulation however as the incandescent lamp, as the heating and also the power consumed varies as the square of the voltage applied. A 5 per cent drop in voltage equals a loss of approximately 10 per cent in revenue to the central station and 10 per cent less energy is available for heating so that unless the voltage is maintained at approximately the rated value the appliances lose their value as conveniences and dissatisfaction results.

The percentage of lighting load as compared to the total generating capacity of the plant may be small, but the incandescent lamp is used so much more extensively than any other electrical energy consuming device that its performance has been accepted by the public as a standard for judging the efficiency of the operating company. The good-will of the public is of incalculable value to the central station, and it is essential, therefore, that a uniform and proper voltage be maintained within reasonable limits on all lighting circuits.

Normal voltage may be maintained at the distributing center, either by supplying a constant bus voltage and designing the distributing feeders for a negligible drop, or by varying the voltage supplied to the individual feeders by means of a voltage regulator to provide compensation for the feeder drop and for the voltage variations at the bus.

The voltage of a generator or a number of generators may be maintained automatically at normal for all conditions of load at the station bus or at any one center of distribution on the system by means of a generator-voltage regulator. Where there are a number of feeders radiating from a station this method of regulation, however, will not be satisfactory unless all of the feeders are laid out for negligible voltage drop which generally is uneconomical. Usually the feeders are of different lengths and the power demands occur at different intervals so that the voltage delivered at the centers of the several feeders will vary widely. It is practically impossible, therefore, to raise or lower the voltage of the station bus so that the voltage at each load center is proportionate to the demand at that center. In order to provide [illegible] method of operating the distributing system it is essential that each feeder should be considered as a unit. The system can be made very simple and economical if care is exercised at the time the initial layout is made, and many existing plants could probably reduce the distributing costs and improve their service by thoroughly investigating their feeding systems with the view toward making them more symmetrical and of uniform regulation. Recording voltmeter charts taken at frequent intervals at various points on each feeder provide a means for detecting voltage irregularities in the feeder which if uncorrected may become magnified and not only impair the service but appreciably effect the revenue.

In laying out a new system, or reconstructing an old one, the area to be lighted should be divided into districts and the maximum load to be handled in each district should be determined, bearing in mind the advantage of having in so far as possible the feeders as nearly equal in capacity as practicable. This insures symmetrical switchboards and feeder equipments and simplicity of maintenance. It is usual when selecting or subdividing the total area to be lighted to take into consideration the actual and anticipated loads in each subdivision, so that the feeder layout will take care of future as well as present requirements. Forethought in this respect often saves considerable expense in the future growth of the system. One district may be 90 per cent loaded while another may be only 25 per cent loaded. The latter, however, may be of such a character as to lead the lighting company to believe that there are prospects of a load equally as great as in the former. If the latter feeder is a duplicate of the first it would of course have much less drop; but in the end if care has been exercised the extra cost and fixed charges of copper necessary to handle the anticipated load will be less than if only sufficient copper were installed to take care of the actual load and a smaller percentage of anticipated load. In laying out the feeder and the mains, the most economical cross-section of copper should be used; i.e., the cost for the conductor, distributed over a period of time corresponding to the life of the feeder, should equal the cost for loss in energy due to the drop. The value of feeder regulation must be taken into consideration, however, as it would not be possible to use the most economical size of conductor without providing some form of regulation if the drop at maximum load is to be maintained within a reasonable percentage.

The choice between voltage regulators to compensate for the voltage drop in the feeder and the installation of conductors of such size as to provide negligible drop depends on the relation between the cost of the line using the most economical conductor and the regulator plus the cost of losses in the line and regulator and the cost of the feeder using the larger conductors to reduce line drop plus the line losses. Consideration, however, should also be given to the fact that the regulator will compensate for the variations in supply voltage which cannot be accomplished by the use of larger conductors. The installation of a regulator will oftentimes be more economical even if the total cost somewhat exceeds the cost of the heavier conductors.

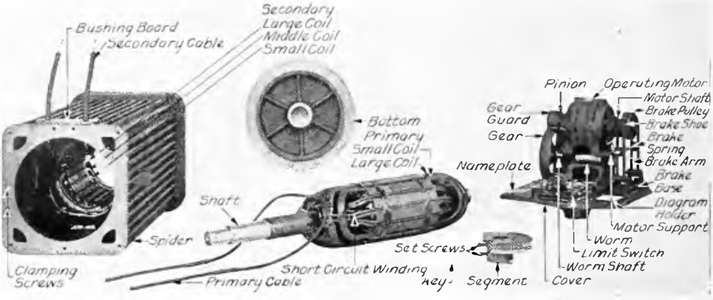


Fig. 1. Disassembled View of a 2300-volt Single-phase Induction Regulator for Distributing Circuit

To illustrate, assume that it is necessary to install a single-phase, 2300-volt lighting feeder of 75-ampere capacity, the load to be equivalent to full load four hours per day, 300 days per year. The most economical size of conductor would be No. 1 on the basis of a 15-year life for the feeder, copper at twenty cents per pound and allowing 2 per cent for taxes, 5 per cent for capital invested, 15 cents per pound for scrap copper, and energy to supply losses at $0.0125 per kilowatt-hour, as well as proper charges for erection and removal. The cost per mile for the feeder would be approximately $184 and the drop would be 4 per cent. If not corrected, this drop, (without considering the drop in the secondary distribution) would mean a reduction of over 12 per cent in candle-power of the lamps and a loss of over 6 per cent in revenue to the central station, or on the basis of ten cents per kilowatt-hour the annual anticipated revenue of $21,000 would be reduced $1260. If larger size conductors were used to reduce the line drop it would necessitate the installation of 350,000-circular-mil cable to maintain regulation within one per cent at the center of distribution, such as can be accomplished by installing a regulator. This would cost approximately $248 per mile. On the other hand, if No. 1 conductors and a regulator to compensate for the drop to the load center were used, the regulator including the cost for losses and installation would increase the cost of the feeder from $184 to $278. Unless the supply is subject to fluctuations, such as occur in feeders tapped from transmission lines where a regulator is necessary, the lower cost favors the installation of the 350,000-mil cable.

If, however, the feeder were two miles long, all other factors remaining unchanged, the full-load drop would be 8 per cent. To maintain regulation within one per cent at the load center without a regulator would necessitate installing 1,500,000-circular-mil cable at a cost of $354 per mile; whereas the extension of the feeder would cut the charge for the regulator in half making the cost to cover the installation of No. 1 conductors and regulator $231 per mile, or a difference of approximately 50 per cent in favor of the latter installation. If the feeder were three miles long, the saving in favor of a regulator would be even more marked. In fact, the minimum cost is obtained when the entire range of the regulator is utilized in compensating for line drop. Inasmuch as the regulators selected would provide 10 per cent boost and 10 per cent lower, a total range of 20 per cent, the feeder could be extended for a distance of five miles and normal voltage would be maintained at the center provided the bus voltage was held constant at a value which would permit the regulator being in the neutral position when the load on the feeder was 50 per cent of maximum. In other words, the regulator should lower the bus voltage 10 per cent at no load, lower 5 per cent at quarter load, be at neutral at half load, and should raise the bus voltage 5 per cent at three-quarters load, and raise it 10 per cent at full load. In this way the maximum benefit to be derived from the regulator will be obtained.

Voltage regulators are not necessary to maintain service, and if they are considered merely as a means to improve the quality of service furnished the consumer, so that the household appliances may be used most efficiently, they may be justly referred to as a luxury or as apparatus designed to provide desirable refinements in service. When their value to the central station is considered as a means for raising the efficiency of the system, for obtaining a greater return on invested capital, for effecting economies in feeder construction as well as improving the service they cease to be a luxury and become a necessity. In laying out the feeding system, it is therefore essential that each feeder be considered separately, its load analyzed, anticipated as well as present, with the same care as is given to the design of the station; and by providing the proper form of voltage regulation, efficiency of operation will not stop at the bus but will be carried through to the consumer.

In the old direct-current system the various feeders differed greatly in length and were unequally loaded so that it became necessary to control each individual feeder. In this respect the alternating-current system does not differ except as to the method employed for obtaining the necessary regulation. Several methods were employed in the old Edison systems:

(1) Connecting and disconnecting feeders at various points in the network.
(2) Feeder regulating rheostats.
(3) Auxiliary buses.
(4) Boosters.

For alternating-current distribution, no method is as satisfactory as the booster or variable-ratio transformer method. Numerous designs of regulators have been developed, some cutting in or out of the circuit certain sections of the secondary or series winding by means of a switch, while others [illegible] position of the secondary winding with respect to the primary or changed the direction and amount of magnetic flux threading the series winding, thereby varying the induced voltage in this winding and providing a means for regulating the line voltage.

Fig. 2 Single-phase Automatic Induction Regulator with Auxiliaries Mounted on Panel

The modern design of regulator, designated as the induction regulator, is similar to a transformer in that it has two separate and distinct windings, primary and secondary, connected respectively across and in series with the feeder to be regulated. The secondary or series winding is assembled on a circular stationary core and the primary or exciting winding is also assembled on a circular core concentric with the stationary core, but arranged so that it can be partially rotated within the former. Voltage regulation is obtained by changing the position of the primary winding with respect to the secondary so that the induced secondary voltage may be varied in value as in a single-phase regulator, or in phase relation to the line as in a polyphase regulator, either raising or lowering the supply voltage in accordance with the change in load on the feeder, or to counteract variations in the supply voltage itself, thereby enabling the central stations to maintain normal voltage at any point on the feeder. The induction type of regulator has proven its reliability by years of service on the lines of many operating companies, it requires no more attention than other electrical apparatus and may be installed either at the generating station, substation, or with slight modifications out of doors, depending on the requirements. The regulator can be designed for controlling either single- or polyphase circuits, for self or artificial-cooling, and for any current or voltage for which it is practical to build generators or motors. Furthermore, it can be designed for either hand, remote-control, or automatic operation. The automatically operated regulator differs from the remote-controlled or motor-operated regulator in that it requires an auxiliary equipment consisting of potential transformer, contact making voltmeter, relay switch, one or more current transformers, and line-drop compensator. The potential transformer steps down the line potential for the contact making voltmeter in the same manner as for the usual indicating voltmeter on the switchboard. The contact making voltmeter responds to variations in the line voltage and when they exceed one per cent either way from normal it completes either the raising or lowering circuit to the relay switch, which is introduced to provide a means of handling the heavier motor current, thereby causing the regulator to raise or lower the supply voltage in accordance with the demand. When normal voltage has again been established, the control circuit is automatically opened and the regulator comes to rest. The current transformers and line-drop compensator are used as a means of reproducing in miniature the resistance and reactance drops in the line so that the regulator can be used for maintaining voltage at the desired value at a distance center irrespective of a change in load or power-factor.

Automatically operated regulators present so many advantages over the other methods of operation that they are used almost exclusively at the present time, and for this reason only this type of regulator will be considered in discussing the application of voltage regulators for the control of distributing feeders, for outdoor installations, and for substations tapping high-tension transmission lines.

CONTROL OF DISTRIBUTING FEEDERS

Inasmuch as the feeding system may be single-phase, quarter-phase three-wire or four-wire, or three-phase three-wire or four-wire, and as the conditions to be met in the proper application of regulators differ slightly for each method of distribution, the different types of systems will be considered separately.

Single-phase Feeders

The automatic regulation of single-phase feeders presents no difficulties, in that there is one definite point to be considered and the boost or lower of the regulator is directly added to or subtracted from the voltage of the feeder. If regulation to compensate for drop to some distant center is desired, one current transformer and line-drop compensator must be included among the auxiliaries, whereas these accessories would be omitted if the regulator is merely to maintain the voltage constant at the station.

Three-phase Feeders

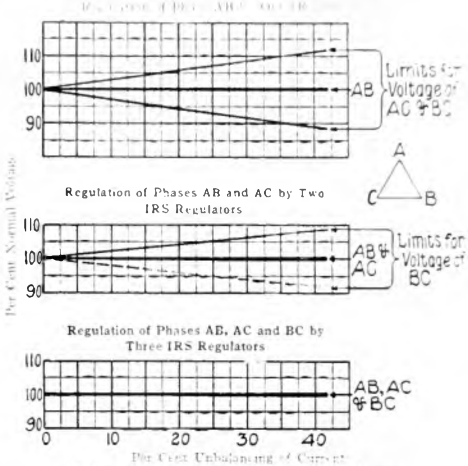
Case 1: At times it may be desirable to connect the lighting load on only one phase of a three-phase feeder. While one single-phase regulator in this case would regulate the voltage satisfactorily, variations in the power-factor of the load would affect the phase relations of the currents from the current and potential transformers to such an extent that unsatisfactory compensation would be obtained unless two interconnected current transformers are used. In such an installation, the regulator has its secondary winding in series with the line and its primary connected across the phase so that at unity power-factor the line current, and consequently the series transformer current, is displaced 30 deg. from the phase voltage or the corresponding secondary current of the potential transformer. If the load on the feeder is balanced, and the power-factor remains constant at approximately unity, satisfactory regulation can be obtained as the line-drop compensator can be set to counteract the error caused by the difference in phase relation of the currents from the current and potential transformers. Should the power-factor vary considerably, however, and this be the prevailing condition, the phase displacement in the currents may become such that practically no compensation can be obtained. By using two current transformers interconnected, one in series with each leg of the regulated phase, a resultant current is obtained which is proportional to the current causing the drop, and which bears the same relation to the potential transformer current as the line current bears to the phase voltage so that correct compensation can be obtained irrespective of unbalancing in load or change in power-factor.

Case 2: Where lighting is connected on only two phases of a three-phase system and motors are connected to the same feeder, two single-phase regulators and three interconnected current transformers should be used. If the third current transformer were omitted, proper compensation could not be secured on account of errors introduced by the phase displacements in the current and potential transformer circuits as already mentioned.

Case 3: Where lighting and power are connected to all three phases of a three-phase feeder, either one three-phase regulator, two single-phase, or three single-phase regulators may be used depending on the balancing of the circuit.

The operation of any automatic induction regulator, whether single-phase or three-phase, is directly dependent on the contact making voltmeter which is a single-phase device. Consequently when a three-phase regulator is used, the voltage on all three phases will be changed equally, the increase or decrease depending on the adjustment required by that phase across which the contact making voltmeter is connected. When two single-phase regulators are used, two of the phases will be adjusted independently and held at the desired value. The regulation of these two phases will have a tendency to improve the voltage across the third or non-regulated phase, but the latter will be subject to variations under unbalanced conditions of load which cannot be entirely controlled. When three single-phase regulators are used the voltage on all of the phases will be maintained at the distributing center at a constant value regardless of the unbalancing.

Under balanced conditions of load the same regulation is obtained with a three-phase regulator as with either two or three single-phase regulators. This is due to the fact that with a balanced load the same adjustment of voltage will be required on all three phases with a change in load. With an unbalanced load, however, the voltage adjustments necessary to maintain constant and equal voltage on all phases depend not only on the change in load but also on the unbalancing in current. For instance, assume that the load on the feeder is made up of a three-phase balanced motor load of approximately 85 per cent power-factor and [illegible] lighting load. On the basis [illegible] unbalancing is determined a[illegible] which the maximum deviation [illegible] average load on the three-phase [illegible] average, then under a condition [illegible]



IR drop = 10 per cent per phase at normal load current

IX drop = 10 per cent per phase at normal load current

Load consists of:

Balanced three-phase at 86.6 per cent power-factor and

Unbalanced at 100 per cent power-factor

$$\text{Per Cent Unbalancing} = \frac{\text{Max. Deviation from Average}}{\text{Average}}$$

Curves show voltage at end of feeder at normal load current

Fig. 3. Variation in Voltage Regulation of Three-phase Feeder Under Varying Conditions in Balancing of Load

cent unbalancing a variation of 4 per cent above and 4 per cent below normal might be obtained on the two non-regulated phases with the three-phase unit, 3 per cent variation either above or below normal on the one non-regulated phase if two single-phase regulators were used, whereas normal voltage would be maintained on all three phases if three single-phase regulators were used.

In controlling a three-phase three-wire feeder there are no conditions of operation under which the use of two single-phase regulators will not result in as good or better regulation than can be obtained by the use of one three-phase unit. Furthermore, if only two single-phase regulators are installed and the unbalancing becomes excessive, it will only be necessary to install the third single-phase regulator in order to obtain satisfactory regulation; whereas it will be necessary to replace the three-phase unit with three single-phase units at a very much greater increase in cost. The single-phase regulators also have the advantage that they are more flexible in that the same regulators can be used without change if the system is changed from three-wire to four-wire grounded neutral distribution. The only advantages for the three-phase regulator are less floor space required and less inspection since only one set of auxiliaries have to be inspected. In general, the cost and efficiency for two single-phase regulators are about the same as for the three-phase unit.

Fig. 4 Single-phase Automatic 2300-volt Pole-type Regulator

Case 4: Three-phase four-wire feeders are in quite common use, the fourth wire being grounded. For such systems three single-phase regulators should be used, the secondaries being connected in series with a phase wire and the primaries excited from phase wire to neutral. Very satisfactory regulation can be obtained by using this method, as it is practically equivalent to three independent single-phase feeders. If the load is unbalanced, however, current will flow in the ground wire and an additional line-drop compensator and current transformer will be required to provide compensation for drop in this wire.

Two-phase Feeders

Two-phase systems may be three or four-wire. In the case of four-wire distribution, correct regulation can be obtained by using a two-phase regulator if the load is balanced. In the three-wire distribution, however, for either balanced or unbalanced conditions of load, or if the load is unbalanced in the four-wire distribution, two single-phase regulators should be used as each phase will then be controlled independently and close regulation can be maintained. If a two-phase unit were installed, the non-regulated phase would be subject to variations since the line drop in the regulated phase affects the voltage of the other phase and no means can be provided for correcting this condition.

Regulators for Outdoor Installation

The recommendation was made that, when laying out the feeding system, an effort should be made to select a size of conductor that will meet the probable future demand rather than one that will merely take care of the existing demand. Unfortunately, communities do not always expand as expected; some sections build up compactly and steadily while others are irregular in their growth or spread over a greater area than originally contemplated when the feeders were

Fig. 5. Single-phase Automatic Regulator Arranged for Outdoor Installation

installed. It would be uneconomical to replace or reinforce the present lines or to install additional feeders for the sparsely settled sections of the community, or for sections where the growth has been irregular as long as the maximum loads on these feeders are considerably below normal. At the same time, the voltage conditions on the feeder as a whole are far from satisfactory with respect to both service and anticipated revenue. The only solution of the problem is to establish two or more load centers, each being supplied from the main feeder but having the voltage maintained at normal regardless of variations on the main feeder. This can be accomplished by the installation of induction regulators designed for outdoor installation. Usually these regulators are installed at the load center, making it unnecessary to provide auxiliaries to compensate for additional line drop although the regulator may be installed at a point distant from the center if this is desirable and arranged to compensate for the drop by employing the usual accessories similar to the station regulators.

This type of regulator is also well adapted for controlling the lighting circuit of an industrial plant supplied with energy from a feeder used primarily for the distribution of power and, therefore, probably non-regulated at the station. A change in voltage does not materially affect the speed of the average motor, but it is detrimental to illumination and affects not only the quality of the product manufactured but the output of the plant and also the safety of the operator.

The advantages of improved illumination are being more generally appreciated by industrial plant managers; but no matter how carefully the lamps, reflectors, and fixtures are selected to provide illumination of the work and surroundings comparable to that obtained during the natural lighting period, the desired results will not be obtained unless the proper voltage is applied and maintained at the lamp terminals.

Voltage Regulation of Substations Tapping Transmission Lines

During the past decade remarkable strides have been made in the distribution of energy at high voltages over great distances from points where power can be generated more economically and more efficiently. Where numerous small generating stations, heretofore entirely isolated, have been tied together, the less efficient generating equipment in many cases is being dismantled and the station converted into a substation or being replaced by an outdoor substation for the transformation of energy from the transmission voltage to a voltage suitable for local distribution. In order to provide voltage regulation for the local system comparable to that obtained from the original generating equipment with its generator voltage regulator, it is necessary to install induction regulators, either indoor or outdoor, as the need for regulation has not been eliminated by the change. In fact, the need for regulation has been accentuated as the line drop on the local system is unchanged and the transmission line is subject to variations which will be impressed on the feeding system if no provision is made to maintain the voltage at normal. In an installation of this kind, a regulator will perform the double function of correcting variations in the supply voltage and also compensating for drop in the distributing feeder.

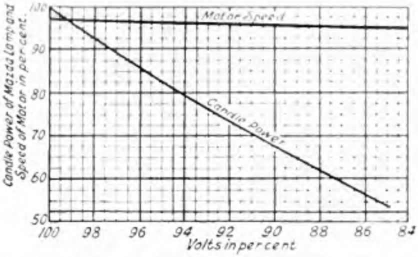


Fig. 6. Variation in Candle-power of Lamps and Speed of Induction Motors with Variation of Applied Voltage

Voltage regulation of the feeding system not only results in improving the service to the consumer and increasing the revenue to the operating company, but it also makes possible the installation of more economical equipment for the generation and distribution of power. Voltage regulation closes the gap between the efficient power plant and the equally efficient appliances in the household, thereby enabling the Utility Company to carry efficiency through to the consumer.

A Year's Record of the Automatic Substation at Butte[*]

By E. J. Nash

Electrical Engineer, Butte (Mont.) Electric Railway

Now that automatic substations have been in service a sufficient time to warrant an examination of the record they have made, the following article reporting a year's operation of such a substation is of interest. The total cost of supply material and maintenance for the Butte automatic substation has been but little over half the estimated amount. Because of this low cost of upkeep and the reliable performance of the substation, "plans are now being made to add another substation of the same type to the system and to make the central substation automatic."—EDITOR.

The design and construction features of automatic substations have received considerable space in the GENERAL ELECTRIC REVIEW,[†] but there has been comparatively little regarding their operating records. The first year's operating records of one of these stations may therefore be of interest, particularly in view of the fact that reliabilty of service is of primary importance. In the following article are mentioned also a few features wherein the automatic substation of the Butte Electric Railway differs, so far as is known, from any thus far described or installed. A few comparisons are given also as to the relative characteristics of automatic and manually-operated stations containing machines of the same type, style, and capacity.

Figs. 1, 4, 5 and 7 show the general appearance of the substation inside and out, the equipment being that found in substations of this type generally. By way of explanation of the presence of the chicken wire netting seen on the poles in Fig. 1, it may be said that this is used for resistance between the rail at the station and the negative side of the synchronous converter in order to insure the desired condition that the voltage drop from the rail at the station to the negative bus be the same as the drop from the rails at any other point to the bus.

Fig. 1. An Attractive Housing for the Automatic Substation at Butte, Mont.

On account of the termination of a contract for power, and also because the company wished to take care of the return current more satisfactorily, it recently became desirable to install a new system of distribution and to use the negative insulated return-feeder system for the mitigation of electrolysis.

The location of a substation at the load center of the system was considered; the cost would have been $19,800 more for copper, plus additional annual line loss of $1700, than if one substation was located at the center of load distribution for the uptown district and another was located in the South Butte residential district where approximately 25,000 people reside. Even under these conditions it would have been more economical to use the copper and suffer the line loss than to install a manually-operated station in South Butte because the company pays each operator $7 per day for an eight-hour shift. As this station would have to run at least sixteen hours a day, making an annual operating charge of $5110, it is

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[*] Reprinted from the *Electric Railway Journal*, March 22, 1919.

[†] "Operation of Railway Substations Without Attendants," by W. D. Beaver, November, 1917, p. 863; "Give the Operator a Job," by C. M. Davis, November, 1916, p. 1020; "Automatic Railway Substations," by C. M. Davis, October, 1915, p. 976; "Automatic Substations," by H. R. Summerhayes, September, 1913, p. 662.

obvious why the automatic substation was the economical solution of the problem regardless of an additional cost of $9000 for buildings, land, and equipment for the synchronous converter.

It was estimated that one day's work per week was sufficient for cleaning and inspecting the apparatus, amounting to $364 annually, as an electrican receives $7 per day. It was estimated that materials would cost $256 per year, including necessary incidental supplies such as oil, waste, brushes, contacts, etc. The total annual charge for material and maintenance was thus estimated at $620; the actual cost was $355.80. Of the latter amount 82 per cent was for labor.

The automatic substation has given very reliable service, for during the year it failed but four times. On two occasions the auxiliary to relay No. 27 failed to open. This relay keeps the station from starting when the alternating-current voltage is low. In failing the first time the clutch and trip coils were damaged, as the voltage was too low for the oil switch motor to complete the closing operation. The damage would not have occurred had the circuit been properly fused, as it was the next time the relay failed. This time the damage was simply a blown fuse. The manufacturer of the equipment, the General Electric Company, replaced the auxiliary to relay No. 27 with a relay of a later type and no further trouble has been experienced.

Fig. 2. Diagram of Distribution System, Butte Electric Railway

On another occasion the rotary was stopped on a very hot day by the operation of the bearing thermostat. This thermostat had a lower temperature setting than was necessary and the converter simply remained idle until an electrican arrived. On another occasion, before electrolytic lightning arresters were installed on the direct-current feeders, lightning entered the station. All the damage in this case consisted in a blown fuse and the burning off of the insulation from the wire of the lighting circuit which was tapped to the feeder.

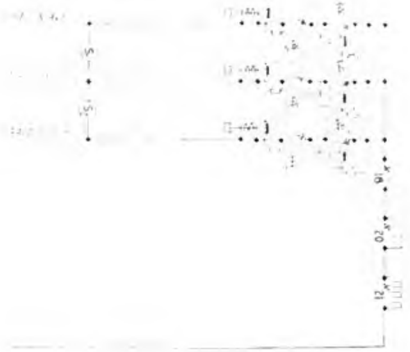

Fig. 3. Simplified Diagram of Substation Connections and Feeders

It happens that the machines in the railway company's central substations are of the same type, style, and capacity as that in the automatic, so that there is an excellent opportunity to compare the operation of these two substations. The synchronous converters are 500-kw., 60-cycle, 660-volt, six-phase General Electric machines, diametrically connected. The full-load rating is 834 amp., and they are designed to carry 50 per cent overload for two hours and 100 per cent overload momentarily. They have flash suppressors,* or arc coolers, as shown in Fig. 6.

The two synchronous converters in the central substation have flashed over, and have flashed to the pedestal. The short-circuit current for the manually-operated substation has been limited to less than 3000 amp. Although on one of the 500,000-circ. mil feeders the nearest trolley tap is more than 10,000 ft. from the substation, a pedestal

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* For a description of flash barriers see "Protection from Flashing for Direct-current Apparatus," by J. I. Linebaugh and J. L. Burnham, GENERAL ELECTRIC REVIEW, July, 1918, p. 499.

flash was experienced from this circuit. By way of contrast to this, the automatic substation has demonstrated its ability to handle a short-circuit without flashing several times when the short-circuit current would have reached a value in excess of 4000 amp., the only indication of trouble was a faint squeak. In one test the trolley wire was short-circuited to the rail within 1000 ft. of the station. In this case a flash started but it was extinguished by the wire arc coolers. This non-flashing feature of the automatic substation is worthy of consideration. It is, of course, due to the use of the flash guards and the load-limiting resistors which have a cushioning effect. These resistors could be used in a manually-operated substation to supplement the circuit breakers.

Fig. 4. Back of Switchboard, with Resistors Above, Heavy Contactors in Center, and Controller Cover in Foreground

As stated previously, lightning entered the automatic substation practically without doing any damage. It also entered the manually-operated substation, where it jumped to the low-voltage release of the synchronous converter circuit breaker and blew the instrument fuses. A bearing was burned out in the manually-operated station, also, which would not have occurred with automatic control.

The automatic substation, as will be seen from Fig. 2, is located in South Butte and operates in parallel with the central substation through an automatic sectionalizing switch. The automatic feeds three separate trolley sections, utilizing practically but one 500,000-circ. mil feeder and the double trolley of the same circuits. This is accomplished through the use of two General Electric automatic sectionalizing switches at a point where two lines branch from the main line. The Oregon Avenue and the Race Track lines receive their power from the Englewood or South Butte lines through sectionalizing switches S_1 and S_2.

The contactors in the automatic substation for the Oregon Avenue and Race Track feeders are used to energize these circuits to close the automatic sectionalizing switches in case they open through overload, as the breakers for the Englewood or South Butte feeders would not open to equalize the separate sections. The Oregon Avenue and Race Track feeders will (with a reduction in voltage) carry the loads of these stations in case the power is not on the Englewood section.

Instead of using a single contactor for the feeders from the automatic substation, which is in parallel with the resistor, use is made of two contactors in each circuit so that in case of a trolley break only the affected section is disconnected from the bus. As will be seen from Fig. 3, one contactor shunts the resistor and the other is in series with the line on the line side of the contactor and resistor.

Fig. 5. Main Switchboard with Controller in Background

The holding coil of the series contactor is wired from the bus through the contact of a thermostat placed over the resistor of that circuit. When the shunted contactor opens, through the opening of the contact of a series overload time-limit closing relay, current passes through and heats the resistor. If the temperature of this reaches a predetermined value the contacts of the thermostat open, thus opening the holding circuit of the line contactor which disconnects the feeder from the bus. By the use of the connection of the holding coils as shown in Fig. 3, the contactors are closed whether the station is running or not. This is necessary, for at night when the automatic substation is not running, the closed contactors furnish power for Oregon Avenue and the Race Track to close the sectionalizing switches in case they open on account of overload.

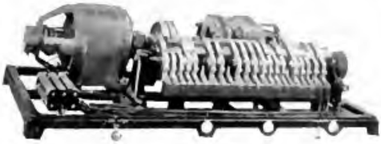
Fig 6. Motor-driven Drum Controller

The operation of the South Butte automatic substation has been so satisfactory that plans are now being made to add another substation of the same type to the system and to make the central substation automatic. By the addition of a second substation, copper to the value of $6,000 would be recovered and this station would be available in case one of the other units failed to function. That this would be economical is evident from the fact that the three operators in the central substation are paid $7665 per year.


Fig. 7. Transformers, Converter and Auxiliaries

In conclusion, and for purpose of completeness, it should be stated that the population of Butte is given by the 1910 United States Census as 39,165. This figure is misleading as it includes only the inhabitants of the small area within the city limits, covering about 5½ sq. miles. There are a number of towns and residential sections adjoining the city with an aggregate population of about 70,000. Consequently the total population served by the railway is at least 100,000.

Fig. 8. Commutating-pole 500-kw. Synchronous Converter, showing Flash Barriers

Mazda Lamps for Motion Picture Projection

By L. C. Porter

Edison Lamp Works, General Electric Company

This article describes some changes that have been made in Edison Mazda Lamps for motion picture projection as the result of further research and experience from service installations. The lamp wattage has been increased to 900 and a tubular bulb used in place of the spherical bulb, permitting a nearer setting of the mirror and consequently a greater volume of light. Some improvements in control apparatus have also been effected and are described in the article.—Editor.

In the December, 1917, issue of the General Electric Review there appeared a discussion of the application of Edison Mazda lamps to motion picture projectors. That article described the principles involved in the lens system and illustrated the apparatus necessary to change the light source of the projector from an arc lamp to an incandescent lamp.

Since that article was written, a great deal of research work has been done and considerable experience obtained from service installations, with the result that some changes have been made in Edison Mazda projection.

The 750-watt lamp has been increased to 900 watts and the bulb changed from a GT-29 to a T-20 (Figs. 3 and 4). The new lamp operates at 30 volts, 30 amperes. It is 10 in. overall, 2½ in. diameter, 3¾ in. light center length, and is fitted with a Mogul base; in other words, it is in the same bulb as the 600-watt, 30-volt, 20-ampere lamp. The new 900-watt lamp should increase the screen illumination considerably over that obtained with the old 750-watt lamp.

The method of mounting the filaments in the bulb of both the 900 and the 600-watt lamps has been changed somewhat from the construction shown in Fig. 5 of the General Electric Review for December, 1917. The relative settings of lamp, lens and mirror, however, remain the same. Because of the fact that the 900-watt lamp is now in the

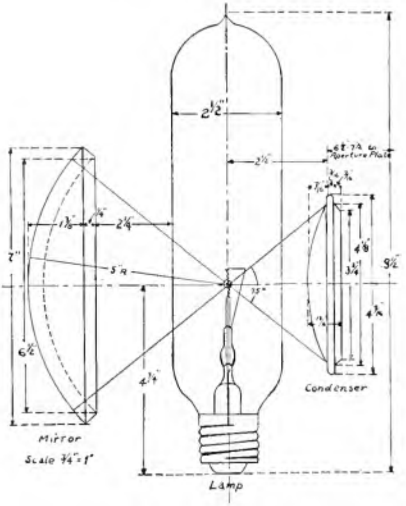

Fig. 1. Drawing showing proper relative setting of Large Spherical Mirror, Motion Picture Lamp, and Large Prismatic Condenser

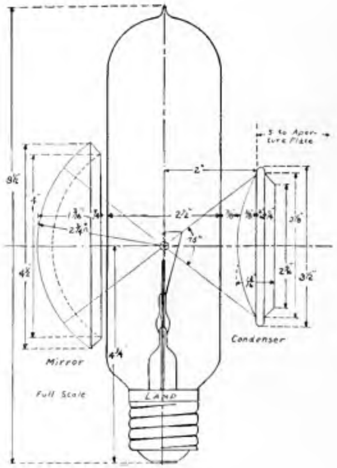

Fig. 2. Drawing showing proper relative setting of Small Spherical Mirror, Motion Picture Lamp, and Small Prismatic Condenser

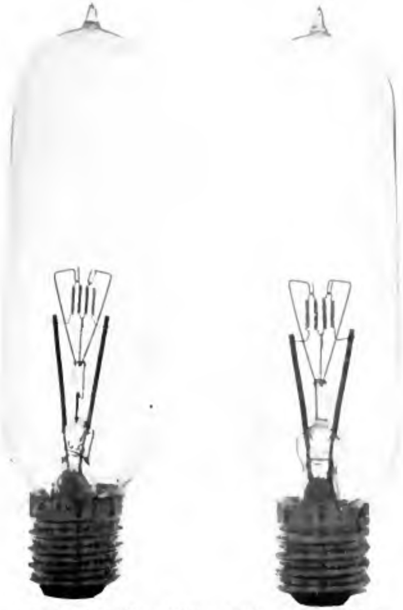

Fig. 3. Front View of 600 and 900-watt Mazda Motion Picture Lamps

Fig. 4. Side View of 600 and 900-watt Mazda Motion Picture Lamps

Fig. 5

Fig. 6

Figs. 5 and 6 Automatic Controller for Edison Mazda Projection Lamps Operating on A C. Circuits.

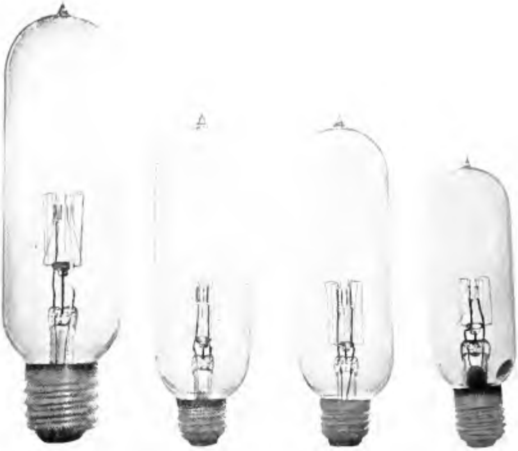

Fig. 7. Tubular Stereopticon Lamps, 100-125 Volt Range

same bulb as the 600-watt, it is possible to use the smaller mirror and condenser, if desired (Figs. 2 and 3). This results in a more compact lamp housing, but has the disadvantages of more rapid mirror deterioration, due to its close proximity to the lamp, and shorter working distance between the condensers and aperture plate.

A new and more compact type of control (Figs. 9 and 10) has been developed, which is known as the Argus current regulator.* This device is made in two sizes, one for the 600-watt lamp and the other for the 900-watt lamp.

By turning the handle on the device, the proper lamp current may be maintained on any line voltage between 100 and 125. With this regulator it is necessary to use an ammeter in the lamp circuit. The meter should be located at least two feet away from the regulator, so that the magnetic field from the latter will not affect the accuracy of the meter.

Another type of regulator has also been developed, and is known as the automatic or constant current regulator (Figs. 5 and 6). This device has many advantages over the hand type of control. No matter how frequently the line voltage fluctuates, nor over what range within the limits of 105 to 125 volts, the regulator automatically holds the lamp current constant at exactly the proper value. No ammeter is required with this control, and when once properly installed it requires no further attention on the part of the operator. This arrangement gives him more time to attend to his machines, and

Fig. 8. Tubular Stereopticon Lamps, 30-12-6 Volt Range

assures maximum life from the lamps with constant illumination on the screen. The control automatically protects the lamp from a heavy inrush of current when it is first turned on. This is not the case with the hand control, if the operator forgets to turn his

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* May be obtained through the Argus Lamp and Appliance Company, Cleveland, Ohio.

handle to the starting position before closing the line switch.

The advantages of the automatic control, particularly the saving in lamp renewals and cost of an ammeter, should more than offset its slight additional cost. The regulator is furnished in two sizes, one for the 600-watt lamp and the other for the 900-watt lamp. It is to be highly recommended for all a-c. installations of Edison Mazda lamps for projection service.*

Fig. 9. Argus Hand Control

Fig. 10. Argus Hand Control with Casing Removed

The large housing shown in Fig. 8 of the GENERAL ELECTRIC REVIEW for December, 1917, remains practically unchanged and has proved most successful in service. There is now available an adapter that may be fastened to the front of an arc housing to enable the use of Edison Mazda lamps without removing the arc housing.† Either the 600 or 900 watt lamp may be used in this adapter.

The field for small motion picture projectors and stereopticon lanterns for home and educational purposes has also been developing rapidly. For this field a line of tubular Edison Mazda lamps has been developed (Figs. 7 and 8). These lamps are to be recommended in old machines wherever the housings will accommodate them and for all new developments. Round bulb lamps will continue to be available for those projectors already in service with housings which will not accommodate the new lamps. The new lamps have the advantage of enabling the condenser to be placed closer to the filament, thus picking up a larger angle of light with a corresponding increase in screen illumination.

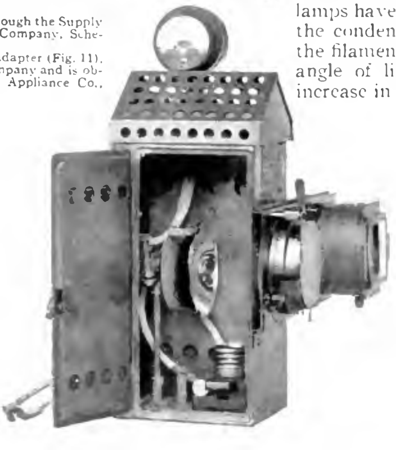

Fig. 11. Argus Lamp Housing

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* These devices can be obtained through the Supply Department of the General Electric Company, Schenectady, N. Y.

† This device, known as the Argus adapter (Fig. 11), is made by the General Electric Company and is obtainable from the Argus Lamp and Appliance Co., Cleveland, Ohio.

BOOK REVIEWS

The Principles Underlying Radio Communication—Radio Pamphlet No. 40, Signal Corps. Prepared by the Bureau of Standards under the direction of the Office of the Chief Signal Officer of the Army, Training Section. May be obtained from the Superintendent of Public Documents, Government Printing Office, Washington, 55¢; 355 pages, illustrated

For the preparation of this book, the staff of the Bureau of Standards was temporarily increased by the following men: Dr. F. W. Grover of Colby College, Prof. C. M. Smith of Purdue, Prof. G. F. Wittig of Pennsylvania (now of Yale), Dr. A. D. Cole of Ohio State, Dr. L. P. Wheeler of Yale, and Prof. H. M. Royal of Clarkson college of Technology, who worked under the active direction of Dr. J. H. Dellinger of the regular staff of the Bureau. Prof. H. V. Bozell of Yale, of the consulting staff of the Bureau, and of the War Department's Education Committee, was in frequent conference on the scope and manner of presentation. The work was edited and published under the direct supervision of Capt. H. L. Brown of the staff of Colonel J. C. Moore of the Signal Corps.

The book is an excellent elementary text on the principles underlying radio communication. It was prepared particularly for the needs of non-commissioned officers of the Signal Corps and men in training to become non-commissioned officers. In general, the book is written upon the assumption that the reader has a mental training equivalent to the usual high school Senior or graduate. This naturally limits the scope of the treaties to more or less elementary considerations, but, in spite of this limitation, it is remarkable how valuable the book is to anyone not already quite far advanced in radio or in things electrical. Even to the electrical and radio engineer the concise, clear, comprehensive treatment is appealing and invites reading.

About half of the book is devoted to the general chapter headings of elementary electricity, including magnetic and electric circuits both direct and alternating, batteries, and dynamo electric machinery. The other half is devoted to radio circuits, electro-magnetic waves, apparatus for transmission and reception, and vacuum tubes. It appeared necessary to develop the theory of electricity from the beginning for the type of man to be reached and to carry radio communication to a point which would make it understandable to the men who had to repair and operate rather complex apparatus.

The treatment is very clear and logical. The illustrations are excellent. Use has been made of only the simplest mathematics, nothing more than arithmetic and simple algebra; definitions, illustrations, and analogies have been used which, perhaps, would not be used for more advanced students but which add much to the attractiveness of the book. For further study frequent references are given to standard books and to derivations and developments of formulæ and facts which are merely stated or shown by analogy. The book as a whole is very readable and provides an excellent text for the amateur, the more advanced operator, or even the advanced student who is just beginning his study of radio. The first half of the book alone is a splendid presentation of the subjects of electrical circuits, batteries, and machines and is suitable as a text or review on these subjects, irrespective of one's interest in radio. In the second half, where radio is emphasized, while in mathematics the book may be elementary, in practical presentation it is sufficiently rigid, concise, and complete for all practical purposes. Much of the historical material of no present value, usually found in radio books, is not present, while there is present much which books even one or two years old do not contain.

As a whole this work, produced as a war time necessity, should be much in demand, and the public should be grateful to the Signal Corps for making it available for general distribution.