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JUNE, 1919

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General Electric Review

A MONTHLY MAGAZINE FOR ENGINEERS

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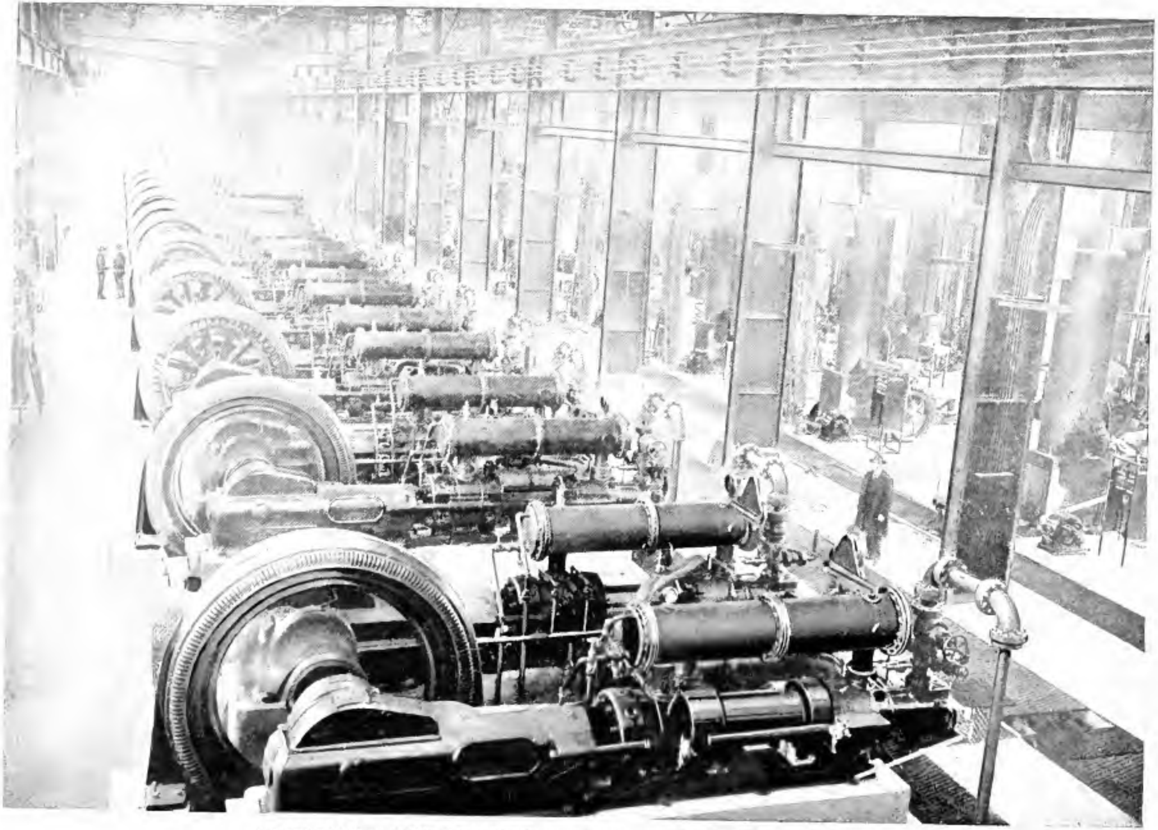
CONTENTS



A BATTERY OF TWENTY SYNCHRONOUS MOTORS DRIVING AIR COMPRESSORS, UNITED STATES AIR NITRATES CORPORATION, MUSCLE SHOALS, ALA.

GENERAL ELECTRIC
REVIEW

THE ELECTRIFICATION OF MAIN LINE RAILROADS

The article published in this issue under the above heading gives ample food for some profitable thought. Although the writers state "we do not propose to suggest that all the railroads in this country will ever be operated electrically, certainly not within a reasonable time * * *" the very presentation of the facts they give start the reader wondering how close we shall approach the complete electrification of our transportation facilities during his lifetime.

The range of electrical apparatus developed to date for traction purposes is such that, from an engineering standpoint, there is no railroad division in the country that could not be successfully equipped. This leaves the extension of the electrification of our steam railroads entirely dependent upon economic considerations, so when we start speculating on the possible degree of the extension of electrification it is only necessary to consider "Will it Pay"? In this connection it should be constantly borne in mind that "Will it Pay" was not the consideration which governed some of our most notable electrification undertakings in the past, but that the inherent limits of the steam locomotive in city terminals and tunnels forced the change. After the change was made it was found that *it did pay*.

The authors state that, on a single track basis, including 50,000 miles of trolley line, there are approximately 450,000 miles of track in the United States and that there are 8,300 miles of track over which electric locomotives are hauling passengers and freight. That is to say, there are 8,300 miles equipped for heavy electrical traction. This leaves a possible mileage, on a single track basis, of 441,700, including all steam lines and trolley lines, which may yet be equipped for heavy electrification. Many miles of city trolley lines will never require such equipment, so for lack of exact data let us assume that there are approximately 400,000 miles of single track in the United States that could be electrified *if it pays*.

The question is *how much* will it pay to electrify? This question will have a different answer each year. From a purely National point of view the number of miles that it will pay to electrify will increase each year, because one of the greatest arguments for electrification, but one which has only recently been brought forward, will be better realized each year, namely, the conservation of our National Fuel Resources.

In 1914 our railroads hauled about 1,000,000,000,000 ton miles and consumed an equivalent of 140,000,000 tons of coal, a truly big expenditure of such valuable National resources as oil and coal. Had all this work been done electrically 100,000,000 tons of coal, or its equivalent in oil, could have been saved in twelve months. How much of this 100,000,000 tons of coal can we save each year? Again the answer to this question will be different as each year passes.

There is no question but that there are many divisions of steam railroad in the United States that it would pay to electrify this year, because of the inherent limits of the steam locomotive in areas of congested traffic, in large terminals, in tunnels, due to heavy grades, the expense of coal and water, bad water and the large percentage of non-revenue traffic which these limits compel in many instances.

When all such mileage as is governed by these considerations has been electrified, there will remain stretches of steam railroad between these "bottle-necks," but there will have been built many new steam plants and hydro-electric stations. When this is an accomplished fact the question of whether or not it will pay to electrify some of the remaining divisions will be entirely different. As each remaining division becomes only a stretch of track between two electrical divisions, conservation of fuel, uniformity of equipment, economy in the distribution of power, and many other reasons will bring many of these divisions into a class where electrification will pay.

The more one dwells on these considerations, the more impelling the thought becomes that the economies to be secured by the electrification of our steam railroads are additive year by year. The more we do the more it will pay to do.

J. R. H.

Electrification of Main Line Railroads

By W. B. Potter

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and

S. T. Dodd

Railway and Traction Engineering Department, General Electric Company

A knowledge of the fundamentals of railroading is essential for the selection of the correct equipment in each main line electrification proposition; interest on investment and maintenance charges are governed by this initial choice. After emphasizing these points and stating the reasons for electrification, the authors give instructive statistical data on the power demands for the electrical operation of steam railroads in the United States, citing some truly remarkable totals. They then discuss the design of electric locomotives, bringing out instructive reasons for some important features in the American designs.—Editor.

The relation of electricity to electrification is much the same as that of steam to the steam railroad, although the manifestation is quite different. We have switches instead of valves, solid conductors instead of pipes, contacts instead of pipe fittings, rotary motors instead of reciprocating engines, but these are differences in kind rather than in function.

The problems presented to the engineer by the electrification of main line railroads demand a comprehensive appreciation of railroading as fundamental to the solution. There are several methods by which electrification may be accomplished and with which there can be no questions as to the successful operation. The duty of those concerned is to choose the method and type of equipment which will ensure the best economic results. The interest on investment and the maintenance are, in particular, among the perpetual expenses which are largely determined by the initial choice.

In our presentation we have endeavored to outline some of the general features rather than attempted to give any detailed description of the apparatus.

The subject is one of world-wide importance, but seems to have been recognized, especially in the United States. Whether this recognition has been stimulated by our railway operating conditions or is due to our own more ready appreciation of economic values, is a question which may be open for discussion, but the fact is, that in spite of our great mileage, we have more actual main line electrification and a greater proportion of our total mileage electrified than all the rest of the world.

The following approximate statements will give a general view of the appreciation of heavy electrification in the United States:

Railway Route Mileage of the World

United States	265,218
Europe	217,000
Rest of the world	230,902
Total	713,120

The 265,000 miles in the United States represents about 400,000 miles of single track. To this must be added about 50,000 miles of trolley lines, making the total railway single track in the United States approximately 450,000 miles.

In considering heavy electrification, if we eliminate the electric roads which are devoted strictly to motor car service, and include under our category those tracks, both steam road and trolley, which are handling freight and passenger service with electric locomotives, we find in the United States approximately 675 electric locomotives operating over 4875 miles of route, or 8300 miles of electrified track. Compared with this, in all the rest of the world there are approximately 450 electric locomotives operating over 1000 miles of route, or 1750 miles of track. That is, the percentage of electrified route mileage in the United States is about ten times as much as the percentage in all other countries combined.

Reasons for Electrification

The reasons which may justify a change in motive power from steam to electricity on main line railroads have been discussed often and at length. Such reasons as freedom from smoke and cinders, increased carrying capacity of track, decreased expense of operation, elimination of delays due to grades and other conditions, increased safety and reliability, and other similar advantages could be tabulated and discussed at length. Probably the freedom from smoke and cinders has been the definite impelling cause in all the early electrifications. Such systems as the Baltimore Tunnel, the New York Central Terminal at New York, the Detroit River Tunnel, the Cascade Tunnel on the Great Northern, were primarily electrified in order to overcome the disadvantage of smoke.

Today, however, there is an argument for electrification which, within the last two years, has been more sharply emphasized than any other. This is the conservation of fuel. When we realize that 25 per cent of the coal mined in the United States is used on its railroads, we see the importance of considering this feature. This, therefore, is the only one among the various reasons for electrification to which we will particularly direct attention.

The energy demand per 1000 ton miles for railroad service varies widely under different conditions. An average has been made of a number of tests on heavy railway service, particularly tests on the recently electrified sections of the Chicago, Milwaukee & St. Paul. These, with due allowance for losses in distribution and the transmission system, give an average of approximately 33 watthours at the power house per ton mile moved over the railroad. For contingencies we might increase this item approximately 20 per cent and we have assumed in the following table 40 watthours per ton mile as an amply conservative basis for estimating the electric energy.

Fig. 1. 115-ton Gearless Bipolar Locomotive. Forty-seven of this original type of locomotive were furnished to the New York Central Railroad for hauling passenger trains out of the New York Central Terminal

In order to present a figure showing the economy of electric operation it is necessary to make some sort of estimate of the ton miles included in railway traffic. Taking the reports of revenue traffic for the year 1914 and including the estimated tonnage of cars and locomotives, we find that the railway traffic for that year amounted to about 1,000,000,000,000 ton miles. Out of this, the movement of coal for railway purposes, together with the coal cars and locomotive tenders carrying the same, amounted to about 12 per cent.

It will be of interest to estimate the electric power which would be required to move this tonnage exclusive of the railway coal haulage.

Power Demand for the Electric Operation of the Steam Railways in United States, 1914

Ton miles, excluding tenders, but including 25 per cent of railway coal cars	930,000,000,000
Watthours per ton mile (assumed)	40
Annual Power	37,200,000,000 kw-hr.
Coal required at central steam power stations at 2.2 lbs. per kw-hr.	40,000,000 tons
Average continuous load	4,250,000 kw.

The actual fuel used on steam locomotives for the year in question was 128,400,000 tons of coal and 40,000,000 bbls. of oil, or a total coal equivalent of 140,000,000 tons. The preceding table shows that the same tonnage could have been moved with electric locomotives by an expenditure of 40,000,000 tons—a saving of 100,000,000 tons per year. It is difficult to know how to emphasize this conclusion. We admit that the statistics which we have presented are more or less approximate, but the indication that electrical operation of the railways in the United States would result in a yearly saving of 100,000,000 tons of coal is in itself a conclusion that, in view of the critical conditions of the last two years, must demand attention.

We do not propose to suggest that all the railroads in this country will ever be operated electrically, certainly not within any reasonable time, but the figures we have presented have been called to your attention to emphasize the importance from this standpoint of considering railway electrification wherever the conditions admit.

The figures which we have presented were prepared on the basis of the 1914 reports when the coal production for the country was 513,000,000 tons. Statistics for the last year are not available, but unofficial estimates have indicated that the coal production for 1918 was 685,000,000 tons. All the figures given in the preceding table would presumably be increased by 25 to 30 per cent in order to represent conditions today.

Although for purposes of comparison we have devoted considerable space to the saving in fuel that would result from the use of central steam power stations for the operation of railways, it is self evident that the utilization of water power is more vital to the subject, as affording the only known means for effectually conserving our limited fuel supply. At the present time, the water power development in the United States amounts to about 5,000,000 kw. Knowledge as to the possible future of hydraulic development is indefinite, as many of the water power sites have not been completely surveyed. Estimates as to the presumable ultimate development vary considerably, but are around 50,000,000 kw.

The relative amount of power required for complete railway electrification is less than is usually supposed. A number of power stations capable of delivering 37,200,000,000 kw-hrs. per year, with an average twenty-four hour load of one half the installed capacity, would have an aggregate installation of approximately 8,500,000 kw. The statistics of steam and hydraulic electric power plants in the United States indicate that in 1917 there were installed, in central stations for lighting and power purposes, approximately 9,000,000 kw., in railway power stations 3,000,000 kw., and in isolated stations 8,000,000 kw., a total installed capacity of about 20,000,000 kw. It is apparent that instead of the problem being prohibitive in size, there is already installed in the country a power station capacity of over twice the requirement for operating all the railroads electrically. The power that would be required really is not excessive as compared with the electrical development which has already been accomplished.

Fig. 2. 120-ton Geared Type Locomotive Operating Through the Detriot River Tunnel of the Michigan Central Railroad

The present tendency of modern power development, both steam and hydraulic, is towards the growth of large central power stations and interconnected distributing systems. These power stations will be situated at points of cheap coal supply or of hydro-electric development, and will furnish power for cities and industries over a wide section of country. The same systems will also furnish power for the railways in their territory.

The Montana Power Company may be cited as an illustration. This company has twelve hydraulic power stations feeding into a common distribution system at 100,000 volts. The total installed capacity is approximately 175,000 kw. with possible extensions by future development of an equal amount. Power is furnished for lighting and industrial purposes to various cities throughout the state and also to the Chicago, Milwaukee & St. Paul Railway. The average twenty-four hour power demand for the 440 miles of the Chicago, Milwaukee & St. Paul electrification is only in the order of 15,000 kw. with a maximum of about 28,000 kw.

Fig. 3. Latest Type New York Central Locomotive Designed for High Speed Heavy Passenger Service Over the Electric Division Between New York and Harmon. Each unit is equipped with eight bipolar gearless motors and weighs 125 tons

Design of Locomotives

A comparison of American electric locomotive development with European, and particularly Continental, shows a characteristic difference in the method of transmitting the power of the motor to the driving wheels. In America the success attained with the many heavy high-speed motor cars, and the utilization of these cars in many cases for hauling trains, naturally led to the building of similar equipment for locomotive purposes only. This type of locomotive represents the most economical design, but as the tractive effort is transmitted through the truck center pin, this type is commonly limited to a weight of about 60 tons. For heavier locomotives of this type, weighing from 60 to 100 tons, the two trucks are usually connected and the tractive effort transmitted directly through the trucks instead of through the locomotive frame.

The Continental designers, having had little experience with heavy motor car equipment, were skeptical of gearing and the practice of mounting motors directly on the axle. Their efforts have been mainly directed towards substituting the electric motor for the steam locomotive cylinder, retaining all of the side rods and adding a few more. There is a difference, however, between driving side rods from a steam piston and from a motor driven crank, which does not seem to have been fully appreciated. In a steam engine the maximum stresses and pin pressures, so far as the driving power is concerned, may be predetermined from the piston area and steam pressure. In an electric locomotive, however, having a motor driven crank and side rods, the maximum stresses are influenced by variations in the wheel centers and the wear of bearings. The mechanical design must be strong enough to withstand the driving torque at an angle of 45 degrees from the center, and at as much less angle as may result from the variations. As an extreme illustration, with one side stripped and the other on dead center, the stresses would be in excess of any practicable design.

The Continental locomotives show many variations by the side rod drive, both with the jack cranks direct driven by the motor through parallel rods or by means of gearing. Comparing only the most important trunk line electrifications in Europe and America, we find that out of nine European railroads operating 210 locomotives, there are represented 28 different types, while out of 14 American railroads operating 364 locomotives

The design of electric locomotives for high-speed passenger service at 60 to 80 miles per hour is a more complicated problem, a substantial saving through the elimination of turn tables, and incident delays, being obtained by designing the locomotive double-ended and capable of running equally well in both directions, this desirable requirement involving features of design differing from that of a steam locomotive built for operation in one direction only.

A problem in the design of a double-ended locomotive is to control the lateral oscillation and to minimize its effect on the track. This characteristic is more in evidence on tangent

Fig. 4. Electric Trains on the Butte, Anaconda & Pacific Railway and on the Chicago, Milwaukee & St. Paul Railway Hauled by 2400-volt and 3000-volt Direct-current Locomotives

only 21 types are represented. The cause for this difference is to be found in the development of the American locomotive from the motor car as we have sketched above, and in the fact that this American development has largely been determined by commerical reasons.

The design of American locomotives, for slow speed freight and passenger service, has been influenced largely by the heavy motor car with motors geared directly to the driving axle. A gearless motor which could develop as tractive effort, a proportion of the weight on the axle comparable to the geared motor, would furnish a still simpler design. Recent developments along this line indicate the possibility of such a gearless slow-speed locomotive at a comparable price.

track where the flanges of the guiding wheels are free to move within the clearance, than on curves where the flanges of these wheels bear firmly against the outer rail. This characteristic also appears, though in a different form, in the single-ended steam locomotive, as the front and rear ends are not both subjected to the reactionary influence of two guiding trucks. In any event the wheels at the front and rear ends must be relied upon to withstand the effect of these lateral oscillations.

In a double-ended locomotive with guiding trucks at each end, any lateral oscillation will deliver a thrust at the truck center plate, both at the front and rear ends. The roll of the locomotive body has little tendency to transfer weight to the outside guiding wheels, and therefore has but little effect in holding down the outer rail. The lateral movement of the locomotive, however, does increase the weight transferred to the outside guiding wheels in proportion to the height of the center plate above the rail head.

The problem presented is to design a double-end locomotive with leading and trailing trucks which shall have sufficient guiding force for the front end, and with such characteristics as to minimize the cause and effect of lateral oscillations.

To minimize the cause of lateral oscillations the front and rear trucks should be restrained so far as possible from any individual movement other than that essential to the proper guiding of the locomotive. Experience has demonstrated that a two-axle truck, with an articulated connection, accomplishes this desired result much more effectually than either a two-axle bogie or pony truck.

To minimize the effect of lateral oscillations the characteristics should be such that the truck will allow a time element during delivery of the thrust against the rail head, and such that any lateral thrust at the center pin will produce a large vertical component at the outer guiding wheels. Raising the bearing point or center plate of guiding trucks to 60 in. or 70 in. above the rail head has shown by tests that these characteristics can be obtained in that manner. W[illegible] attention to the fact that a [illegible] double-ended, high-speed locomotive [illegible] obtained by a proper [illegible] of the front and rear trucks.

For high-speed passenger service with speeds of the order of 60 to 80 miles per hour, on a locomotive equipped with geared motors the gear reduction approaches a small ratio if the armature is to be kept within practical rotative speeds. This presents all the disadvantages of increased weight due to gears, with their cost of maintenance, without the compensating advantage of the increase in tractive effort usually gained by gear reduction. Consequently, it appears to us that for such speeds and for such service the gearless motor with the armature mounted directly on the axle presents the best solution. The bipolar gearless motors on the New York Central Railroad which have been in service for twelve years have shown very low maintenance.

Fig. 5. 300-ton Geared Locomotive for Operation Over the Rocky Mountain Division of the Chicago, Milwaukee & St. Paul Railway. Two locomotives of this type are used to haul 2800-ton freight trains over the two per cent mountain grades

Collection of Current

The trolley pole and wheel which has so well served the electric railway is not well adapted for the heavy service we have been considering, nor is it a convenient device for movement in both directions. The pantograph collector which requires no attention on reverse movement has long been used, but it is only within the past few years that its capacity as a collecting device has been fully demonstrated. Rolling and sliding contacts have both been tried with results distinctly in favor of the slider. The wear of the working conductor, or trolley wire, is due far more to the destruction by arcs at the point of contact than from the mechanical friction, hence it is most important that the wire be so supported as to eliminate any rigid spots which are the usual cause of this arcing. The wire should be lifted slightly and really supported by the collector rather than that the collector should run underneath a wire held in rigid relation to its support. Lubrication of the collecting surface not only reduces the wear but seems to slightly improve the contact, presumably because of less tendency to chatter than with bare metal. The amount of current that can be successfully collected seems limited only by the current capacity of the working conductor. Tests have shown no arcing at the contact with 3000 amperes at 30 miles, and 2000 amperes have been collected with equal success at over sixty miles per hour. A copper conductor with copper wearing strips on the collector has been found to give the best results. Measurements taken on the Milwaukee Railroad indicate the working conductor will have a life of over 100 years before it will have to be replaced because of wear.

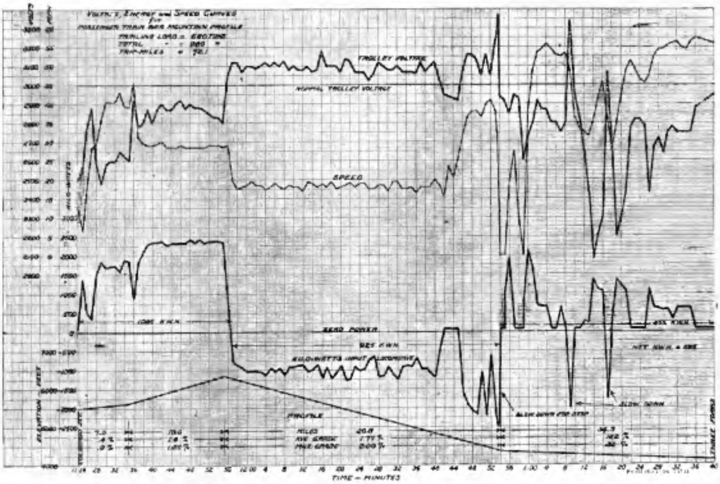

Fig. 6. Voltage, Energy, and Speed Curves for a 960-ton Passenger Train Running Over the Rocky Mountain Division of the Chicago, Milwaukee & St. Paul Railway from Colorado Junction (Butte) to Three Forks. The profile is shown below and the energy curve shows the amount of power regenerated on the two per cent grade

Regeneration

Regeneration as used in this connection implies the use of electric braking, and the utilization of the energy in the train as electric power which is fed back into the distributing system. The train on a down grade drives the motors as generators, which is comparable to the action of falling water in a hydro-electric power station. Regeneration is of special advantage in the long grades encountered in mountain districts, and grades of 20 to 50 miles in continuous length are found on almost all the railway lines crossing the continental divide. It eliminates the surging in the train and the variations of speed which are encountered in holding the train by air brakes. In addition to this, the wear of brake shoes is eliminated and the delays which are often due to overheated brake shoes on long grades are also avoided. The electric braking takes place entirely at the front end of the train, taking up all slack, and permits the air reservoirs to remain fully charged in reserve for emergency.

The amount of power returned to the trolley by regeneration varies with the amount of the grade and the type of train. On specific tests it has been shown that a train on a 2 per cent grade has regenerated 12 per cent of the power required to pull the same train up the grade. On a 1.66 per cent grade 23 per cent has been regenerated. The records for a particular month over the entire Rocky Mountain Division of the C. M. & St. P. for both freight and passenger trains show that the regeneration was equivalent to 11.3 per cent of the total power used.

Conclusion

We have attempted to give a broad survey of the field of railway electrification and some of the recent developments therein.

The fact that the developments in this field are greater in our own country than any other should be most encouraging to those who believe that the United States has taken and will maintain the lead in industrial development of the world.

Among the many reasons for considering railway electrifications, none stand forward so prominently as the possibilities in the direction of conservation of fuel supply. The fact that 140,000,000 tons of coal are used for railway service points toward electrification as assuming the greatest importance in the conservation of fuel.

On locomotives for freight and slow speed passenger service it seems probable that the use of geared motors mounted directly on the axle will be continued. On locomotives for high speed passenger work the motors will presumably have some type of gearing or preferably be of gearless design. The characteristics of the guiding trucks in their design and method of attachment are important for high-speed running.

We find that incidental difficulties in connection with operation of heavy service electrically are being solved. The collection of any reasonable amount of current from an overhead conductor offers no difficulty; while regeneration solves in a practical manner the problem of braking on long grades and returning the available power to the power system instead of wasting it in brake shoes.

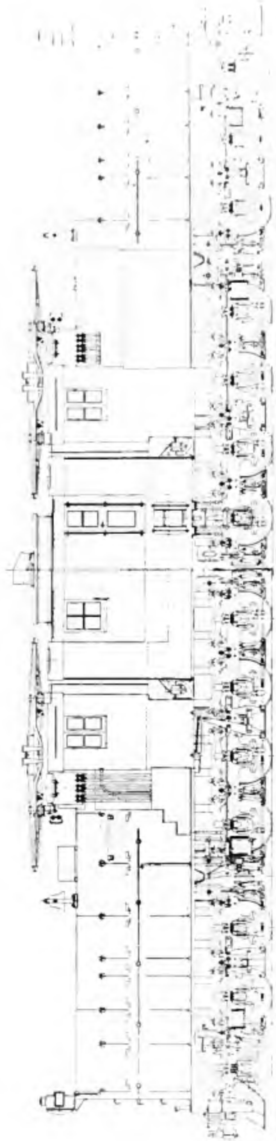

Fig. 7. Outline of 265-ton Passenger Locomotive Under Construction for the Chicago, Milwaukee & St. Paul Railway Cascade Electrification

Turbines for Mechanical Drives

By R. R. Lewis

Turbine Sales Department, General Electric Company

This article is the first of two which deal with a comparatively recent development in the construction of small and medium size turbines for the direct drive of pumps, etc. A description is given of the facility with which a selection can be made of standard parts to produce the turbine best adapted to the conditions of the particular application. In our next issue Dr. S. A. Moss will explain some of the problems in the design of these turbines.—Editor.

To meet the demand for a reliable and efficient steam turbine in small and medium sizes to drive centrifugal pumps, fans, and other moderate speed apparatus, the "Type L" mechanical drive turbine was designed.

These machines have been on the market about two years, and hundreds of them are in successful service, having established an excellent reputation for reliability and efficiency.

Many of these turbines are located in basements and other more or less inaccessible places where they are likely to receive the minimum of care and attention, but their ruggedness and simplicity have enabled them, under adverse conditions, to perform their duties with perfect success.

The reliability and efficiency of this type of turbine are assured by the utmost care in design and manufacture, and by the use of the best materials throughout. The design has been made as simple as possible; the turbine consisting essentially of a bucket wheel mounted on a shaft and enclosed in a steel casing, a nozzle for directing steam into the buckets, and an opening for the escape of exhaust steam.

One of the greatest difficulties met in the design of this line of turbines (or group of turbines with interchangeable elements) was to fulfill the requirements of moderate cost and at the same time to make the machines suitable for a wide range of operating conditions. For instance, in driving centrifugal pumps the speed depends largely on the head under which the pump is to operate, and turbines for this service must run at speeds from 800 to 3600 r.p.m. Again, the steam pressure may be anywhere from 75 to 200 lb. or over, the back pressure may be from atmospheric pressure to 20 or 30 lb., or the turbine may be required to operate with a vacuum. The capacity required may be 10 or 600 h.p.

It would, of course, be out of the question to develop a special turbine for each combination of conditions; but practically the same result is secured by designing certain standard elements, a number of which can be combined to form a complete turbine that will exactly fit any particular case.

The plan of construction adopted for these turbines involves the use of one, two, or three bucket wheels, a variation in the length of the buckets, and the arc of steam admission through the first-stage nozzles. In addition, the size of the steam and exhaust connections is varied and also the governor parts for regulation at different speeds.

Before assembling one of these machines for a particular duty, it is necessary to know the

(1) Capacity in brake horse power,
(2) Steam pressure,
(3) Superheat or moisture,
(4) Back pressure, or vacuum,
(5) Speed of revolution,
(6) Direction of rotation.

It is optional whether the turbine shall have one, two, or three stages; but the machine with the greater number of stages usually is more efficient but more expensive.

The turbine is of the Curtis impluse type in which the steam is given a relatively high velocity by passing through a divergent nozzle. It then immediately enters the revolving buckets, and as its velocity becomes reduced it gives up its energy to the buckets, causing a rotation of the wheel and shaft.

The steam in entering the turbine passes first through the emergency valve chest, if one is used, then through a steam strainer which prevents the entrance of scale or other foreign particles. It next passes through the governor valve and enters the turbine proper through the first stage nozzles. After passing through the buckets of a single-stage turbine it passes out of the exhaust opening. In the case of a two-stage turbine, the steam after leaving the first bucket wheel would pass through an opening in the diaphragm between the stages and through the second-stage nozzle, then through the second-stage buckets and into the exhaust.

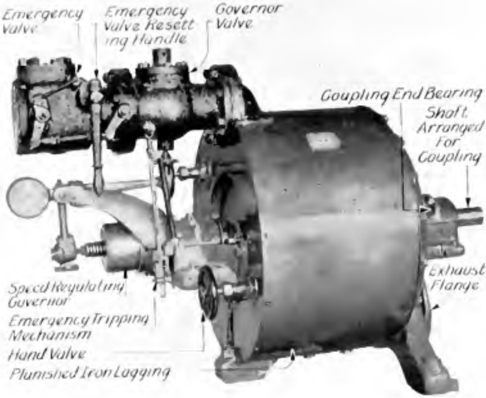

Fig. 1. Typical Mechanical Drive Turbine with Speed Regulating and Emergency Governors and Hand Wheels

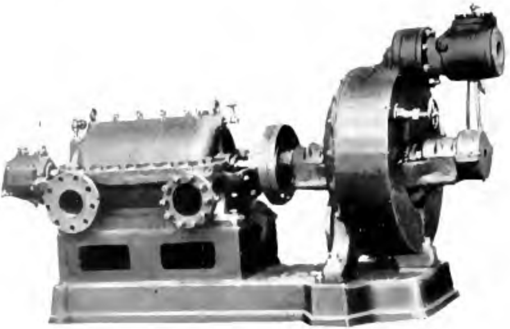

Fig. 3. Turbine Direct Connected to Pump

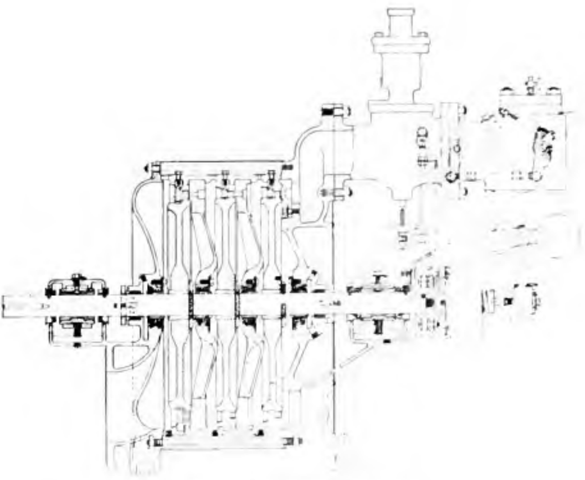

Fig. 2. Cross-section Drawing of a Mechanical Drive Turbine

Fig. 4. Turbine Direct Connected to Boiler Feed Pump

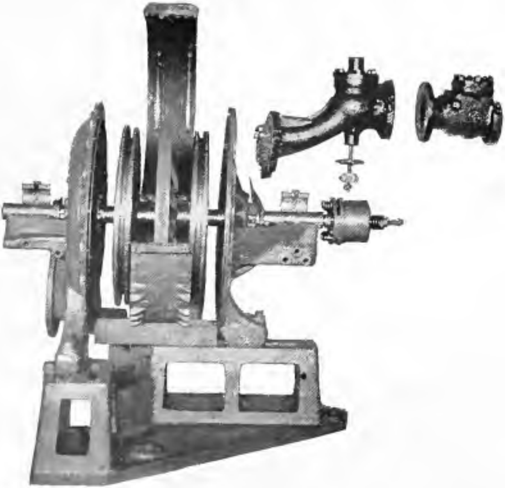

Fig. 5. Partially Disassembled Mechanical Drive Turbine

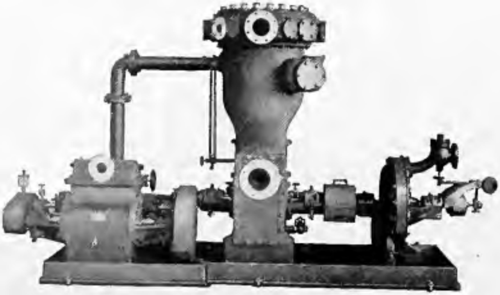

Fig. 7. Turbine Connected to Condenser Pump

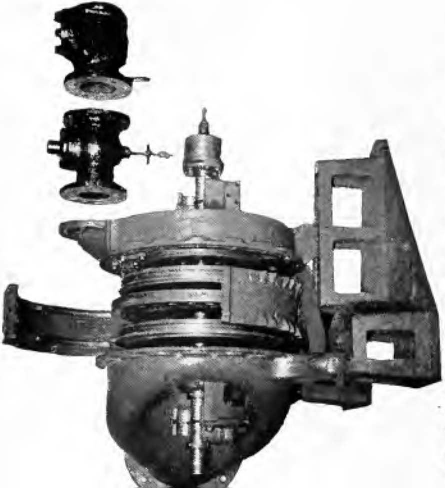

Fig. 6. Turbine similar to that in Fig. 5 except that the one here shown has a long Arc Head and Large Exhaust instead of a Short Head and a Small Exhaust

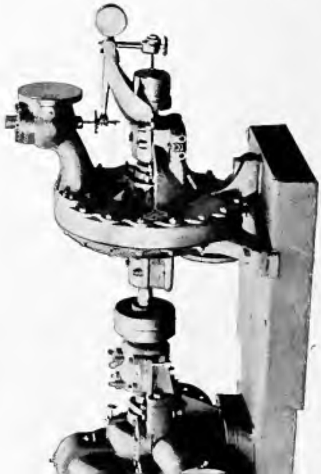

Fig. 8. Turbine Direct Connected to Pump

Fig. 9. **Floor upon which are assembled the turbines described in this article**

Fig. 11. Turbine Direct Connected to a Condenser Circulating Pump

Fig. 10. A Battery of Mechanical Drive Turbines operating Central ... P...

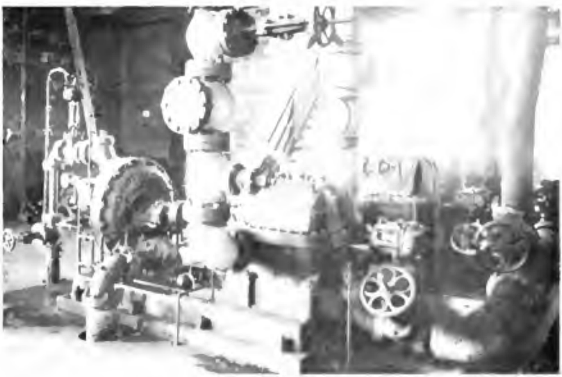

Fig. 12. Turbine Direct Connected ...

The wheel casing is made of steel and is split horizontally. To this are bolted the high and low-pressure heads. The heads support the main bearing brackets and are provided with feet on which the turbine rests. The high-pressure head also supports the steam chest and governor valve. The low-pressure head carries the exhaust flange.

The wheel disks are of steel and are keyed to the shaft. Each disk carries two rows of buckets made of bronze and dovetailed around the periphery.

The diaphragms are held by grooves in the casing. The bearings are babbitt lined and ring oiled.

The governor is of the centrifugal type and is mounted on the end of the shaft. It operates, through a bell crank, the governor valve which is of the double balanced poppet type.

By means of a simple device the speed may be altered while the turbine is running, the governor continuing to exert full control at the altered speed.

When desirable, an emergency governor may be fitted to the machine. This device is entirely independent of the governor, and in emergency shuts off the steam supply and prevents excessive speed.

For operation at two different steam pressures, or whenever the best efficiency is required at various conditions of load or speed, one or two hand valves may be used. These valves modify the effective capacity of the nozzles.

Varnished Cambric Cable for Underground Service

By W. E. Hazeltine

Chicago Office, General Electric Company

As varnished cambric cable for underground service is less liable to breakdown than paper-insulated cable, it is particularly suitable for the lines of the smaller operating companies, since these have not the interconnected networks of the larger companies nor can they afford the maintenance of a large cable repair force and cable stock. The following article describes the structure of varnished cambric cable and points out the features wherein this cable is superior to those of the paper or rubber insulated type.—Editor.

As there are many localities throughout the country, particularly in the middle west, that will eventually remove their overhead wires and install an underground cable system, the present time is opportune for investigating the merits of the different materials required and for preparing a preliminary survey.

In laying out an underground distribution system, many questions arise such as the location and construction of conduit system, number and kind of conduit, location of manholes, sizes and types of cables, junction boxes, subway transformers, etc. These are subjects of vital importance and all require careful investigation, for the proposed system should be adequate for the future as well as for the present, it being an expensive proposition to make alterations in a conduit system once installed.

As a discussion of all features of such a system would be impracticable, the scope of this article will be confined to the various types of cable available.

Undoubtedly, the conduit decided upon will be of fiber or tile, surrounded by concrete, and will contain lead-encased cables.

There are three types of standard cable insulations used for underground cables; paper, rubber, and varnished cambric.

Paper insulated cable has been adopted by practically all the larger operating companies for underground service, principally on account of its low initial cost and for its ability to withstand working temperatures found in conduit systems without serious deterioration. The initial cost of paper-insulated cable is lower than that of either the rubber or varnished cambric type; and, where large quantities are required, it reduces the investment in cable to a minimum. However, as paper insulation absorbs moisture readily, the life of a paper cable is dependent upon the lead sheath remaining intact, a breakdown occurring in approximately one month after the sheath becomes punctured by electrolysis or mechanical abrasion. Extreme care must be exercised in drawing paper-insulated cable into the conduit so as not to injure the sheath, and in splicing to be sure that moisture is excluded. The operating systems of the larger companies are so interconnected that a breakdown is not always a serious factor; and, furthermore, they are in a position to carry a reserve stock of cable and maintain a cable repair force, including high-grade cable splicers, while a small company cannot incur this expense.

Rubber-insulated cables are used to some extent, but when subjected to constant heating in conduits the insulation suffers continual deterioration.

For the smaller operating companies, whose systems are not interconnected, continuity of service is essential, and there is no question but that varnished cambric insulated cable is best adapted for such installations. Varnished cambric cable has long since passed the experimental stage, it having been in general use for about 20 years with exceedingly satisfactory results. During this time, the insulation has been constantly improved so that the present cable is far superior to that originally produced. Varnished cambric cables are somewhat cheaper in first cost than rubber cables and they possess all the good qualities of rubber with none of its disadvantages. The method of insulating consists of applying successive layers of lapped varnished cambric tape wound on spirally under tension with a plastic, moisture-repelling, high insulating compound evenly distributed between. This produces an absolutely uniform cable insulated with a hard [illegible] flexible wall of insulation, the copper is at all times central in the insulation and furthermore, there is no tendency for the conductor, especially when of large size and weight, gradually sinking to the bottom of the insulation and decreasing the effective thickness of the insulating wall. An important feature is that the composition of the plastic compound is such that it has no injurious effects upon the cambric tape; and, as this compound is non-hardening, it prevents the insulation from drying out and allows the layers of insulating tape to slide on each other, the insulation remaining intact when the cable is bent.

Fig. 1

When operating at voltages of 2500 and under, varnished cambric cable will stand a higher working temperature than will rubber; and, at higher voltages, will operate at the same working temperature without the insulation deteriorating. The life of varnished cambric cable is therefore indefinite.

The insulation possesses high dielectric strength, enabling it to withstand surges, has high insulation resistance, is not injured by mineral oils, and allows heat generated to be radiated freely. It also possesses a considerable amount of elasticity, permitting it to be handled readily even at low temperatures without danger of the insulation cracking; and, as it does not absorb moisture, it is unnecessary to boil out the ends when splicing, as with paper cable.

Varnished cambric cables may, therefore, be installed by the same class of labor, because the installation and splicing is accomplished under practically the same conditions as with rubber-insulated cables.

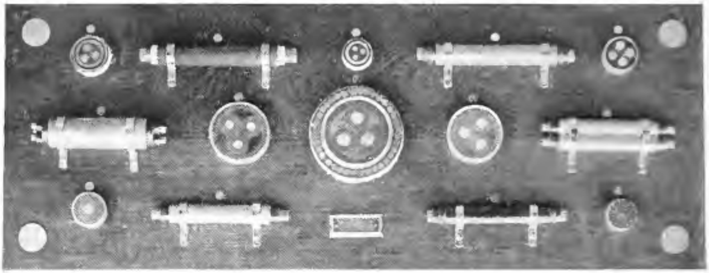

Fig. 2

In addition to its being especially adaptable for underground service, the insulation being non-hygroscopic like rubber, varnished cambric cables are used extensively with either weatherproof or flameproof braid applied directly over the insulation for inside power house, substation, and industrial plant wiring. For use in mines the cable is wire armored for vertical suspension and lead encased for distribution below the surface. For submarine use, lead-encased cable with jute and wire armor is used.

Varnished cambric lead-encased cables with jute and double steel taped finish are used extensively for burial direct in the ground in connection with ornamental lighting systems and for power circuits, where conditions do not warrant a conduit system. Plain lead-encased varnished cambric cable installed in fiber conduit is also used to a great extent for street lighting systems.

Taking into consideration the foregoing advantages, it must be conceded that varnished cambric cable is well adapted for almost any field of service.

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Welding Mild Steel

By H. M. Hobart

Chairman Welding Research Sub-committee

The impetus given to electric welding, especially electric arc welding, was a result of the exigencies of the war. Although the urgency for the more rapid construction of ships no longer exists, the electric welding processes have been found to possess so many real advantages that it would be inexcusable [illegible] the research work which holds forth the promise of perfecting the art to a point where it will be used extensively in general manufacture. That interest has not waned is evidenced by the recent formation of the American Welding Society, the membership of which includes those engineers who have done the [illegible] to further the art of electric welding. This abstract of Mr. Hobart's paper, presented before the A.S.M.E. at New York City in February, is a comprehensive discussion of electric welding, and forms a suitable supplement to the other papers we have published on the same subject.—Editor.

This paper deals principally with investigations undertaken by the Welding Research Sub-committee of the Welding Committee of the Emergency Fleet Corporation. The general object of the investigations has been to extend the use of welding in the construction of merchant ships and, specifically, to provide a definite basis for obtaining the best economy and efficiency in employing welding in place of riveting in the construction of the hulls of such ships.

Composition of Ship-plate Steel

The chemical composition of the steel employed in such hull construction varies with the thickness of the plates. Through the courtesy of Mr. H. Jasper Cox, of Lloyd's Register of Shipping, the following information may be given concerning the kind of steel plate employed in American Shipyards in 1918 for the hull construction of merchant ships.

Lloyd's requirements do not relate to the chemical composition. They require a tensile strength of 58,000 lb. per square inch (40.75 kg. per sq. mm.) for their lower limit and 72,000 lb. per square inch (50.59 kg. per sq. mm.) for their upper limit. For the information of the Committee, Lloyd's obtained from their surveyors at various works data of the carbon content, which is as follows:

Works		Carbon Contents for Plates	
		¼ Inch Thick	1 Inch Thick
A		0.14	0.23
B		0.14	0.25
C		0.19	0.25
D		0.20	0.30
E	Upper Limit	0.30	0.35
	Lower Limit	0.24	0.29
F	Upper Limit	0.25	0.30
	Lower Limit	0.21	0.27
G	Upper Limit	0.25	0.35
	Lower Limit	0.22	0.28

For shapes, Works H employ:

Shapes about ½ in. thick, 0.24 per cent to 0.30 per cent carbon.

Shapes about 1 in. thick, 0.28 per cent to 0.35 per cent carbon.

Small shapes such as:

2½×2¼×¼-in. angles, about 0.15 per cent carbon.

4×4×⅞-in. angles, about 0.20 per cent carbon.

From several tons of half-inch thick (12.7 mm.) plate from the yard of the Chester Shipbuilding Company, which was employed in making many sample welds in an investigation designated the Wirt-Jones Tests, seven analyses were made at the Bureau of Standards. The maximum and minimum percentages of each of the impurities for these seven samples were as follows:

	Maximum Per Cent	Minimum Per Cent
Carbon	0.25	0.24
Manganese	0.46	0.45
Phosphorus	0.043	0.039
Sulphur	0.031	0.027
Silicon	0.052	0.024

For this material the Bureau of Standards reports:

Yield point, 37,850 lb. per sq. in.

Ultimate tensile strength, 63,500 lb. per sq. in.

Elongation in 2 in., 38.6 per cent.

The following manufacturer's data apply to about ten tons of half-inch ship plate supplied by the Worth Steel Company of Claymont, Del., and to be used for testing electrodes:

Chemical Analysis (Ladle Analysis)

Carbon	0.29 per cent
Manganese	0.37 per cent
Phosphorus	0.015 per cent
Sulphur	0.032 per cent

Physical Properties

Tensile strength—lb. per sq. in.	67,400
Elongation, per cent in 8 inches	25.25 per cent

Another lot of about $1\frac{1}{2}$ tons of $\frac{1}{2}$-in. and 1-in. ship plate kindly furnished to the Committee by the American Steel and Wire Company for the purposes of the Committee's researches was analyzed by the Electrical Testing Laboratories with the following result, four (4) analyses being made for each thickness:

	MAXIMUM PER CENT		MINIMUM PER CENT	
	½ Inch	1 Inch	½ Inch	1 Inch
Carbon	0.24	0.28	0.22	0.26
Manganese	0.44	0.53	0.40	0.47
Phosphorus	0.033	0.033	0.028	0.027

The specifications of the American Society for Testing Materials for structural steel for ships (serial designation A 12–16, p. 98, A.S.T.M. *Standards*, 1918) are in abstract as follows:

Phosphorus (acid steel), not over 0.06 per cent.
Phosphorus (Basic steel), not over 0.04 per cent.
Sulphur, not over 0.05 per cent.
Tensile strength, between 58,000 and 68,000 lb. per sq. in.
Elongation, min. per cent. in 8-in. 1,500,000 tensile strength.

From the above data we have a good idea of the kind of steel in connection with which it was the Committee's first and specific task to investigate welding.

Two kinds of welding are under investigation at present:

(1) Fusion welding.
(2) Spot welding.

These are totally different kinds of welding. The fundamental difference is that while in fusion welding no pressure is employed, the success of spot welding is entirely dependent upon the application of both heat and pressure. For the spot welding of thick plates, the required pressure is very great.

The main features of each of these two kinds of welding will now be stated:

Fusion Welding

The term fusion welding is employed to cover gas welding and electric-arc welding.

Gas welding is usually effected by simultaneously fusing with an oxyacetylene flame (1) the material at and near the surfaces which it is desired to join, and (2) some material (which is usually similar in composition) in the form of a rod, the tip of which is subjected to the heat of the flame. The oxyacetylene flame is directed with one hand and the welding rod is manipulated with the other hand.

Electric-arc welding may be subdivided into several classes. The two broadest classes are:

(a) Carbon-arc welding
(b) Metal-arc welding

In carbon-arc welding, an arc is established between a carbon or graphite electrode (usually a graphite electrode) and the two pieces of steel which it is desired to join. This graphite electrode is manipulated with one hand and a welding rod is fed into the weld by the other hand. The manual activities in carbon-arc welding are seen to be quite similar to those in gas welding. In neither case is it necessary for the material of the welding rod to traverse the arc.*

In metal-arc welding, we find a fundamental difference in this latter respect, since in metal-arc welding of mild steel, the arc, instead of having a graphite electrode for one terminal of the circuit, is established between a steel welding rod (or welding electrode) and the two steel parts requiring to be joined. There is always a distance of a matter of a tenth of an inch (2.5 mm.) or more between the end of the welding rod and the work. This distance is bridged by an electric arc. The form in which the steel exists during its passage from one end of the arc to the other is at present the subject of investigation by several independent experimenters Their conclusions are awaited with interest.

The material cannot pass as a continuous liquid stream, since then there could be no interruptions in the metallic circuit and hence there could be no arc. It can pass as a series of liquid drops, and these can even momentarily short-circuit the arc, the duration of the short-circuit being too brief to be apparent to the operator or ordinary observer unaided by special apparatus. Or the drops can be so minute as to be incapable of effecting a short-circuit. If this should be the case, we can conceive of the metal passing as a stream of finely-divided liquid. Still another possibility is that the steel may pass as a highly-heated gas and condense on the opposite surfaces. It is suggested by physicists that, in its passage through the arc, the steel may undergo instantaneous transformations of which no human knowledge at present exists.

* Both for carbon-arc welding and gas welding, the edges of the parts to be joined sometimes may be so designed as to obviate the need for any additional material; in other words, no welding rod is necessary in such cases.

There would appear to be more of these complex possibilities in metal-arc welding than in gas welding or in carbon-arc welding. Nevertheless, it is precisely metal-arc welding which is at present proving very attractive to engineers. It is too early to return a verdict as to whether this wide-spread tendency toward metal-arc welding is based on sound premises or whether there ultimately may not be a reaction (for certain kinds of work) back to carbon-arc welding. It may be that there has been undue precipitancy in the general stampede which has taken place from carbon-arc welding (which was the first to be developed) to metal-arc welding, which is a later development.

Spot Welding

Spot welding, as developed for use in ship construction, consists in bringing into good contact, by hydraulic or pneumatic pressure, over-lapping portions of the plates or parts requiring to be joined, and in sending through the spot of contact a sufficiently large current to heat the plates or parts at this point to a welding temperature. The weld is effected by the combination of pressure and heat.*

Research

When, in the Spring of 1918, Professor C. A. Adams, of the Welding Committee of the Emergency Fleet Corporation, appointed several of us to be members of a Welding Research Sub-Committee, we found ourselves facing a task of great interest and importance and of enormous magnitude. It was desired that our investigations should be directed chiefly to the application of welding in the construction of the hulls of merchant ships. As regards such mild-steel plates as are employed in the construction of merchant ships, it was soon demonstrated that while sound and quite ductile welds could be depended upon for plates of not over one half inch thickness, there was less certainty of good results with plates of greater thickness. But at that time there was no general recognition of the most suitable current to be employed for welding. It was rare to find more than 150 amperes used, even for the heaviest work, and as low as 100 to 125 amperes was found to be the [illegible] for welding plates of half inch [illegible].

It now has been quite conclusively [illegible] that stronger and more ductile [illegible] half-inch thick plates are obtained [illegible] least 200 amperes. The author [illegible] fully 300 amperes should be used for butt welding three-quarter inch thick plates, and a matter of at least 400 amperes for 1-inch thick plates. These are some twice as great currents as have heretofore usually been employed in arc-welding plates of these thicknesses.

In view of this subsequent experience it is clear that the disappointing lack of strength and ductility in certain welds of thick plates made nearly a year ago was a practically certain consequence of using such small currents.

It would be easy to yield to the temptation to enter discursively upon comments and opinions regarding the many points on which experienced welding specialists hold widely diverging opinions. All these specialists are producing thoroughly reliable work, but this is not saying that they are all producing nearly as good work as could be produced under the most appropriate conditions for each case. Indeed, the author's observations lead him to the conclusion that while excellent arc welding is being done on a wide scale, there is a margin for improvement over the present average quality, which, so far as it can be expressed by a sort of resultant of such physical characteristics as:

(a) Bending and torsion tests
(b) Tensile strength
(c) Elongation at fracture

may be assessed as amounting to at least 25 per cent.

Bare and Covered Welding Wire

As to bare electrodes it is generally considered that uniformity is very essential. An operator may be getting along very nicely, but will suddenly come to bad places in the welding wire. Heretofore it has been considered necessary to reject such wire. The claim is now made by some people that by merely dipping the electrode wire in suitable material, it may be salvaged. Thus, in the Welding Committee's specification for electrode wire (given on page 449) occurs a note to the effect that "If electrodes to the above specification sputter or flow unevenly, they may be dipped in milk of lime (whitewash) before welding. This dipping may be done

*Excellent discussions of the subject of spot welding and descriptions of several spot welders built for use in ship construction are given in the four following papers in the GENERAL ELECTRIC REVIEW, December, 1918: Research in Spot Welding of Heavy Plates, by W. L. Merrill, p. 919; Spot Welding and Some of its Applications to Ship Construction, by H. A. Winne, p. 923; An Electrically Welded Freight Car, by Jos. A. Osborne, p. 912; Some Recent Developments in Machines for Electric Spot Welding as a Substitute for Riveting, by J. M. Weed, p. 928.

in quantity on stock on hand and allowed to dry, or the welder may keep a pot of solution on hand into which the electrode may be dipped immediately before welding." This method of salvaging electrode wire was developed by the Schenectady Research Laboratory of the General Electric Company.

Also, it has been demonstrated by Mr. E. Wanamaker that the application, by dipping, of a kind of coating which he has developed (and the precise composition of which he will doubtless contribute to the discussion of this paper), permits of doing good work with electrodes which would otherwise be useless.

Preferable Kind of Covering for Welding Wire

With regard to covered electrodes, while some claim that a thin covering obtained by dipping, accomplishes the desired purpose, others contend that it is desirable to provide a thick covering of appropriate material, which, in turn, is suitably impregnated. Moreover, even for covered electrodes, the usual belief is that the greatest care should be given to the composition and quality of the welding wire to which the covering is applied. In other words, it is not generally held that the use of inferior wire salvaged as indicated in the second paragraph back, will permit of obtaining the best quality of welds. It is important that the covering shall be so designed as to be consumed at a definite rate as compared with the rate of consumption of the enclosed welding wire. A consequence is that any particular gauge of covered welding wire must be used within rather close current limits.

For overhead welding one firm exploiting covered electrode supplies a special (and additionally high-priced) grade in which the covering is impregnated with a more viscous material than is used for the electrodes which the firm supplies for other welding operations.

Preferable Composition for Bare Welding Wire

There is a great diversity of practice as to the preferred composition of bare electrodes suitable for welding mild steel plates. As instances of extremes it may be said that amongst widely used electrodes, while one type consists of almost pure iron, other types have nearly two tenths of one per cent of carbon and one half of one per cent of manganese, and still other types run very much higher than this in manganese. This is quite aside from the subject of special compositions for welding high-carbon steel and for welding cast iron. It is anticipated that quantitative measurements will indicate superiority in tensile strength for some compositions and superiority in ductility for other compositions. Mr. R. E. Wagner has exhibited some very ductile welds made with electrodes containing small percentages of magnesium and of boron sub-oxide.

It is only within the last few months that there have been available any specifications for use in establishing the merits of welding wire. These are now available in the Welding Committee's specification setting forth a "Standard Procedure for Testing Welding Electrodes." This specification was prepared by the Welding Research Sub-committee in collaboration with Professor H. L. Whittemore, representing the Bureau of Standards, and with representatives of manufacturers of welding electrodes.

In Table I are given the compositions of various electrodes in current use.

The American Steel & Wire Company has requested the omission from the table of any analyses of electrodes which it has furnished for arc welding. This is for the reason that material has been supplied to a large number of users, varying considerably in analyses in accordance with the ideas of the purchasers. There does not as yet seem to be an agreement as to the most advantageous chemical composition for electrodes, and the Company is not prepared either from observations of the results obtained by its customers or from its own experimental work to make a definite recommendation.

The Welding Committee has issued the following specification for electrode wire for electric welding. The specification was prepared under the immediate direction of Mr. Herman Lemp.

Specification for Electrode Wire for Electric Welding in Connection with Mild Steel *

Welding Committee Emergency Fleet Corporation

Revised to December 20, 1918

(NOTE.—This wire may or may not be covered.)

1. *Chemical Composition*

Carbon	Not over 0.18%
Manganese	Not over 0.55%
Phosphorus	Not over 0.05%
Sulphur	Not over 0.05%
Silicon	Not over 0.08%

2. *Sizes and Weights*

Diameter, in Mils	Diameter, in Fractions of an Inch	Pounds per 100 Ft.	Feet per 100 Lb.
125	1/8	4.16	2400
156	5/32	6.51	1535
188	3/16	9.37	1066

(Allowable tolerance six mils plus or minus.)

* These specifications are published as an appendix to the original paper.—EDITOR.

3. *Material.* The material from which the wire is manufactured shall be made by any approved process. Material made by *puddling process not permitted.*

4. *Physical Properties.* Wire to be of uniform homogeneous structure, free from oxides, pipes, seams, etc., as proved by photomicrographs.

5. *Workmanship and Finish.*—

(a) Electric welding wire shall be of the quality and finish known as the "Bright Hard" or "Bright Soft" finish—"Black Annealed" or "Bright Annealed" wire shall not be supplied

(b) The surface shall be free from rust, oil or grease; a slight amount due to lubrication during last drawing is permissible.

6. *Tests.*—Electrodes must, before shipment or after delivery, show good commercial weldability when tested by an experienced arc welder. The electrode material shall flow smoothly in relatively small particles through the arc without any detrimental phenomena.

Note.—If electrodes [illegible] spatter or flow unevenly, they [illegible] milk of lime (whitewash) before [illegible] dipping may be done in quantity [illegible] and allowed to dry, or welder [illegible] solution on hand into which the el[illegible] immediately before welding.

7. *Delivery, Packing, and Shipping.*—E[illegible] shall be furnished in straight lengths [illegible] inches or 28 inches, put up in bundles of 50 pounds or 100 pounds as ordered. Each bundle [illegible] wrapped in heavy paper securely wired and marked on one end showing diameter in mils, trade name and grade of wire.

Composition of Metal Deposited in Weld

A few analyses have been made of chemical compositions of the metal deposited in the weld. Results of the analyses of four sets of electrodes before and after the metal was deposited are quoted below from the Westing-

TABLE I

COMPOSITION OF WELDING ELECTRODES FOR METAL ARC WELDING

Trade Designation of Electrode	Carbon	Manganese	Phosphorus	Sulphur	Silicon	Remarks
Page Steel & Wire Co. Armco	0.01	0.025	0.005	0.025	0.005	
Wilson Welders & Metals Co. Grade No. 6	0.15 to 0.23	0.60 to 0.75	less than 0.04	less than 0.04		Also 0.25 per cent copper
Grade No. 9	0.30 to 0.40	about 1.00	less than 0.04	less than 0.04		
Grade No. 8	0.17 to 0.22	0.30 to 0.45	less than 0.04	less than 0.04		
Grade No. 17	0.10	0.30 to 0.45	0.06	0.06		
Quasi-Arc Co.	0.08 to 0.12	0.45 to 0.55	0.00 to 0.06	0.00 to 0.06	0.05 to 0.08	Flux covering of blue asbestos fiber (Crocidolite) enclosing percentage of aluminum or other metal in form of fine wire capable of giving strong reducing action.
Roebling Co.	0.16	0.56	0.032	0.024	0.016	
Toncan Wire	0.10	0.16	0.01	0.046	trace	
Electric Arc Cutting & Welding Co.	0.25	0.30	0.05	0.05	0.05	
Siemund Wenzel Co.	0.10 and under	0.30 to 0.50	0.05 and under	0.05 and under	trace	
Norway-iron Wire	0.05	0.02	0.025	0.007	0.08	
Double Arc Co., of England	0.085	0.35	....	0.054	0.108	Flux covered.
T. Scott Anderson Co., of England	0.057	0.32	....	0.026	0.014	Flux covered.
E. A. Jones & Co., of England	0.22	0.25	0.001	0.026	0.024	Nickel-plated and flux covered
Engineering and Equipment Co., of England	0.12	0.51	....	0.08	0.016	Flux covered.
Central Steel & Wire Co. Swedox	0.05	0.18	0.04			
The Spencer Wire Co. Basic open hearth steel electrode	0.06	0.12 to 0.20	0.013 and under	0.03 and under		

house Chapter in Captain Caldwell's report. To these results are added analyses of Toncan Wire as supplied to the author by Mr. R. E. Wagner. It is notable that most of the carbon and manganese is burned out in traversing the arc.

Polarity

For carbon-arc welding, the standard practice is to connect the graphite electrode to the negative terminal Mr. Wagner states as his experience that it is very difficult to weld with the carbon arc when the polarity of the carbon is positive. He states it to be almost impossible to direct the heat to the point desired and the welding qualities of the arc under this condition are very poor. He concludes: "Our experience has taught us that it is next to impossible to weld with a carbon arc unless the work is positive and the electrode negative."

For metal arc welding with bare wire, the electrode is usually connected to the negative terminal, but instances occur of bare welding wire which works best when the opposite polarity is employed. Also for some particular sizes and sorts of welds best results are sometimes obtained by a reversal of the polarity. With electrodes heavily covered with flux, the positive terminal is almost always connected to the electrode. Plenty of more or less plausible reasons for these differences have been offered on various occasions. On careful reflection none of these reasons proves particularly satisfying. Amongst other considerations the fact of the entire practicability of arc welding from an alternating-current circuit and of overhead welding have to be taken into account in judging some of these explanations. As yet, we have no satisfactory hypothesis as to what goes on in the welding arc.

Direct Current *versus* Alternating Current for Arc Welding

While up to rather recently it had usually been contended that arc welding required a direct-current supply, there are now many advocates of alternating current.* At present there appears to be no agreement as to the applicability of alternating current to carbon arc welding.

Periodicity for Alternating-current Arc Welding

Amongst the advocates of the use of alternating current, there is no agreement with reference to the periodicity. Although it is generally maintained that arc welding is only thoroughly practicable with as high a periodicity as 50 or 60 cycles per second, there is, on the other hand, expression given to the opinion that the use of twenty-five cycles, or less, is equally satisfactory. In October, 1918, Mr. R. E. Wagner reported to the Welding Research Sub-committee that at the Pittsfield Works of the General Electric Company he had found from his tests that alternating current for arc welding could be used with a frequency as low as 12½ cycles and as high as 500 cycles. Mr. Wagner states that while there is no difficulty at either of these extreme periodicities, the arc is more readily held at 500 cycles than at 12½ cycles.

* For discussion of alternating-current versus direct-current for arc welding, see article by H. M. Hobart, GENERAL ELECTRIC REVIEW, December, 1918, page 840—EDITOR.

Analyses of Electrode—Per Cent of Impurities

	Carbon	Manganese	Phosphorus	Sulphur	Silicon
Roebling	0.16	0.56	0.032	0.024	0.016
Norway	0.049	0.021	0.025	0.007	0.08
C. R. S.	0.11	0.72	0.097	0.123	0.011
H. R. S.	0.13 to 0.17	0.50	0.012	0.045	0.011
Toncan	0.10	0.16	0.010	0.046	trade

Analyses of Deposited Metal—Per Cent of Impurities

	Carbon	Manganese	Phosphorus	Sulphur	Silicon
Roebling	0.05	0.18	0.031	0.036	0.011
Norway	0.05	0.018	0.020	0.072	0.011
C. R. S.	0.05	0.11	0.086	0.072	0.011
H. R. S.	0.14	0.14	0.012	0.039	0.011
Toncan	0.042	0.081	0.019	0.026	0.000

Bare or Covered Electrodes for Alternating-current Arc Welding

While some maintain that arc welding with alternating current is only at its best when flux-covered electrodes are used, it appears to have been conclusively demonstrated by others that excellent results are being obtained under commercial conditions with bare electrodes and an alternating-current supply. A novice can more quickly learn to weld from an alternating-current supply if he employs flux-covered electrodes. But if he can ultimately learn to weld just as rapidly and successfully with bare electrodes, the difficulties in the initial stages of his education should not be regarded as being of much consequence. Mr. Wagner finds that when welding with alternating current, "manipulation may be simplified in many cases by treating the electrode with a thin coating of ordinary lime."

Relative Speeds of Alternating-current and Direct-current Arc Welding

Some contend that alternating-current welding is slower. Mr. R. E. Wagner, who has had much to do with the development of both kinds of welding, states that "on the average the speed of welding with alternating current and direct current are about the same. We have had cases where alternating current is faster and vice versa."

Consideration of the Power Factor for Alternating-current Arc Welding

A view presented with considerable persistency is that the low power-factor associated with alternating-current welding leads to capital and operating costs off-setting any advantages. One answer made is to the effect that since for ship welding on an extensive scale, motor-generators are required, this only affects the generator and its circuit and does not affect conditions as regards the motor or the circuit from which it is supplied.

Consideration of the Circumstances that Alternating-current Arc Welding is Essentially a Single-phase Load

Similar considerations are involved in regard to the necessity of providing for the characteristics of a single-phase load. It is well known that single-phase motors and generators are much heavier, more expensive and less efficient than polyphase motors and generators. With 30 or 40 arc welding outfits distributed fairly evenly on the different phases of a polyphase [illegible] be sufficiently balanced to [illegible] but this would correspond to [illegible] large welding installation. In [illegible] will be necessary to arrange for [illegible] to constitute a single-phase load and [illegible] adequate provision to obtain [illegible] service with this condition.

Regarding the possibility of improving the power factor, Mr. W. S. Moody makes the following very suggestive statement:*

"Where a number of arcs are to be used within a reasonable distance of each other, the series system may be used. In this arrangement the secondary of an ordinary constant-current transformer supplies current to the primary of all the welding transformers in series. The individual transformers insulate the welding apparatus from the series circuit and transform from the series current to current of proper value for the arc. In this case the inherent reactance of the series transformer is low, but other features of the design are the same as those discussed above. The power factor of such a system can be safely made much higher than where individual arcs are operated in multiples from constant potential circuits."

Spot Welding is a Single phase Load

Mr. J. M. Weed, who has had a great deal of experience with large spot welders, has kindly written the following paragraph on this subject:

"For welding plates from 3/8 in. to 3/4 in. in thickness, the single-phase currents required would be from 30,000 to 50,000 amperes and the kilovolt amperes required at 60 cycles would range between 300 and 900 at power factors of from 0.35 to 0.50. These low power factors, combined with the fact that this load would be for short periods at very frequent intervals, would make it decidedly undesirable from the central station standpoint. The condition would be much improved at 25 cycles, as the same machine would operate equally as well at 25 cycles as at 60 cycles, with about half the kilovolt amperes and about double the power factor. The intervals of operation would, however, be the same as for 60 cycles. If, however, a motor-generator set, with suitable flywheel attached, be provided for operating these machines, these disadvantages are all practically eliminated, this arrangement being such that the motor stores up energy in the flywheel during the interval of no load, the flywheel supplying a large part of the energy

* GENERAL ELECTRIC REVIEW December, 1918, p. 937.

during the period of welding. By this means, for instance, a single phase load of 900 kv-a. at 0.50 power factor for 30 second periods and with intervals of 1½ minutes between periods would be converted to a practically continuous 3-phase load of approximately 200 kv-a. at about 0.85 p-f."

Ductility of Arc Welds

Attention has been pertinaciously drawn to results of a very few tests which have appeared to indicate that metal-arc welds are inherently utterly deficient in ductility, yet the Committee has had also before it the results of many well-authenticated tests of ductile metal-arc welds.

It has been claimed that gas welds are more ductile. On this matter Mr. R. E. Wagner writes:

"At several meetings of the Welding Committee, special stress has been brought to bear on the bending qualities of acetylene and gas welds. We have done some experimenting with average acetylene and arc welders, and our impression is, that the acetylene and arc welds are in the same class with respect to bending. I submit herewith a photograph showing comparative bends in acetylene and arc-welded joints. Both welds were taken from half-inch plate and both samples were bent under the same conditions, that is, the sharp edge of an angle iron was placed along the weld and pressure applied to the angle iron to make a sharp bend. These, I think, are average comparative results. * * * * * As far as our experiments are concerned, we feel, as regards physical characteristics, that acetylene and arc welds are in the same class."

Respective Fields of Gas and Electric Arc Welding

On this subject, under late of October 22, 1918, Mr. R. P. Jackson, of the Westinghouse Electric & Mfg. Co., reports to the Welding Research Sub-committee as follows:

"With reference to the comparative uses or fields of gas and electric-arc welding which came up at the last meeting, it was thought it might be well for some of us to express our opinions on the matter based on our experience with both kinds of welding. In general, we have found gas welding to be more satisfactory for thin material, say ⅛ in. and under, and for general repair work, particularly where various kinds of steel and cast iron are involved. For example, if repairs have to be made on broken machinery, lugs rebuilt, pieces attached to high-carbon steel and work of this character, then the gas-welding methods are superior and the extra cost not ordinarily prohibitive. When it comes, however, to depositing a large amount of metal and welding up structural steel or plates of ¼ in. thickness and upward, the results obtained by the ordinary direct-current arc with the metal electrode are at least equal to the gas welding work and certainly cheaper. In general, too, the finish of gas welding is more regular and better looking and where that is a consideration it may give a preference to gas. In fact, in the Westinghouse factory at East Pittsburgh, there has been considerably more gas work done than electric, but the electric arc welding is on the increase, not so much in displacing gas as in displacing riveting."

A view taken from a gas welding publication is as follows:

"The arc process is chiefly used for filling up blow holes in large steel or iron castings and building up worn surfaces which have not to be machined. With this process the results obtained are somewhat uncertain, and it is generally conceded, apart from the vital question of cost, that fusion produced by the burning of gases is to be preferred to the electric process. Welds made by the electric process are sometimes rough, hard, brittle, and unworkable—in most cases this is highly objectionable, but not always so. With any fusion method of welding, annealing of the metal adjacent to the weld is desirable. It is impossible to do this annealing with an electric welder, but with gas welding the blow pipe flame can be used for heating up the metal surrounding the welded part, and also for heating metal away from the weld, so as to counteract any strains that may be set up in the piece as the weld cools off. There are certain classes of work for which electric welding is the most suitable system, and, on the other hand, there are many classes of work where it would be most impractical, and which can be done satisfactorily only with gas welding. For general workshop use, a gas welding outfit is far better, not only because of its greater economy in installation and operation, but also because of its wider range of usefulness."

In the absence of any experience to the contrary, this latter view appears fairly plausible, and it is natural that it should have received wide acceptance. But an enormous volume of experience in arc welding has gradually accumulated and it controverts the correctness of the view. Unfortunately the experimental data available on the subject of gas welding is surprisingly meagre. The Welding Research Sub-committee has concluded that there is practically no test data from which it can draw any safe generalizations as to the mechanical characteristics of *gas welds*, and that it will be necessary to embark upon its own investigations to obtain suitable data.

Gas welding was an established art before there was any large amount of electric welding. This was still the state of affairs in England until shortly before the author was there in the Autumn of 1917. But the war conditions had occasioned in England such a shortage of supplies of oxygen and carbide that the Government, as a war measure, practically forced the wide substitution of arc welding for gas welding. The British Government, in entering upon this policy, had relatively little concern as to the comparative merits of the two methods except in so far as that any merit or advantages found to be associated with arc welding would naturally assist in bringing about its use in place of gas welding.

It was, however, with considerable surprise that it was ascertained that the true economic field for arc welding as compared with gas welding was a very wide one, and that, simply due to inertia and tradition, engineers had been continuing in the contrary belief. Major James Caldwell, of the Admiralty Controller's Department, had wide responsibilities in this task of substituting arc welding as rapidly and generally as possible. Major Caldwell provided the author with the results of his investigations into the relative costs of gas and electric arc welding. These results, which correspond to conditions in December, 1917, are set forth in Table II.

From Table II it is seen that electric-arc welding was found to be a faster process for all thicknesses of steel. The British Admiralty results furthermore indicate the economic field for the two methods. The verdict from the data in the table is in favor of gas welding for thin plates and of electric-arc welding for thick plates. But the comparison is based on the very high cost of electrodes set forth below:

Standard Wire Gauge	Cost in Cents per Foot	Feet per Pound of Contained Iron Wire	Cost in Cents per Pound
Number 8	3.6	15	54
Number 10	2.6	23	60
Number 12	2.4	35	84

By substituting a typical American price for labor and substituting the cost of bare

TABLE II

COMPARATIVE COSTS OF WELDING BY OXYACETYLENE AND ELECTRIC ARC

Thickness of Metal, Inches	OXYACETYLENE: Gas per Hour, Oxygen Cubic Feet	OXYACETYLENE: Gas per Hour, Acetylene, Cubic Feet	OXYACETYLENE: Cost for Gas per Foot Run Pence	OXYACETYLENE: Iron Wire for Filling, Pence	OXYACETYLENE: Labor per Foot Run	ELECTRIC ARC: Power per Foot Run, Volts	ELECTRIC ARC: Power per Foot Run, Amp.	ELECTRIC ARC: Power per Foot Run, Kw.	ELECTRIC ARC: Labor per Foot Run, Pence	ELECTRIC ARC: Cost of Electrodes per Foot Run, Pence	OXYACETYLENE: Feet Run per Hour	OXYACETYLENE: Total Cost per Foot Run, Pence	ELECTRIC ARC: Feet Run per Hour	ELECTRIC ARC: Total Cost per Foot Run, Pence
1/16	3	2.0	0.116	0.131	0.40	100	30	0.075	0.3	12 in. No. 12 = 1.2	30	0.647	40.0	1.575
1/8	9	6.3	0.77	0.196	0.856	100	75	0.312	0.5	18 in. No. 12 = 1.8	14	1.822	24.0	2.612
3/16	13	9.0	1.72	0.262	1.33	100	100	0.50	0.6	24 in. No. 10 = 2.64	9	3.312	20.0	3.74
1/4	17	13.0	2.70	0.250	1.50	100	140	0.70	0.6	22 in. No. 8 = 3.6	8	4.45	20.0	4.90
5/16	27	16.0	4.21	0.327	1.714	100	110	1.10	1.2	12 in. No. 10, 18 in. No. 8 } = 4.02	7	6.25	10.0	6.32
3/8	34	24.0	6.82	0.458	2.00	100	120	1.61	1.61	18 in. No. 10, 24 in. No. 8 } = 5.58	6	9.278	7.4	8.802
7/16	41	29.0	9.90	0.655	2.40	100	120	2.00	2.0	24 in. No. 10, 36 in. No. 8 } = 8.04	5	12.955	6.0	12.04
1/2	48	34.0	14.50	0.786	3.00	100	120	2.40	2.4	30 in. No. 10, 42 in. No. 8 } = 9.6	4	18.286	5.0	14.40

Labor taken at 1 shilling per hour.
Oxygen taken at [illegible] pence per cu. ft.
Acetylene taken at 1 pence per cu. ft.
Iron for filling taken at 0.131 pence per ft.
The above figures are based on the British Oxygen Co. standards.

Labor taken at 1 shilling per hour.
Current taken at 1 pence per B.O.T. unit
Electrodes, No. 10, 1.32 pence per ft.; No. 8, 1.8 pence per ft.; No. 12, 1.2 pence per ft.

electrodes, such as are used with entire success in America, in place of the cost of flux-covered electrodes of the expensive type employed in arriving at the results set forth in the table, the revised results show a lower cost for arc welding than for gas welding for all thicknesses above $\frac{1}{16}$ in. The question of the quality of the weld is another matter, but judging from the general reputation of the work of all sorts done by gas welding and by electric-arc welding, they are both thoroughly reliable. No more exact comparison can be made till we have carried through to completion really elaborate tests of gas welds in order to permit of making a sound comparison with the large amount of research data already obtained with electric-arc welds.

In response to a request for his opinion as to the respective fields for gas and electric arc welding, Mr. R. E. Wagner, of the Pittsfield Works of the General Electric Company, writes as follows:

"The present well-tried field for electric-arc welding is confined entirely to welding plates and forms, and a great deal of work has been done on plates varying in thickness from $\frac{1}{16}$ in. to $\frac{3}{4}$ in. Up to $\frac{1}{8}$ in. plates, the cost of gas and electric welding is about the same. Beyond this, the cost is in favor of the electric process. No difficulty is experienced in machining electric welds made with the metallic electrode. While it is recognized that the electric-welded-in material will not stand bending equal to that of the plate in which it is deposited, it is on the average equal to gas-deposited material in this respect."

Relative Ductility of Arc Welds Made Respectively With Bare and Covered Electrodes

By some authorities, ductility is believed to be most readily obtained by employing flux-covered electrodes. On the other hand, the Committee has knowledge of several kinds of bare electrodes of various compositions which, in competent hands, make reasonably ductile welds.

Speed of Arc Welding

All sorts of values are given for the speed, in feet per hour, with which various types of joints can be welded. Operators making equally good welds have widely varying degrees of proficiency as regards speed. Any quantitative statement must consequently be of so guarded a character as to be of relatively small use. In general, and within reasonable limits the speed of welding will increase considerably when larger currents are employed. It appears reasonable to estimate that this increase in speed will probably be about 25 to 35 per cent for high values of current. This increase is not directly proportional to the current employed because a greater proportion of time is taken to insert new electrodes and the operator is working under more strenuous conditions. Incidentally, the operator who employs the larger current will not only weld quicker but the weld will have also better strength and ductility.

On this point Mr. Wagner writes as follows:

"I would not say that speed in arc welding was proportional to the current used. Up to a certain point ductility and strength improve with increased current, but when these conditions are met, we do not obtain the best speed due to increased heating zone and size of weld puddle. Speed may fall off when current is carried beyond certain points."

In a research made by Mr. William Spraragen for the Welding Research Subcommittee on several tons of half-inch-thick (12.7 mm.) ship plate, the average rate of welding was only two feet (0.6 m.) per hour. Highly skilled welders were employed, but they were required to do the best possible work, and the kinds of joints and the particular matters under comparison were very varied and often novel.

However, in the researches carried on by Mr. Spraragen it was found that about 1.9 lb. (0.8 kg.) of metal were deposited per hour when using a $\frac{5}{32}$ in. (3.9 mm.) bare electrode and with the plates in a flat position. The amount of electrodes used up was about 2.7 lb. per hour, of which approximately 16.5 per cent was wasted as short ends and 13 per cent burnt or vaporized, the remainder being deposited at the speed of 1.9 lb. per hour mentioned above.

For a 12-foot-cube tank of ½-in. thick steel welded at Pittsfield, the speed of welding was three ft. per hour. The weight of the steel in this tank was 16,000 pound and the weight of electrode used up was 334 lb. of which 299 lb. was deposited in the welds. The total welding time was 165 hours corresponding to using up electrodes at the rate of just two pounds per hour. The total length of weld was 501 ft., the weight of electrode used up per foot of weld thus being 0.60 lb. The design of this tank comprised 18 different types of welded joint. Several different operators worked on this job and the average current per operator was 150 amperes.

For the British 125 ft. long cross-channel barge for which the shell plating was composed of ¼-in. and $\frac{5}{16}$ in. thick plates, in Mr. H. Jasper Cox's paper read before the Society of Naval Architects on November 15, 1918, and entitled, "The Application of Electric Welding to Ship Construction," it is stated that:

"After a few initial difficulties had been overcome, an average speed of welding of seven ft. per hour was maintained, including overhead work which averaged from three to six ft. per hour."

In a report appearing on page 67 of the Minutes and Records of the Welding Research Sub-committee for June 28, 1918, Mr. O. A. Payne, of the British Admiralty, states:

"A good welder could weld on about one pound of metal in one hour with the No. 10 Quasi-Arc electrode, using direct current at 100 volts. An electrode containing about 1½ ounces of metal is used up in about three minutes, but this rate cannot be kept up continuously."

The Quasi-Arc Co. publishes the following data for the speed of arc welding in flat position with butt joints, a 60 deg. angle and a free distance of ⅛ in.

Thickness of Plates in Inches	Speed in Feet per Hour
⅛	30
¼	18
½	6
1	1.3

I cannot, however, reconcile the high speed of welding ½-in. plate published by the Quasi-Arc Co. at six ft. per hour, with the report given above by the British Admiralty that a good welder deposits one pound of metal per hour with the Quasi-Arc electrode. If the rate given by the Quasi-Arc Co. is correct, it would mean that about four lb. of metal were deposited per hour. On this basis, the rate must have been computed on the time taken to melt a single electrode and not the rate at which a welder could operate continuously, allowing for his endurance and for the time taken to insert fresh electrodes in the electrode holder and the time taken for cleaning the surface of each layer before commencing the next layer.

From his observations the author is of the opinion that a representative rate for a good welder lies about midway between these value given respectively by Mr. Payne and by the Quasi-Arc Co., say for ½-in. plates, some two lb. per hour. This, it will be observed, agrees with Mr. Sparagen's experience in welding up some six tons of ½-in. ship plates with a dozen or more varieties of butt joint and Mr. Wagner's results with the eight-ton tank. Even this rate of two lb. per hour is only actual time of welding operator after his plates are clamped in position. This preliminary work and the preparation of the edges, which is quite an undertaking and requires other kinds of artisans, accounts for a large amount of time and should not be underestimated.

The practice heretofore customary of stating the speed of welding in feet per hour has led to endless confusion as it depends on type of joint, height of welt and various details. A much better basis is to express the speed of welding in pounds of metal deposited per hour. Data for the pounds of metal deposited per hour is gradually becoming quite definite. The pounds per foot of weld of metal required to be deposited can be readily calculated from the drawings or specifications. With the further available knowledge of the average waste in electrode ends and from other causes, the required amount of electrode material for a given job can be estimated.

Suitable Current for Given Cases

For a given type of weld, for example, a double Vee weld in a ½-in. thick ship plate, it was found that while some operators employ as low as 100 amperes, others work with over 150 amperes. Some, in making such a weld, employ electrodes of only ⅛ in. diameter and others prefer electrodes of twice as great cross-section. For the particular size and design of weld above mentioned, the Welding Research Sub-committee has had welds made with from 200 to 300 amperes. The conclusion appears justified that the preferable current for such a weld is at least 200 amperes. If the weld of the ½-in. thick plate is of the double-bevel type, some 50 amperes less current should be used for the bottom layer than is used for the second layer, if two layers are used. For ¾-in. thick plates, the most suitable welding current is some 300 amperes. This is of the order of twice the current heretofore most usually employed for such a weld.

Mr. Wagner writes: "We have made a number of tests to determine the effect of varying current on the strength of the weld.

Tests were made on a ½-in. plate with current values as follows: 80, 125, 150, 180, 202, 275, and 300 amperes. These tests show improvement in the tensile strength and bending qualities of welds as the current increases. The speed of welding increases up to a certain point and then decreases."

Effect on Arc Welding of Voltage Employed

Mr. Wagner reports as follows:

"We have made a number of tests to determine the influence of variable voltages on the strength and character of electric welds. The experiments were made welding ½ in. plate with 150 amperes held constant and voltage varying as follows: 40, 75, 100, 125, 150, 200, and 225 volts.

"This test demonstrates that there is no material difference in the tensile strength, bending qualities or the appearance of the welded-in material. There is this advantage, however, in the higher voltage, that variations in the strength of the arc do not materially affect the value of the current.

"A curve-drawing ammeter was installed on the welding circuit which showed variations in current at 75 volts but at 150 volts the current curve was practically a straight line."

Preferable Size of Electrode

On certain railways, a single diameter of electrode is employed independently of the size or shape of the plates or parts being welded. The experience of other people leads them to make use of several different sizes of electrodes according to the size of the job and the type of joint. Present British practice appears to be to use such a size of electrode as to have a current density of some 4000 to 6000 amperes per square inch. The investigations of the Welding Research Sub-committee are indicating that at least 10,000 to 12,000 amperes per square inch is suitable for electrodes of ⅛ in. and $\frac{5}{32}$ in. diameter and well up toward 10,000 amperes per square inch for electrodes of $\frac{3}{16}$ in. and ¼ in. diameter.

Automatic Machinery for Arc Welding

Several firms are developing machinery for feeding the electrode automatically. Such machinery appears to be capable of making excellent welds at higher speeds than are attainable by hand feeding.

Carbon-arc Welding

With the advent of metal-arc welding there has been a tendency to neglect the carbon-arc method. It is quite possible that this attitude is not justified, for not only is there now a definite field where the carbon-arc method is advantageous but developments in the art may greatly extend its application.

It is generally agreed that the carbon-arc method is not applicable to vertical and overhead welding, which is, of course, a serious handicap in ship-hull work. The majority opinion of competent observers (with, however, some emphatic dissenting views) appears to indicate that carbon-arc welding is not as reliable as metal-arc welding in ordinary welding, because:

(a) Carbon is carried into the deposited material, thus reducing its ductility.
(b) It is most difficult to obtain good fusion on account of overlapping of deposited metal on the original metal.
(c) It is more difficult to manipulate and thus requires greater skill.
(d) It is a much hotter arc which means greater discomfort to the operator and therefore lower efficiency.
(e) Greater cooling stresses are developed because larger areas of adjacent metal are heated.

On the other hand, it is contended by some that carbon-arc welding can be developed to the point where these objections will no longer exist and thus gain the advantages of this method, the principles of which are:

(a) No preparation of the abutting edges is necessary.
(b) Greater rate of deposition of metal and therefore greater speed of welding, particularly in heavy work.
(c) Probable greater adaptability to automatic welding.

It should be stated that there is very general agreement as to the superiority of the carbon arc over the metal arc for heavy work where strength is not so important, especially cast-iron welding and the filling of holes in iron and steel castings.

Preparation of Welding Edges

British practice permits the use of smaller angles when the edges of the plates are V'd, than accords with American traditions. If the smaller angles give welds which are equally satisfactory in all respects, the decreased amount of electrode material required, the decreased consumption of electricity, and the increased speed are advantages not to be overlooked, but obviously the matter requires careful investigation. American practice, which up to recently has been with a very wide angle, appears to have required the consumption of about twice as great a weight of electrode as British practice with the smaller angle. The urgent importance of determining whether the use of the smaller angle involves any sacrifice in quality is evident. There is already considerable basis for the belief that actually better results attend the employment of a smaller angle of bevel when a suitably large current is used. A shoulder in place of the heretofore commonly used sharp bottom edge of the bevel also constitutes a material gain not only in the saving in welding material, but also in the quality of the weld.

Mr. Wagner states that at the Pittsfield Works of the General Electric Company they have long adopted the practice of using a 30-deg. bevel for plate edgings and that they find it satisfactory for all thicknesses up to 3/4 in. He states that this angle gives sufficient room for depositing the metal, reduces the time to weld and the amount of metal deposited.

In one of Mr. Spraragen's researches, various angles of bevel were used. Although the physical tests have not yet been made, we can gain from Table III valuable lessons on the time, amount of metal, and electricity consumed for these different angles of bevel. The "free distance" in each case was 1/8 in. and the welding was done in a flat position with 5/32 in. bare electrodes. In each case the weld had a length of three feet.

Quality of Overhead Arc Welding

The British Admiralty regards overhead welding as too inferior and too expensive to be employed when it can possibly be avoided. In America a large amount of overhead welding is done in railway shops and it is claimed that it is simply a matter of training operators to the required degree of proficiency.

Number of Layers to be Employed

Good progress is being made in obtaining knowledge of the relative characteristics of welds made with different number of layers and of the most suitable current and the most suitable size and type of electrodes to employ for each layer. The tendency is toward the use of at least two layers for 1/2-in. thick plates, and three layers for 3/4-in. thick plates.

Rigid vs. Non-rigid Methods of Welding

On this question it is more a matter of determining the conditions essential to obtaining good results with whichever of the two methods is most appropriate for each particular purpose.

The term rigid is applied to the process of arc welding, in which the two parts to be joined by welding are, prior to welding, held rigidly by bolting or clamping, or by a series of preliminary tack-welds distributed at various points. The rigid plan is the most obvious for welding the hull plates of ships, but its critics claim that the resultant joints are deficient in ductility due to the presence of internal stresses. It is considered that by suitably arranging the order of welding it is practicable to so distribute the heat as to avoid these stresses. At any rate there are many alternative orders of procedure in making welds by the rigid method, and elaborate researches should be made to ascertain the procedure which will yield the best result.

The non-rigid method consists in placing at a slight angle to each other the two plates to be welded. As the welding operation progresses along the seam the angle gradually closes and when the weld is completed the width of the welded seam is equal throughout its extent. Such welds are generally considered to be very free from internal stresses, and hence more ductile.

Consequences of Different Lengths of Arc

The metal arc is much shorter than the carbon arc. As a result, the metal arc weld has the advantage that there is less opportunity for oxygen and nitrogen to gain access to the weld and so far as relates to this feature the metal arc weld should be better. But with the carbon arc the added metal does not traverse the arc, the tip of the welding rod being held down close to the surface on which it is to be deposited. This may render the deposited material less subject to contamination in carbon arc welding than in metal arc welding since it has not traversed the arc.

Coming to the exclusive consideration of metal-arc welding, the greater the welding current the less is the area represented by the cylindrical surface of the arc per pound of metal traversing the arc, and consequently the less should be the contamination by oxygen and nitrogen from the surrounding air. So far as this circumstance is concerned, the greater the welding current, for a given case, the greater should be the ductility of the joint. On the other hand, it seems probable that even the most skilful operators will be unable to hold quite so short an arc with the larger current.

Spot and Arc Welding

A good deal of progress is being made in America in the use of spot welding for the joining of thick plates. It is believed that spot welding has a great future as applied to shipbuilding, and several large spot welders have been built for shipyards. In some of its applications, spot welding affords a method of preliminarily joining the hull plates, after which the required additional strength is provided by arc welding. The Welding Research Subcommittee has already made some progress in comparing combined spot and arc welds and combined rivet and arc welds with riveted, spot-welded, and arc-welded joints. It is not a question in such an investigation of spot *versus* arc welding, but of spot *and* arc welding.

In the tests mentioned, the specimens were made up of the following combinations:

(1) Spot and fillet welded (Fig. 1) (two samples made).
(2) Fillet welded—made by welding fillets about two inches in length at the ends of the plates (Fig. 2) (two samples made).
(3) Riveted and filled welded (Fig. 3) (one sample made).
(4) Spot welded—made by welding two spots approximately one inch in diameter, on the plates (Fig. 4) (two samples made).
(5) Riveted joint, made by a $\frac{1}{2}$-in. × 4-in. × 12-in. plate with two plates $\frac{1}{2}$-in. × 4-in. × 16 in., using two $\frac{3}{4}$-in. rivets and a 4-in. lap. (One sample made).

The results of the test show the comparative strength of the joints as follows:

Spot and Fillet Welded—Ultimate Load	*50,350 lb.
Fillet Welded—Ultimate Load........	*37,000 lb.
Riveted and Fillet Welded—Ultimate Load	†35,000 lb.
Spot Welded—Ultimate Load........	*28,000 lb.
Riveted Joint—Ultimate Load......	†13,000 lb.

Spot welds, as compared with arc-welded butt joints, have the disadvantage of the increased weight corresponding to the overlap.

* Average of tests on two samples.
† Only one sample made.

Condition of Surfaces to be Welded

While for spot welding the surfaces may sometimes be too clean to obtain the best weld, this cannot be the case with fusion welding. The question of the extent to which it is practicable to go in freeing the surfaces from impurities prior to making the fusion weld is entirely a commercial one. The cleaner the surface, the better the weld. In spot welding it is desirable to have clean surfaces under the electrodes, but scale between the two plates is a positive advantage.

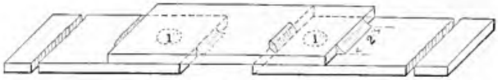

Fig. 1. Fillet and Spot Welded

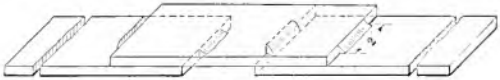

Fig. 2. Fillet Welded

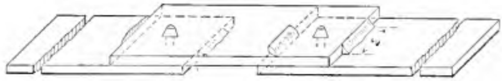

Fig. 3. Riveted and Fillet Welded

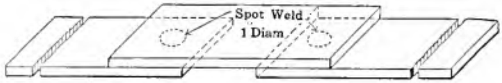

Fig. 4. Spot Welded
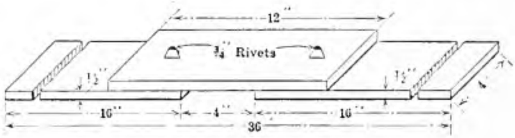
Fig. 5. Riveted Joint

Pre-heating and Heat Treatment and Hammering While Cooling

Pre-heating, heat treatment, and hammering, as applied to fusion welding (both gas and electric) have been the subjects of research, but as yet nothing adequately comprehensive has been planned. It is very important that these deficiencies should be recognized and remedied.

Question of Need for Special Machines for Welding

A great variety of machinery for supplying and controlling the current for welding is on the market. Some of this machinery comprises elaborate mechanisms in virtue of which it is claimed that it would be very difficult for even a novice to make a bad weld. Some advocate the use of simple resistance to be inserted in series with the arc on any available circuit, and claim that any additional machinery is superfluous. The capital outlay for the equipment of a welder (at the point of consumption) when the first kind of equipment is used, may be a matter of over $1000, while in the second case, well below half of the sum is sufficient.

Technique of Testing Welds

The ideal weld should presumably be at least as strong and as durable as the metal of the members joined together. In other words, the section containing the weld should have the same chemical and physical characteristics as adjacent sections in the original metal. A weld is therefore measured by the degree of approximation to this condition as determined by mechanical, chemical and metallurgical tests of:

(a) The parent metal
(b) The welded joint
(c) The deposited material in the weld.

While during the last year the Welding Research Sub-committee has made a great deal of progress in establishing standard procedures for the mechanical testing of welds, much still remains to be done. Obviously, the procedure for testing the original metal should follow standard practice as recommended by the American Society for Testing Materials, but there is considerable difference of opinion and uncertainty as just how and what mechanical tests should be made of the welded joint and of the deposited metal. For instance:

(a) Should all the usual observations be taken when making a tensile test of a welded joint? Obviously the strength of the union between the two pieces of metal should be determined, but in view of the non-homogeneity of the specimen, does not a very different significance attach to yield point, elongation and reduction of area? Where a series of welds having the same ratio of deposited material to original metal is concerned, such data are undoubtedly important for comparison purposes, but for evaluating a weld in terms of the original metal, questions are repeatedly being raised as to just what extent these data have value.

(b) Would not more reliable information as to the ductility of the weld be obtained if elongation and reduction of area measurements were made on specimens prepared from the deposited metal or from specimens cut lengthwise of the weld instead of crosswise?

(c) Similarly with the bending test, which is a test for ductility. There are some (including the author) who would make the bend with the axis of the mandrel *normal* to the weld instead of parallel thereto, which latter position is the one usually employed. It may be that both tests should be made; the normal position as test of the ductility of the deposited material and the parallel position as an additional test of the union between the deposited material and the original metal.

TABLE III.

TIME, METAL, AND CURRENT USED WITH WELDS OF DIFFERENT BEVELS

	Angle of Bevel Used, in Degrees			
	15	30	45	60
Amperes	160	145	118	125
Weight of electrode used up (lbs.)	2.56	3.83	4.63	6.63
Weight of metal deposited (lbs.)	1.70	2.55	3.65	5.08
Weight of metal wasted (lbs.)	0.86	1.28	0.89	1.55
Pounds deposited per hour	1.82	1.61	1.82	1.81
Feet welded per hour	3.22	1.90	1.50	1.07
Circuit kilowatts	9.91	9.00	7.68	8.25
Kilowatt-hours per foot of weld	3.10	4.70	5.10	7.70

(d) How important are torsion tests and impact or shock tests in measuring welded joints?

(e) Fatigue tests of welded joints are generally conceded to be vital and the importance of obtaining reliable information as to how this test should be made probably transcends (at present at least) that attached to any other research in the field of fusion welding. The researches should be made:

 (1) With the Moore bending fatigue machine
 (2) With rod samples rotated at high speed as employed by Lloyd's Register in England
 (3) With the Strohmenger torsion-fatigue machine
 (4) With the Cammell-Laird bending fatigue apparatus
 (5) By the Upton-Lewis test.

After the necessary research work has been done to solve these and other similar questions pertaining to the testing of welds, standard specifications for the testing procedure can be prepared which will be properly balanced between the cost of making the tests and the amount of testing necessary to insure a reliable estimate of the weld.

Conclusion

The extent of the field of application for fusion welding and spot welding is but little appreciated by engineers other than those who have been directly connected with welding developments. It is evident that this field is an enormous one, including as it does, all structures where steel is employed, such as bridges, building structures, tanks of all types and kinds, railway rolling stock, and ships, in addition to numberless miscellaneous applications in industry in general.

However, engineers associated with welding research should be on their guard that their enthusiasm over this great field of application shall not lead them into prematurely endorsing the use of fusion welding or spot welding in constructions where the consequences of failure involve serious menace to life and property, as may often be the case. For example, a particularly important case is that of pressure vessels and especially large high-pressure containers. The success in 100 installations will not excuse failure (accompanied possibly by fatalities), in the one hundred and first installation. It is the opinion amongst the best informed engineers that before fusion welding can advisedly be employed for large high-pressure vessels, much vigorous and elaborate research work should be carried out on the fatigue characteristics of fusion welds of long seams, and that this research work must comprise full-sized structures since the conditions cannot be reproduced in test samples.

In fact, if the general acceptance of welding, particularly by inspection boards, underwriters, and classification societies, is to be accomplished in a reasonably short time, such extensive research work on a large scale is absolutely essential in order to demonstrate conclusively that welded joints are equal to or better than joints made by other methods. Obviously, the development of the art could proceed along the lines of the usual order of evolution, as in the cases of previous arts, but this would, as in those cases, involve the lapse of years.

For structures subjected to less extreme stresses, such as the hulls of ships, the adequacy of fusion welding as a substitute for riveting is in process of being thoroughly demonstrated in actual practice in Great Britain. It is recognized that the hulls of ocean-going ships are exposed to very great stresses; nevertheless there is a clear distinction between the magnitude of those stresses and the stresses to which many large, high-pressure containers are subjected.

The author hopes this paper will aid in focusing attention on the vast importance of the welding art, particularly by occasioning discussion of the many problems in welding research, some of which have been mentioned in the paper.

The author cannot undertake to give adequate acknowledgment of his indebtedness to his many associates in the preparation of this paper. The most generous assistance has been given him on every hand. Mr. William Spraragen has extended much assistance in preparing data and in many useful ways. Mr. F. M. Farmer, Chief Engineer of the Electrical Testing Laboratories, has given very generously of his time in advising the author in detail about many points which arose in the course of the preparation of this paper.

Synchronous Motors in the Meat Packing Industry

By T. J. Byrnes

Chief Electrician, Cudahy Packing Company

The contents of this article, descriptive of the electrical activities of the Cudahy Packing Co[illegible] indicative of the utility that can be made of synchronous motors in the meat packing industry. Th[illegible] how low power-factor conditions in the Omaha plant, caused by a very large number of small [illegible] were first improved by the installation of a synchronous motor driving a deep well pump. He then [illegible] later installation of additional small induction motors again lowered the power-factor and how an improve[illegible] was again effected by the selection of synchronous motors for driving the large refrigerating unit[illegible] The [illegible] lation of synchronous motors is of particular interest in that slip-ring induction motors have [illegible] employed heretofore for electric-driven refrigerating compressors. It is also to be noted that synchronous motors of the speed and rating of those described are cheaper than slip-ring motors of the same size.—Editor

Little has been written regarding the electrification of the meat packing industry for the following reasons: First, until comparatively recently the larger packers of the country have manufactured their own power—principally direct current; second, the importance of power had been given very little consideration, because electrical energy was used to drive only the smaller machinery throughout the various plants.

Realizing the necessity of making a special analysis of the application of modern electrical equipment to its industry, the Cudahy Packing Company during the last ten years formed a special Electrical Engineering Department in connection with its Mechanical Department.

After careful consideration, it was decided that the first step necessary was to adopt alternating current as the basis; and consequently, its various plants were changed from a direct-current to an alternating-current basis. This gave a much broader field to work in; and after the installation of several thousand induction motors, the engineers decided that their operating conditions, from the standpoints of power-factor and economy, could be materially improved by the installation of synchronous motors when large units were needed. Then followed a series of new developments in the industry.

The first move in this direction was the installation in the Omaha plant of a 400-kv-a. vertical synchronous motor, direct connected to a deep well pump (over 2000 feet deep) requiring 300 mechanical horse power. The surplus capacity of this unit was used for power-factor correction. This installation raised the power-factor of the plant (aggregating over 4000 horse power in motors) from 74 to 85 per cent.

Several hundred motors were later added, mostly of the small induction type which again tended to reduce the power-factor of the plant. In consequence of this, it was decided that further progress should be made in overcoming these losses. Accordingly, the proposition of driving the refrigeration machines by electric power was investigated; but the large belts necessary for coupling up the steam-driven machines already installed, together with the great amount of floor space required, made this arrangement prohibitive. The steam-driven units were, therefore, replaced by direct-connected units driven by synchronous motors.

The problem of designing these ammonia compressors was submitted to the writer, and he, in connection with Mr. John Westerlin, of the Westerlin-Campbell Company of Chicago, designed a machine which has since become the standard of the Cudahy Packing Company; and the success of this unit has been such as to cause considerable favorable comment from some of the other large refrigerating plants throughout the country.

The Cudahy Packing Company has standardized upon a 300-ton compressor of 150 r.p.m., using a 500-h-p. synchronous motor mounted on the crank shaft of the compressor and adjoining the flywheel, the stator being mounted upon a base-rail which forms a common bedplate with the ammonia compressor and which allows for shifting the stator to one side so as to permit repairs to either the stator or rotor coils with but little effort. Due to a full-sized by-pass system on the ammonia compressor, but 35 per cent of full-load torque is necessary to start the machine which is brought up to full speed in eight seconds. The motors are wound for 6600 volts, 3-phase, 60 cycles, a motor-driven exciter furnishing the direct current for the synchronous motors. The flywheels, forming part of the unit, have been so designed as to eliminate all line disturbances as far as practicable.

Fig. 1. Front View of Switchboard in New Main Substation. Cudahy Packing Co., Omaha, Neb.

Fig. 3. Control Board and Motor-generator Exciter Set for Machines in Fig. 5

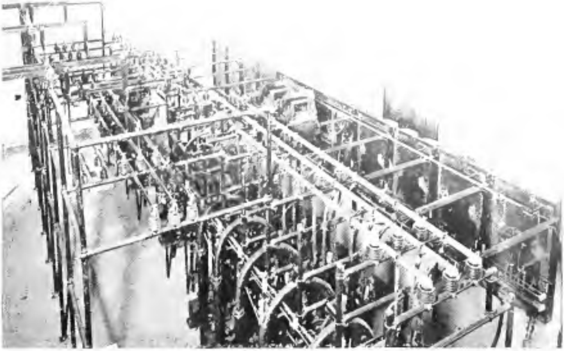

Fig. 2. View of Switching Arrangement in New Main Substation

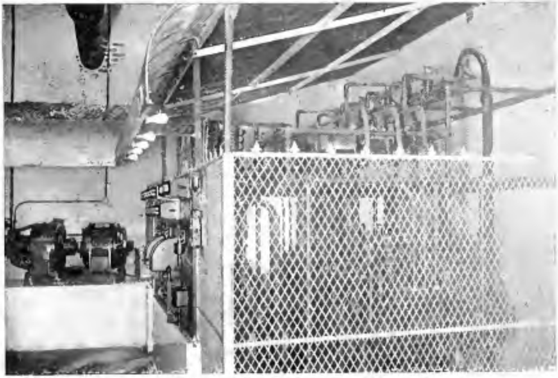

Fig. 4. End View of Control Board shown in Fig. 3

Fig. 6. Close-up View of One of the Machines Shown in Fig. 5, Cudahy Packing Co., Omaha, Neb.

Fig. 5. Two 300-ton Refrigerating Machines Driven by Two 500-kv-a. each, 6600-volt, 3-phase, 60-cycle General Electric Synchronous Motors

The installation of two of these motors recently at the Omaha plant has raised the power-factor of the plant to 95 per cent, on a total load of over 6000 horse power in motors.

The Cudahy Packing Company has installed machines of this type at its Kansas City, and Kansas and Salt Lake plants; and after two years of service it is convinced that this type machine will supersede to a great extent the low-speed, steam-driven units of the past.

The switchboard used in connection with the control of the refrigerating machines and also the switchboards installed in the main substation are of the remote-control type, all oil circuit breakers being solenoid operated. The switchboard panels themselves are made of slate, 48 in. high, set up on a 30-in. concrete pedestal faced with white enameled tile.

All oil circuit breakers, with their solenoids, are mounted back to back on pipe framework back of the switchboard. Ample space is allowed between the switchboard and the oil circuit breaker structure for working on either the backs of the panels, or on the circuit-breaker structure, so that if an attendant, for example, wishes to remove one of the oil tanks he will have ample room. This system, of course, also gives very good ventilation around the switchboard and the switch and bus structure.

The solenoids for the oil circuit breakers in the main substation receive their energy from a battery and motor-generator set. The solenoids in the ice machine station receive their energy from a motor-generator and battery set, this set of course running continuously.

Buses are mounted directly above the oil circuit breakers on pipe framework, so that the oil circuit breaker and bus structure are all one. This is a standard arrangement.

All outgoing lines run out from the oil circuit breakers in conduit under ground. All cables that are used in this conduit are lead covered. In this connection, it might be of interest to mention that no potheads are used at the point where the cable leaves the conduit for connection to the oil circuit breaker. A very unique system is used in that the conduit is run up to the point where the bend starts for the connection of the cable to the oil circuit breaker; and, from this point on, the lead sheathing is cut away and a section of it is turned back over the conduit. Great care is used to present a very smoothly rounded lead surface to the cable, so that no abrasion will result. This is further assisted by being packed at this point with oakum.

Fig. 7. New Main Substation, Cudahy Packing Co., Omaha, Neb.

In connection with this installation, there is another feature which the Cudahy Packing Company is putting in practice in all of its plants and which has been found invaluable to attendants; viz., the color scheme used. Different voltages are represented by different colorings. This refers to the bus structure in particular, but it is applied also to the small wiring on the backs of the panels and the control wiring in the circuit breaker structure. The alternating-current potential wiring has one color, the current transformer secondary wiring a second color, and the direct-current control wiring a third color. In case a fault develops, this arrangement makes it very simple for the attendant to place his finger at any desired point in the small wiring on any one of the three above outlined circuits without having to trace it from its source.

The switchboards in the plants are all protected from tampering by diamond-mesh grills with a door having a Yale lock, the key to which is held only by the authorized attendant.

Central station power is used at all the plants, but the equipment has been installed with a view to being able to operate from their own power equipment, should the decision be made to generate their own power at any time.

The various plants of the Company are now operated electrically throughout, with the exception of a part of the refrigerating equipment which is being changed over to electric drive as rapidly as possible.

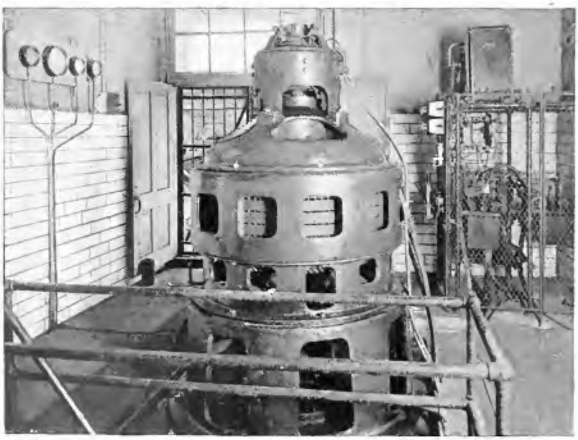

Fig. 8 400 kv-a. Synchronous Motor on Deep Well Pump, pumping 2000 gallons of water per minute from 150 feet working head into the mains at 75 lb. pressure, Cudahy Packing Co., Omaha, Neb.

Methods for More Efficiently Utilizing Our Fuel Resources

PART XXVIII. FUEL PROBLEM OF CANADA SOME NATIONAL AND INTERNATIONAL ASPECTS

By Arthur V. White

Consulting Engineer, Commission of Conservation of Canada

While the extreme east and west of Canada supply coal to those sections of the United States immediately to the south, the middle provinces of Canada are dependent upon the United States for their supply. Canada is, therefore, now taking active steps toward the development of the vast deposits of lignite in Saskatchewan and Alberta. For a number of years Mr. White has been actively advocating the further development of the great fuel resources of Canada in order to lessen her dependence upon the United States for coal. Editor.

So much has been said, drawn from seemingly authoritative sources, respecting the "unbounded extent of the natural resources of Canada," that it is little wonder the popular view is entertained that Canada's resources are practically unlimited, and perpetual prosperity only waits upon their fuller development. For Canadians, however, to hold and be governed by such a view is to live in a "fool's paradise."

Little more than a decade ago, a large majority of the people of the United States believed that the natural resources of their country were unbounded, and that there was hardly any limit to material progress based upon their development. Even in that country, however, there were many who did not share these views, and through their efforts special investigation was made respecting the actual conditions of the natural resources of the nation.

Natural Resources of Both the United States and Canada are Exhaustible

No country possesses, within its own borders, more varied and extensive resources than the United States, yet it is now recognized that many of these are within measureable distance of exhaustion. This fact was so clearly demonstrated that prompt action by the trustees of the nation became imperative. So far as one can judge, natural resources from the 49th parallel to the Gulf of Mexico are better situated, geographically, and must always be more desirable than those from the 49th parallel to the Arctic ocean; thus, by reason of situation, Canada's usable natural resources are in variety and extent less than those of the United States.

Those who have observed the rapid disappearance of many of the natural resources of Canada and the present alarming rates at which some are being consumed realize that the situation, as a whole, is one of great gravity. Consequently, true conservation in Canada is as great, if not a greater necessity than in the United States.

Resources Must be Wisely Used and Conserved

It is true that some resources, such as minerals—perhaps more especially coal, oil, and gas if used, must in time, necessarily become exhausted. On the other hand, such resources as the soil, plant growth, waterways and ground waters, may be conserved and transmitted to posterity unimpaired, or at least unabused, just as a good husbandman passes on his farm in an improved condition to that in which he received it. The policies advocated by the Commission of Conservation of Canada have aimed at passing on to succeeding generations in an improved condition the heritage of the natural resources of this country.

By intelligent and thrifty use, the natural resources of Canada may beneficently serve the needs of a large population. If, however, Canadians become really dependent upon necessary commodities supplied them by other countries, they must be prepared to accept the circumstances in which they may suddenly find themselves if the supply of such commodities is cut off. Such circumstances will be aggravated by any abuse of our assets.

Coal Scarcity and Coercion

There is, apart from food, raiment, and shelter, perhaps no single commodity which has been found so necessary as fuel—chiefly coal—for the maintenance of life and for the carrying on of commerce and transportation. Recently the public interest has been keenly aroused respecting the nation's fuel supply and increasing dependence upon hydro-electric energy. War conditions have driven home to Canadians as never before the tremendous gravity of their position with respect to fuel.

Countries like Norway and Sweden, Denmark, Holland, and Switzerland—countries, indeed, which were neutral—were practically dependent upon the warring nations for coal, and found themselves seriously curtailed in obtaining this commodity. They were forced to recognize the momentous fact that the countries which possess coal are able, absolutely, to dictate the terms upon which coal will be supplied to others.

Portion of Canada Dependent Upon United States for Coal

Now, a very large portion of Canada—and for this one may hold in mind much of the populated territory extending, say, from Quebec to Winnipeg—has become increasingly dependent for its fuel supply upon the coal fields of the United States, and absolutely dependent upon that country for its annual supply of some 4,500,000 tons of anthracite.

In addition to the use of imported anthracite for heating and domestic purposes, large quantities of bituminous coal—some 10,000,000 to 14,000,000 tons—are also imported annually from the United States, largely for power purposes.

The known anthracite fields of the United States are within measurable distance of exhaustion. Doubtless, in the not distant future, the United States will feel compelled so to conserve this valuable commodity that the exportation of it may be largely restricted, if not entirely cut off. There are available many examples, arising out of the great European war conditions, where the United States has found it necessary to place stringent embargoes upon natural and manufactured products.

Now, if Canada is to be in a position to command special consideration under possible restricted trade conditions, she must realize the value of her own resources and have them strictly under national control in order that she may be enabled to deal on a basis of *quid pro quo*. When the commodities of commerce are exchanged there must, of course, be a substantial basis for barter. When Germany demanded gold from Switzerland she offered to exchange coal. Suppose that the United States, in the conduct of her commerce, concluded that it was in the general interest of her citizens only to *barter* coal for certain commodities which she specially required, what desirable commodities has Canada to barter?

Nothing is further from the thought of the writer than to suggest that it is or that it would become the arbitrary desire of the United States to deprive Canada of the coal which at present is so necessary to life in Canada. It is important, however, to take cognizance of the fact that a nation, pressed by the demands of its own people, may be compelled, under certain conditions, to deprive other nations—in part at least—of even the necessaries of life until the needs of its own citizens are met. No country can be expected to send out of its confines that which is essential to the very existence of its own people.

It is not the policy of Canada to embargo her exports. She must, however, conserve against the day of her own need such resources as are available for barter. It certainly is sound policy to insure that commodities of national importance should not be exported without an adequate *quid pro quo*.

Some portions of the United States are as badly in need of coal from Canada as portions of Canada are in need of coal from the United States. Between these two great countries there is an exchange of many natural and manufactured products, and the problems which from time to time arise in connection with such interchange can be satisfactorily solved and the whole situation reduced to a good working basis.

Canada's Rich Water-power Heritage

Other than the products of her agricultural lands, mines, and forests, there are certain resources in Canada of unique and special value. Canada has an especially rich heritage in her water-powers, including her equity in international waters. To a large extent these water powers are still under the control of the people. This control is being zealously guarded so that as the country develops and sites come into the sphere of active economic importance they may be developed and used in the general public interest. Men far-sighted in the fields of industry and finance have foreseen the extent to which present and future generations will become increasingly dependent on power, whether it be steam or hydro-electric.

Any estimate for the water powers of Canada must be presented and considered with a due appreciation of its limitations. Table I representatively sets forth the water-power situation in Canada. By no means may all the water powers be economically developed.

Canada has been aggressive in the development and utilization of her water-powers, and no large communities are better supplied with hydro-electric power and light than are places like Montreal, Ottawa, Toronto, Hamilton, Winnipeg, Calgary, Vancouver and Victoria.

The most striking example of hydro-electric energy being developed and distributed on a large scale in order to afford a supply of cheap power and light for communities is found in the work of the Hydro-Electric Power Commission of Ontario.*

This Commission, co-operatively with over 200 Ontario municipalities, has upwards of 3,000 miles of transmission line, and serves over 120,000 customers. In fact, nearly half the population of Ontario is supplied with electricity through the agency of the Commission. The capital investment of the Province in connection with these undertakings approximates $55,000,000, in addition to which the various municipalities co-operating with the Commission have made an investment of some $20,000,000 in connection with their local distribution and [illegible] systems. This extensive [illegible] of electric [illegible] result in the annual [illegible] of [illegible] of tons of coal.

TABLE 1

WATER POWERS OF CANADA

(Tentative Schedule)

Province	Total Estimated 24-hour Low-water Horse Power		[illegible] Horse Power
Prince Edward Island	3,000		500
Nova Scotia	150,000	(b)	30,000
New Brunswick	300,000	(b)	15,000
Quebec	6,000,000		900,000
Ontario	6,060,000		1,000,000
Manitoba	2,700,000		83,000
Saskatchewan	250,000		5,000
Alberta	450,600		33,000
British Columbia	3,000,000		300,000
Yukon	100,090	(c)	13,000
North West Territories (d)	....		
Total for Canada	18,953,000		2,379,500

(a) This column presents aggregates of installed capacities.
(b) Special investigation now in progress.
(c) A rough estimate made for inclusion in this summary, probably low.
(d) No reliable data available.

Niagara River Water-power Development in Canada

At Niagara Falls, great power development has already taken place. There [illegible] of the large power plants in Canada [illegible] stated as in Table II.

Niagara Water Allotted by Treaty all Taken

The total diversion for both countries [illegible] 56,000 cubic feet of water per second from the Niagara River as provided by the Boundary Waters' Treaty has now been fully allotted, and before long will all be in actual use by plants on both sides of the river. Suggestions are continually being made to have the Treaty revised so as to permit of greater diversion. One recent proposal is that under a new Treaty each country shall be permitted to divert 60,000 cubic feet of water per second, which corresponds to approximately 1,800,000 electrical horse power assuming 30 h.p. to be developed per cubic foot of water.

Canada an Exporter of Electricity

About 125,000 h.p. of Niagara hydro-electric power is exported to the United

*A brief but comprehensive historical survey of the evolution of the Hydro-Electric Power Commission of Ontario, by Arthur V. White, is given in the Commission of Conservation's report, "Water-Powers of Canada," Ottawa, pp. 35-56. For a valuable resume of activities of the Commission, consult, "Electric Power Generation in Ontario on Systems of Hydro-Electric Power Commission," by Arthur H. Hull, in *Proceedings of American Institute of Electrical Engineers*, January 1st, 1919; also published in The *Canadian Engineer* issues of December 12 and 19, 1918.

States. Canada is exporting electrical energy from New Brunswick to the State of Maine, from Quebec to New York, from Ontario to New York and to Minnesota, and from British Columbia to Washington. The United States is importing from Canada about 200,000 h.p. years of electrical energy.* Many factors, of course, enter into the determination of the equivalent of this electrical power in terms of anthracite. Speaking in round figures, and taking cognizance of some of these special factors, the electrical power now imported by the United States would be the equivalent of not less than 3,000,000 tons of coal—and doubtless is a quantity substantially greater, even 6,000,000 tons or possibly more, the determination of the equivalent being dependent upon what in any set of circumstances are found to be the governing factors.† It will thus be perceived that, on a power basis, the coal equivalent of the electric energy exported to the United States approximates the quantity of anthracite imported by Canada from the United States.

This electrical energy is, of course, much more profitably employed for power than for heating purposes. In this connection it may briefly be commented, with respect to the restricted possibilities of electric heating, that for years past the author has been emphasizing the comparatively limited use which can be made of electric energy as a *wholesale* substitute for coal for heating,—including the heating of buildings. The sooner it is realized that hydro-electric energy can never as a heating agent be an adequate substitute for coal for the citizens of Canada, the sooner will action be concentrated upon sources from which real relief may be derived—there is no use entertaining hope towards a source from which no sufficient relief can come. At the annual meeting of the Commission of Conservation in November, 1917, the author stated that "The extent to which electric energy will be available for heating has been much overrated and, realizing the underlying physical limitations one cannot be enthusiastic respecting the extent to which it may be utilized." This

TABLE II

NIAGARA POWER PLANTS IN CANADA

Plant	Rated Capacity of Present Installation. Horse Power	Approximate Maximum Generating Capacity. Horse Power
Canadian Niagara Power Co.	112,500	100,000 (a)
Ontario Power Co. (controlled by the Hydro-Electric Power Commission of Ontario)	159,000	162,000 (b)
Electrical Development Co.	135,800	125,000 (c)
Ontario Power Co.'s new pipeline (Installed by Hydro-Electric Power Commission.) Completed 1919	32,000	32,000 (d)
Present Total Development	439,300	419,000
Chippawa Plant under construction by Hydro-Electric Power Commission of Ontario, ultimate development	300,000	300,000 (e)
Total Development now provided for	739,300	719,000

(a) At times has generated about 103,000 h.p.

(b) At times has generated about 163,000 h.p.

(c) At times has generated 146,000 h.p., but it is claimed that the water used to generate this amount exceeds the quantity legally usable to generate the 125,000 h.p. specified in the contract.

(d) This pipeline has a nomial capacity to supply water for 50,000 h.p., but the balance of water in excess of that required for the two new 15,000 kv-a. generators is used to increase the efficiency of operation of the older portion of the plant.

(e) To operate under a head of 305 feet and to utilize the descent of the Lower River.

*For discussion of various aspects of problems respecting the exportation and use of electrical energy, consult the following articles by Arthur V. White: "Exportation of Electricity," which appeared in the *University Magazine*, October, 1910, pages 460 *et seq.* Consult, also *Toronto World*, March 18, 1912; also "Exportation of Electricity—An International Problem; Relation of a Possible Coal Embargo by United States to a Curtailment or Stoppage of Canada's Electric Power," in *The Monetary Times Annual* of January 5, 1917, pages 21 *et seq;* also "Coal Problem of Canada Demands National Action—A Solution of a Vital National and International Question" in *The Monetary Times Annual*, January 4, 1918, pages 25 *et seq*; also consult, "Barter Power for U. S. Coal," in *The Globe*, Toronto, November 27, 1917; and *Monetary Times*, Toronto, January 18, page 9, and February 22, 1918, page 26.

†Consult the Hydro-Electric Power Commission of Ontario Report on the "Rate of Coal Consumption in Various Electric Generating Stations and Industrial Establishments in Canada and the United States," by A. S. L. Barnes, Toronto, 1918.

statement being made at a time of serious hardship due to power and fuel shortage attracted widespread attention.*

St. Lawrence River Water-powers

Outside of the Niagara District the greatest amount of water-power of immediate economic importance is found along the St. Lawrence River. On a conservative basis, the low-water power of the international portion of the St. Lawrence River may be estimated at about 800,000 h.p., of which Canada is entitled to one half, or 400,000 h.p. The correspondingly estimated low-water power on the portion of the river which lies wholly within Canada is about 1,400,000 h.p., thus making an estimated total for Canada of 1,800,000 low-water continuous h.p. Assuming the diversity load-factor of the present Niagara system of the Hydro-Electric Power Commission of Ontario, Canada's 1,800,000 h.p. on the St. Lawrence would take care of a power demand of some 2,400,000 h.p. The St. Lawrence river power sites are detailed in Table III.†

Coal Resources of Canada

Now, we have seen how great are the water-power resources of Canada, and these, it may be observed, are largely spread over the areas which have no natural coal. These areas now import coal, which will no doubt be increasingly supplied from the Canadian mines. Considering the country as a whole, Canada in respect of quantity, quality, and accessibility for mining purposes, possesses coal deposits which compare favorably with those of the greatest coal mining countries of the world. Canada, as we have seen, can never depend upon her water powers as a sole source for heat. Consequently, the alternative open to her, and it is this to which special attention is directed, is to develop, and that as rapidly as possible, both her own fuel and power resources, and by co-ordination of transportation and other cognate agencies to provide for the distribution of fuel to all communities in the Dominion. In some respects it is more important to move coal and have it adequately stored and distributed throughout Canada than it is to move the grain out of the country.

The coal fields of Canada may conveniently be divided into four main divisions:

1. The bituminous coal fields of Nova Scotia and New Brunswick.
2. The lignites of Manitoba and Saskatchewan, and the lignites, sub-bituminous and anthracite coal fields of Alberta and the eastern Rocky Mountain region.

TABLE III

WATER-POWER ON THE ST. LAWRENCE RIVER

(Tentative Schedule) (a)

Site	Head Available	Estimated Low-water 24-hr. h.p.	Average Estimated 24-hr. Low-water h.p.
Morrisburg-Rapide Plat	11–15	170,000–230,000	200,000
Long Sault rapid	30–40	500,000–650,000	575,000
Coteau rapid	15–17	230,000–260,000	250,000
Cedars rapid (b)	30–32	490,000–525,000	500,000
Split Rock and Cascades rapids	14–18	220,000–280,000	250,000
Lachine rapid	20–30	300,000–450,000	375,000
Total		1,910,000–2,395,000	2,150,000

(a) In this table, to have the estimates fairly representative of the possible quantities which might be expected under representative low-water flow conditions, some allowances have been made for efficiency and other factors.

(b) Under development for about one third of the low-water flow of the river. Consideration would be given to the possibility of combining the Coteau, Cedars, Split Rock and Cascades; also of increasing the Lachine power.

*For several years past attention has been drawn by Mr. White to the relatively limited use that can efficiently be made of electrical energy as a heating agent. On February 11, 1918, when addressing the important Fuel Conference held by municipalities in Galt (see *Galt Reporter*, February 12, 1918), Mr. White again emphasized his contention that, as a general proposition, electrical energy is more serviceably employed for strictly power purposes, while fuel, such as coal, oil, etc., is more profitably employed for heating. At this meeting he set forth the underlying principles governing in this matter. See *Monetary Times*, March 1, 1918, page 18. Consult, also, *Annual Reports of Commission of Conservation*, Ottawa; and article by Mr. White, "Electricity will not Replace Coal," in *Industrial Canada*, Toronto, April, 1918.—Editor.

†From "Power Possibilities on the St. Lawrence River," by Arthur V. White, Ottawa, 1918. See, also, by same author, "Long Sault Rapids, St. Lawrence River, an Enquiry Into the Constitutional and Other Aspects of the Project to Develop Power Therefrom," Commission of Conservation, 384 pp. Ottawa, 1913.

TABLE IV

ESTIMATED COAL RESOURCES OF CANADA (a)

Province	Area of Coal Lands Square Miles	Semi-Anthracite Tons	Bituminous Tons	Sub-bituminous Tons	Lignite Tons
Nova Scotia	521		10,691,000,000		
New Brunswick	121		166,000,000		
Ontario	10				27,500,000
Manitoba	48				176,000,000
Saskatchewan	13,406				65,793,000,000
Alberta	81,878	845,900,000	217,918,000,000(b)	932,053,000,000	29,095,000,000
British Columbia	6,045		77,923,000,000(b)		5,715,500,000(c)
Yukon	2,840		275,000,000(b)		5,159,000,000(c)
N. W. Territories	300				5,280,000,000(c)
Arctic Islands	6,000		6,600,000,000		
Total	111,169	845,900,000	313,573,000,000	932,053,000,000	111,246,000,000

(a) Consult "Coal Fields and Coal Resources of Canada," by Dr. D. B. Dowling, Geological Survey of Canada; also "Coal Situation in Canada," by W. J. Dick, in *Transactions of the Canadian Mining Institute*, 1916.

(b) Includes some anthracite coal.

(c) Includes some sub-bituminous coal.

TABLE V

COAL PRODUCTION AND DISTRIBUTION IN CANADA

Coal Production in Canada (a)

Province	1916 Short Tons	1917 Short Tons	1918(b) Short Tons
Nova Scotia	6,912,140	6,327,091	5,852,802
New Brunswick	143,540	189,095	267,746
Saskatchewan	281,300	355,445	345,310
Alberta	4,559,054	4,736,368	5,941,864
British Columbia	2,584,061	2,433,888	2,568,591
Yukon	3,300	4,872	2,900
Total	14,483,395	14,046,759	14,979,213

Distribution of Coal Produced (c)

	1916	1917	1918
Sold for consumption in Canada	10,701,530	10,469,468	11,210,628
Sold for export to United States	1,451,075	1,301,881	1,351,179
Sold for export to other countries	284,513	301,060	317.135
Total Sales	12,437,118	12,072,409	12,878,942
Used by producers in making coke, steel, brick, etc	804,814	690,573	682,304
Used by producers for colliery operation and by workmen	1,241,463	1,283,777	1,417,967
Total used by producers	2,046,277	1,974,350	2,100,271

(a) Consult "The Production of Coal and Coke in Canada," by John McLeish, B.A., Chief of the Division of Mineral Resources and Statistics, Department of Mines, Ottawa.

(b) Preliminary figures, subject to minor modification.

(c) This is merely a record of distribution by the companies operating the collieries. The figures "Used by producers making coke, steel, brick, etc," do not represent the total amounts of coal used even in making coke by coke-oven operators.

3. The semi-anthracite and bituminous fields of Vancouver Island, Queen Charlotte Island, and the interior of British Columbia, and the lignites of Yukon.

4. The low-grade bituminous coal and lignites of the Arctic-Mackenzie basin.

The coal areas and estimated quantities for the different provinces are shown in Table IV. There should, of course, for practical consideration, be a substantial reduction made in these quantities, due to waste in mining operations.

mines, considerably larger amounts of coal would have been marketed in territory west of Montreal. No doubt increased quantities of coal will be shipped each year into central Canada through the [illegible] navigation afforded from the sea to the Great Lakes by the present canal system of Canada.

As a result of the efforts of the Fuel Administration in Canada, there have been assembled considerable data not before available relating to the Canadian coal trade. Some of these data have now been incorporated in a valuable report on the Coal Trade of Canada. Table VI from this report summarizes the facts respecting the output, importation and consumption of coal in Canada.*

TABLE VI

COAL OUTPUT, IMPORTATION AND CONSUMPTION OF COAL IN CANADA

Calendar Years (Net Tons)	1915	1916	1917
West of Head of Great Lakes			
Output British Columbia	2,208,289	2,783,849	2,676,760
Output Alberta—Anthracite	125,732	140,544	118,717
Output Alberta—Bituminous	1,026,237	2,335,259	2,206,868
Output Alberta—Lignite	1,082,922	2,172,801	2,537,829
Output Saskatchewan—Lignite	243,125	294,264	360,623
Imported from U.S.A.—Anthracite	298,895	533,846	514,688
Imported from U.S.A.—Bituminous	1,423,882	2,550,352	2,825,702
Total tonnage made available	7,609,082	10,810,915	11,241,187
Exported	864,160	1,105,718	1,029,532
Net consumption	6,744,922	9,705,197	10,211,655
East of Head of Great Lakes			
Output Nova Scotia	7,513,739	6,911,995	6,345,335
Output New Brunswick	126,923	143,658	189,668
Imported from U.S.A.—Anthracite	3,773,135	4,040,368	4,805,000
Imported from U.S.A.—Bituminous	7,622,449	10,739,478	14,394,122
Total tonnage made available	19,036,246	21,835,499	25,734,125
Exported	902,383	1,029,641	703,824
Net consumption	18,133,863	20,805,858	25,030,501
Total consumption in Canada	24,878,785	30,511,055	35,242,156

Canada's Coal Production and Distribution

Canada annually produces 15,000,000 tons of coal. Her coal and coke production in 1916, 1917, and 1918, are given in Table V. Canada is making special efforts to increase the production of, and areas served by, her coal mines. This is evident from the figures in the table for the Province of Alberta, the mines of which, in 1918, increased their production by over 1,200,000 tons. The falling off in production from the Nova Scotia mines is more apparent than real. It is believed that but for the fact that the British Admiralty required, for war purposes, vessels which ordinarily would have been used for transporting coal from the Nova Scotia

Canada's Lignite to be Briquetted

Canada is making serious effort towards the development on a large scale of her lignite and peat resources; also, towards the increased utilization of her coal fields in the East and in the West. The sum of $400,000 has been made available to the Honorary Advisory Council for Scientific and Industrial Research of the Dominion Government for the erection of a carbonized lignite bri-

*Consult "Report of the Coal Trade of Canada for the Year Ended March 31, 1918," issued by the Internal Trade Division, Dominion Bureau of Statistics, 8vo., xiv, 59 pp., Ottawa, 1919.

quetting plant of 30,000 tons of briquettes per annum. Of this sum, $200,000 was voted by the Dominion Government and $100,000 each by the Provinces of Manitoba and Saskatchewan. Work incident to the construction of the plant is under way. The estimated cost of the briquettes per ton at the mine, including all fixed charges amounting to 20 per cent on the capital, is $7.00.*

Peat Resources of Canada

Respecting the peat bogs of Canada, Dr. Eugene Haanel, Director of Mines, Canada, has strongly urged the necessity of developing our peat resources, and at a recent annual meeting of the Commission of Conservation of Canada he gave an able, forceful, and serious address upon this subject which the people of Canada cannot too carefully consider. Dr. Haanel affirmed the commercial and economic practicability of peat production. Many persons who have had their interest and hope aroused in the prospects of commercial peat, feel that sufficient time has already been available for "experimenting" with peat. They feel that if essential conditions respecting the acquirement of bogs are rightly provided for, and the employment of the best processes of manufacture and handling, costs, etc., are known, the peat industry should by this time have become commercialized the same as other profitable industries. Throughout Canada there have already been discovered areas of peat bog estimated to aggregate 37,000 square miles. According to a broad estimate by Dr. Haanel, and assuming an average depth of bog of six feet, this area corresponds to over 28,000,000,000 tons of peat, having a fuel value equivalent to over 16,000,000,000 tons of good coal. Manitoba, Ontario, Quebec and New Brunswick have peat bog areas aggregating 12,000 square miles.†

The Province of Ontario has recently created a Peat Commission, which it is stated has two experimental plants in process of construction.

Petroleum Resources in Canada

Canada is known to possess great areas of rich petroleum-bearing shales and sands. Although considerable work has been performed in such areas—as in New Brunswick—nevertheless, the industry cannot really be said to be commercialized. Having in mind the success of the oil shale industry in Scotland, there appears little doubt but the corresponding industry in New Burnswick, Nova Scotia, and elsewhere, will ere long become extensive.

According to all indications, the year 1919 will see the greatest prospecting propaganda for oil that has occurred in Canada. Many interests—Canadian, British and United States—are arranging for prospecting parties with modern equipment and oil experts to prospect, especially in Alberta and British Columbia.

Respecting the possibility that petroleum will be discovered, particularly in the Viking area and the Peace and Athabaska valleys, "the situation may be summed up as very promising," states Mr. James White in his recent monograph on the "Fuels of Western Canada."‡

He states further:

"A small quantity of dark oil obtained in one of the wells in the Viking gas field is an encouraging indication, and oil has also been found in the Pelican Rapids gas well. Seepages of oil have been found near Waterton lake in southwestern Alberta, and in the Flathead valley in southeastern British Columbia.

"In northern Alberta there are enormous tar seepages which evidence an upwelling of petroleum unequalled elsewhere in the world. Along the Athabaska river they extend from Pelican rapids to Fort McKay, a distance of over 100 miles. The known occurrences indicate that there is in sight at least 6½ cubic miles of bitumen, and the petroleum from which it was derived must have been many times greater. While this enormous amount of petroleum has escaped, there must be untapped reservoirs in the Devonian limestones whence it was derived. Similar seepages occur near the Peace and Mackenzie rivers.

"Near Peace River Landing, oil has been found in two wells, 900 and 1,100 feet deep, respectively. The first well is reported to have yielded 3 to 4 bbl. per day when oil was struck in the upper portion of the tar sands and to have had a maximum production of about 9 bbl. Drilling, however, was continued through the tar sands, which are about 80 feet in thickness at this point, and

* Consult "The Briquetting of Lignites," by R. A. Ross, Report No. 1, Honorary Advisory Council for Scientific and Industrial Research, Ottawa, 1918. Consult, also, "Carbonizing and Briquetting of Lignites," by W. J. Dick, Commission of Conservation, Ottawa, 1917; also by same author, "Canada's Own Coal and the Fuel Problem," in *Industrial Canada*, April, 1918; also "Fuels of Western Canada and Their Efficient Utilization" (revised edition), by James White, Commission of Conservation, Ottawa, 1918.

†Consult "Peat as a Source of Fuel," by Eugene Haanel, Director Mines Branch, Ottawa, 1918.

‡See note under Lignite, *Supra*.

a heavy flow of water and gas was struck immediately below the sands.

"The second well is in the tar sands and is reported to be yielding about 25 bbl. per day."

There is marked evidence that Canadians are alive to the important possibilities of the petroleum industry, and the results of the efforts to be made in 1919 are looked forward to with the greatest interest.

Canada Seeks Efficiency in Fuel Consumption

Canadians are recognizing the fact that it is fairly incumbent upon them to apply every permanent means within their power to utilize coal in the best and most efficient manner. It is recognized that coal shortage may recur, and therefore the lessons of the recent shortage must not be forgotten. It is true that the lessons of the coal shortage of 1902-03 were all too soon forgotten, but surely those of the distressing times of the winter of 1917-18 will prove more lasting.

We must not forget the "heatless days;" the times when gasoline could not be used; the denial of fuel for certain luxuries, as use on private yachts; the curtailment of fuel for the manufacture of such apparatus as musical instruments, talking machines, etc.; the allotment to florists for greenhouse purposes of only 50 per cent of the fuel they were accustomed to receive; the compelled use in certain districts of wood for fuel; the restrictions upon the use of natural gas; the prohibited use in many cases of anthracite and the substitution therefor of bituminous coal; the daylight saving legislation on both sides of the Atlantic; the cutting down of illuminated advertising; and the enforced "lightless nights." These and many other facts must be held in mind as indicating how wide-spread and absolutely necessary have been the efforts for economy with respect to fuel. In the period of reconstruction, and afterwards, the demand for fuel will doubtless be such that many of the restrictions placed upon its use during the war period will in one form and another find permanent expression.

In Canada, as in the United States, it is expected that coal consumers will endeavor to effect economies by the systematic employment of every reasonable means which modern progress can devise. Some of such means may suggestively be enumerated as follows:

Some Means for Obtaining Greater Efficiency

In the use of coal generally, [illegible] may be effected by adopting the [illegible] minous and lignite coal to [illegible] and other manufacturing processes [illegible] save the valuable by-products [illegible] same time produce from inferior [illegible] satisfactory and clean-burning fuel [illegible] a proper co-ordination of the use of [illegible] and coal according to their respective places of greatest efficiency; and by a greater utilization of gas. Those interested in the coal-gas-producing industries are looking forward to the greatly increased use of gas and the recovery of by-products, including the coke.* Manufacturers of stoves and heating apparatus are giving serious attention to the production of apparatus more suitable for satisfactorily burning the softer coals.

In the production of power, savings may be effected by taking advantage of the greater efficiency of the modern steam turbine and of large hydraulic units, and by the inter-connection, especially over large areas, of various electric plants—whether steam-electric or hydro-electric, or combinations of both—with the object of securing the greatest efficiency in the supply of power and light to districts respectively served.

By co-ordinated efforts by communities, savings may be effected by staggering the hours of closing of factories, by the adoption of the skip-stop system for street railways, by daylight-saving legislation, by the enactment and enforcement of wise laws designed to eliminate the wastes resulting from the smoke nuisance.

In manufacturing establishments, savings will be effected by the more efficient use of light and power, by the elimination of uneconomical plants and processes, by the installation of means to use more economical fuel for direct heating, by the substitution wherever possible of hydro-electric for steam-developed power, and by standardization.

By the electrification of steam railways, especially if operated by hydro-developed power, enormous savings in fuel consumption may be made by the reduction of the amount of coal to be hauled, by the saving of energy resulting from the regeneration of electricity by improved methods of braking, by the reduction of the number of buildings and divisional points due to the greater radius of action of electric locomotives, and where fuel-power is employed, by its economical production in large modern generating stations. Canada is looking ahead to great

* Consult "Possibilities Ahead of the Gas Industry as Revealed by a Digest of Reports from Various Sources," by G. W. Allen in *Proceedings of 11th Annual Meeting of the Canadian Gas Association, 1918.*

development in the near future in the electrification of steam railways. The Ontario Government and municipalities already have this problem in hand.

In all such efforts to attain the efficiency possible by intelligent saving and co-ordination, Canada may be relied upon not to fall short of her privileges. Recognizing that the days of the wide-spread use of anthracite are numbered, her bituminous coals and lignites will be subjected to by-product and other manufacturing processes with the object of producing a satisfactory and clean-burning fuel. Canada does not desire to ignore the march of progress in these fuel problems, nor will she be backward in effecting economies for the prevention of needless fuel and power wastes.

Canada Must Bestir Herself Respecting Her Fuel Resources

Now, in conclusion, it must be recognized that anthracite as a fuel is a luxury. Within the last twenty-five years many farmers and citizens, especially in outlying communities where formerly only wood was used, now use anthracite. It became easier and more convenient for the farmer to haul his coal from the railroad siding than to go into the bush and chop his year's supply of wood.

A great portion of this Dominion, like the farmer, has become dependent upon others for coal.

Canada, even though she may regret being deprived of the luxury of clean-burning anthracite or the easily-delivered bituminous coal, must, nevertheless, arouse herself and bestow the necessary intelligent labor upon her own fuel resources in order to make them available for her national needs.

There is no necessity for Canada, with her vast resources of fuel and water power, to go cold or to have her industries throttled by reason of power shortage; but Canada may have a sore trial in both these respects unless every possible effort is speedily made to deal with the fuel and power situation in a comprehensive manner.

Once a broad national policy has been determined, financial and other assistance should be promptly rendered to enable sane and businesslike development of Canada's lignite, peat, and other fuel resources for the benefit of the nation, to be carried out by competent technical officials entrusted with this great and honorable responsibility. As we have already noted the work has been commenced

Officials of the government of Canada, such as those in the Geological Survey, Department of Mines, the Commission of Conservation, and other organizations, have knowledge of existing conditions and of practical means by which much of the stress may be relieved. To carry out these measures of relief and to place Canada in a reasonably independent position with respect to fuel will take time; but there is no doubt that if matters are dealt with in a broad statesmanlike manner, and the necessary encouragement of financial and other assistance is given to those who are competent, Canada will, at a minimum of effort and expense, be relieved of a menace with respect to her coal supply which threatens not only her economic life, but the well-being of a large proportion of her citizens.

Records and Maintenance of Aluminum-cell Lightning Arresters

By F. S. Piper

Electrical Engineer, Manchester Traction, Light and Power Company

While no single method of maintaining aluminum-cell arresters can be said to be [illegible] the method described below and employed by the company with which the author [illegible] so inexpensive and reliable as to warrant its description as a model [illegible] system.—Editor.

To be assured that electrolytic lightning arresters will provide the greatest protection at all times, it is necessary to charge them regularly, to measure the charging current frequently, and to follow up the information obtained. The performance of this work should be supplemented by the keeping of such records as will clearly indicate the condition of the arresters and, in so far as possible, detect negligence on the part of the attendant.

The lightning protection equipment of the Manchester Traction, Light and Power Company includes sixteen 33,000-volt aluminum-cell arresters located in five widely separated stations. During the months of June, July, and August the arresters are charged three times daily; once by each of the three shifts. Throughout the remainder of the year the arresters are charged twice daily.

Each station is supplied with a duplicating book of weekly record sheets, one page of which is illustrated in Fig. 1. On these sheets the operator records the time of charging the arrester and signs his initials. The charging current is measured once each week and is also recorded in the book. Space is provided for recording mechanical defects, loose parts, or any unusual occurrence observed when charging the arrester or measuring the charging current.

These report sheets are mailed to the office of the electrical engineer each week on the day following the test of charging current. They are inspected and the value of the charging current is plotted on a yearly curve on a 5 by 8 inch card ruled for the purpose, Fig. 2. A glance at this curve will show any variation in the charging current.

BROOK ST.

ELECTROLYTIC ARRESTERS—WEEKLY CHARGING RECORD

MANCHESTER TRACTION, LIGHT & POWER COMPANY

Week Beginning Monday August – 5 – 1918

Arresters to be Charged 3 Times Daily in June, July and August. Twice Daily, Remainder of Year.

		CHARGED A.M.		P.M.		A.M.		AMMETER READINGS				191	
DAY	DATE	TIME	BY	TIME	BY	TIME	BY	TANK*1	TANK 2	TANK 3	TANK 4	CIRCUIT	NO
Monday	5	5:25	W K	8 20	C E W	10:50	R C C	.25	.275	.31	.28	Kelleys-Brook	1
Tuesday	6	6 50	"	9 30	R C C	11:20	C E W	.325	.35	.35	.35	" "	2
Wednesday	7	5:20	"	9 35	"	10 30	"	.35	.40	.40	.41	Back Bus 4000	
Thursday	8	5 30	"	9:20	"	10.30	"	.38	.39	.39	.40	Front " 4000	
Friday	9	6 00	"	9 15	"	11 45	"	.31	.34	.31	.32	Back " 2200	
Saturday	10	5:20	"	9 20	"	10.15	"	.33	.33	.36	.36	Front " 2200	
Sunday	11	5:25	"	11 00	"	11.40	"	.39	.35	.325	.33	Kel Brook 11000	

Make note of any repairs needed or unusual symptoms, condition of arc, etc. *No. 1 tank is the tank farthest from Transfer device

REMARKS:

Fig. 1. Sample Sheet from the Lightning Arrester Weekly Record Book of the Manchester Traction, Light & Power Company showing dates and times of charging and charging currents

Of course this record can be "faked" if the operator does not feel like charging the arrester, and this has been done. In one case the night operator failed to charge the arrester but filled out his records. This practice continued until the weekly charging current test showed an increase in current and an inspection one morning, after a snow storm of the previous evening, revealed no tracks around the arrester. After this discovery the curve soon returned to normal.

Each week when the charging current is measured the operators are expected to make inspection for defects such as loose bolts and nuts, broken insulators, etc., to observe if the gap settings appear to be changed, and to note these conditions or anything unusual on the weekly report sheet.

Each spring the arresters are overhauled to make sure that they are in good condition for their "busy season." The cone stacks are removed from their tanks and each cell is tested to ascertain the condition of the film. Any cell not showing up well on this test is marked and inspected when taking down the stack. A few of the top cones are taken off and inspected even if they show up well in the test, as these cones are the most worn and are a good index of the condition of the remainder of the stack. Any pitted or punctured cones are rejected. It is best to replace those rejected with used cones instead of new ones, but if it is necessary to use new cones, they should be placed at the top of the stack.

The instructions of the manufacturers are carefully followed in the reconstruction of badly damaged arresters. In forming difficult films, care is taken not to apply the voltage long enough to heat the electrolyte.

Considerable time was required at some of the stations to get the proper voltage for forming the films, as long runs of wiring would have to be made to get to a 220-volt circuit.

To more readily obtain a suitable forming voltage, a portable outfit was devised, consisting of a standard 110 to 330-363-440-volt 200-watt potential transformer mounted in a box with resistance and two indicating lamps. Connections were provided for a voltmeter and an ammeter with short-circuiting key. Fig. 3 is a diagram of the outfit. As there was no 250 to 270-volt tap on a standard transformer, it was necessary to so connect the coils that the primary voltage bucked the secondary voltage from 363 to about 253 volts, assuming a 110-volt supply. An ammeter with a one-ampere scale is used to read the current and the short-circuiting key is provided to avoid damage to the ammeter by the first rush of current.

The procedure in forming a cell is to insert the contact plug between the edges of the cones and watch the lamps die down as the film forms, then press the key and read the charging current on the ammeter. This method allows the use of the one-ampere ammeter, which forms a part of every charging current indicator. The source of current may be any convenient alternating-current lamp socket, as five amperes is the maximum current taken from the circuit. This film-forming outfit may be used without the ammeter and voltmeter by observing the lamps die down as the film forms. Fig. 4 is a photograph of the outfit.

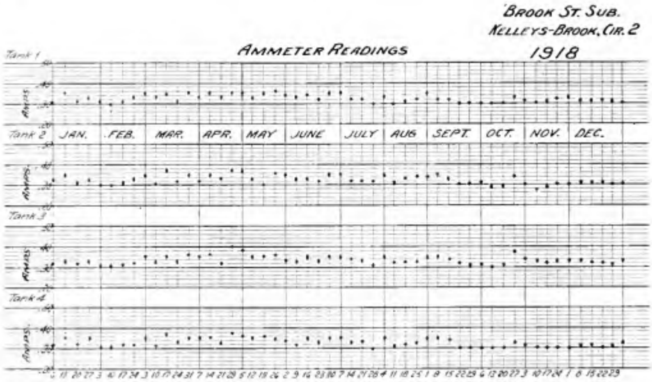

Fig. 2. Sample Report Card of Lightning Arrester Charging Current plotted weekly in the Electrical Engineer's Office from the Report Sheets, Fig. 1

In adjusting the spheres and horn gaps, gage blocks are used. Two of these are shown in Fig. 7. Gage block "a" is for horn gaps for 33,000-volt and 11,000-volt arresters. Each step is plainly marked with voltage rating of the arrester and "upper" and "lower" gap. Gage block "b" is for 33,000-volt sphere-gap and 11,000-volt horn-gap arresters. Here the upper sphere gap is adjusted to the thickness

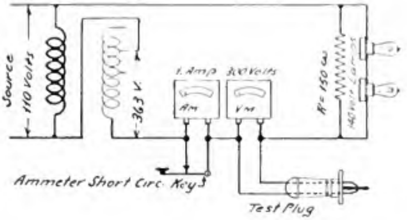

Fig. 3. Wiring Diagram of Film Forming Outfit shown in Fig. 4

Fig. 4. Portable Outfit with Indicating Devices for Forming Films on Lightning Arrester Cones

of the block. The lower sphere gap is the largest step and the horn gap is the second step. The smaller steps are for the 11,000-volt arrester.

Proper safeguards are provided for the men when working on the arresters. As all the circuits are in duplicate and each circuit i capable of carrying the whole load between the stations, the circuit is killed and grounded and short-circuited at both ends and the disconnecting switches are opened so that any possible error in switching will not endanger the men. Figs. 5 and 6 show the grounding devices employed. When the line is alive, the ground wire serves as a guard wire for the roof entrance wires and also as a support for ground sticks when not in use.

Any company using electrolytic arresters could well afford the slight expense in making such records and inspections.

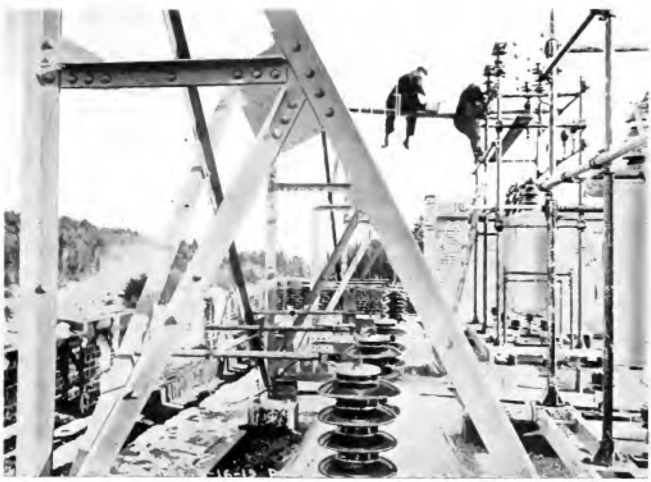

Fig. 5. Roof of One of the Manchester Traction, Light & Power Company's Stations showing Aluminum Cell Lightning Arresters and Entrance Bushings with Lines Grounded by the Grounding Sticks shown in Fig. 6

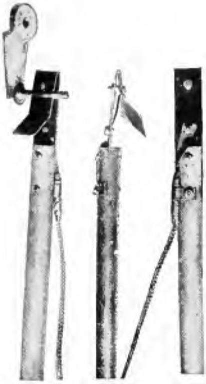

Fig. 6. Near View of Grounding Sticks showing the Method of Attachment

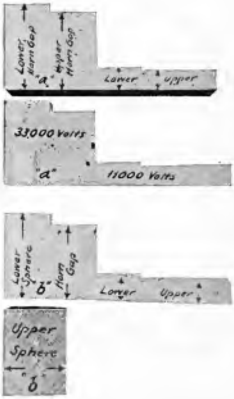

Fig. 7. Gauges used for Conveniently Setting and Checking the Setting of the Lightning Arrester Horn and Sphere Gaps

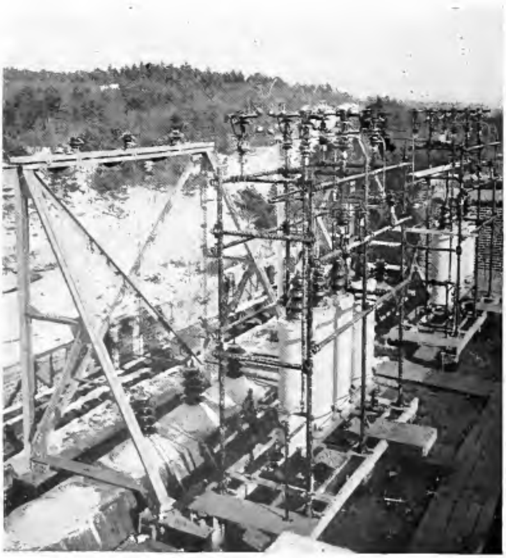

Fig. 8. Another View of the Roof shown in Fig. 5. The Lightning Arrester, Horn and Sphere Gaps, and Sticks Grounding the Lines at the Entrance Bushings are Clearly Visible

Prolongation of Life of Tribolium Confusum Apparently Due to Small Doses of X-rays

By Wheeler P. Davey

Research Laboratory, General Electric Company

"The days of our years are three score years and ten; and if by reason of strength they be fourscore years, yet is their strength labour and sorrow; for it is soon cut off, and we fly away." 90th Psalm. For ages, perpetual youth has been the dream of mankind, and the efforts to reach beyond the allotted span of "three score years and ten" have been many. It is, of course, self-evident that the results recorded in this article can not be applied directly to any other form of life without prolonged experimentation. It is too much to hope that we, or even our children's children, will learn how to prolong human life in this way. But it is surely a long step forward to be able to prolong the life of even a tiny grain pest like tribolium confusum.—Editor.

In a previous article* by the author experiments were described which showed: first, that X-rays when given in sufficient quantity were able to shorten the life of tribolium confusum; and second, that the length of life after X-raying could be expressed by a mathematical formula, the theoretical derivation of which was given. It is the purpose of this article to give the results of further experiments showing that it is apparently possible to materially lengthen the life of these same organisms by giving sufficiently small doses of X-rays.

In the article referred to, curves were given showing that the minimum dose necessary to kill *all* the beetles was $500 \frac{MAM}{25^2}$ at 50 kv.† Some of the less resistant beetles could be killed by smaller doses, but the curves for 100 and $200 \frac{MAM}{25^2}$ at 50 kv. had portions in which the death rate was lower than that of the controls. Comment on this was reserved until it could be confirmed by further experiments. Ample confirmation has now been obtained.

The experiments undertaken fall into two groups: those in which very small doses of X-rays were given daily throughout the life of the beetles; and those in which the X-ray dose was given all at one time, as in the work previously published. In each of these groups of experiments it has been shown possible to duplicate results time after time, subject only to those general limitations which are inseparable from biological work. Typical experiments in each group will be described in the following. The apparatus and technique were the same as in the work previously reported.

Experiment A: Prolongation of Life Due to Small Daily Doses of X-rays

Six groups of approximately 950 individuals each were taken. These were known as groups *IV*, *IW*, *IX*, *IY*, *IZ*, and *JA*.

Group *IV* was the control.

IW was given $6\frac{1}{4} \frac{MAM}{25^2}$ at 50 kv., 25 ma. daily.

IX was given $12\frac{1}{2} \frac{MAM}{25^2}$ at 50 kv., 25 ma. daily.

IY was given $25 \frac{MAM}{25^2}$ at 50 kv., 25 ma. daily.

IZ was given $50 \frac{MAM}{25^2}$ at 50 kv., 25 ma. daily.

JA was given $100 \frac{MAM}{25^2}$ at 50 kv., 25 ma. daily.

After 159 days the beetles were practically all dead. The data on the death rates were then collected and plotted as shown in Fig. 1. These graphs furnish ample proof that it is possible to reduce the death rate of tribolium confusum by small daily doses of X-rays.

Table I gives readings from these graphs to the nearest whole number. These readings, taken from the smooth curves of the graphs, do not differ from the actual experimental data by more than one per cent.

Except while being X-rayed or counted, the beetles were kept in an incubator at 34–35 deg. C. In order to make sure that the results were not affected by some possible "temperature co-efficient of life,"‡ the con-

* "Effect of X-rays on the Length of Life of Tribolium Confusum," *General Electric Review*, Feb. 1917, p. 174.

† *i.e.*, 500 milliampere-minutes at 25 cm. distance at 50 "root-mean-square" kilovolts.

‡ Loeb & Northrup, Proc. Nat. Acad. Sci., Aug. 1916.

trols were taken out of the incubator while group *JA* was being rayed, and were kept out during the whole raying. Since group *JA* was rayed the longest time each day, this meant that the controls were cooled off for a

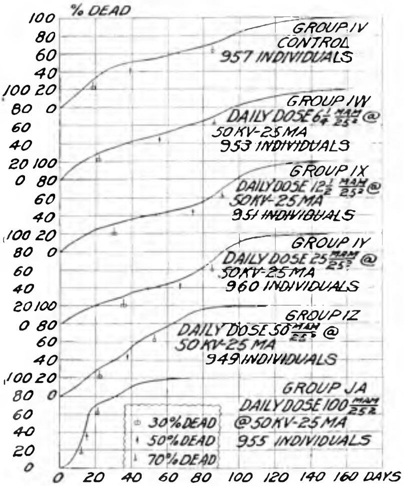

Fig. 1

longer time than groups *IW*, *IX*, *IY*, *IZ*. Therefore, if cooling off for a few minutes each day happened to tend to increase the length of life, then the controls were made to live longer than they otherwise would. The actual increase in length of life observed in groups *IW*, *IX* and *IY* is, therefore, not due to any possible effect of temperature, but occurs in spite of it. After so many boxes of beetles in *JA* were dead that the time of raying group *IZ* was greater than the time of raying *JA*, the controls were kept out of the incubator while group *IZ* was being rayed.

Some data not given in the graphs may be of additional interest. Each group was divided into two sub-groups of about the same number of individuals each. It was found that the idiosyncrasy was great enough that the curves of the corresponding sub-groups could not be exactly superimposed. However, it was found that this idiosyncrasy was always less than the changes in death rate caused by X-rays. By way of illustration, Table II shows the percentage of beetles dead in each sub-group: on the day when 50 per cent of the controls were dead, and on the day when 50 per cent of the X-rayed group were dead. This table shows that the *lowest death rate among the controls* (group *IV*) was higher than the *highest death rate among the beetles of groups IW, IX, IY*.

It is interesting to note in this connection that the *total* dose received by these beetles was greatly in excess of that minimum dose which, when given all at once, would have caused premature death.

A further analysis of the data of groups *IV* to *JA* will be of interest. The curves shown in Fig. 1 when re-plotted on probability paper* appear as shown in Fig. 2. It

* The ordinates of probability paper are so spaced that the ordinary curve of the probability integral is represented by a straight line.

TABLE I

Number Days after Raying	Per Cent Dead Group *IV* Control	Per Cent Dead Group *IW* $6\frac{1}{4}\frac{MAM}{25^2}$ at 50 kv. Daily	Per Cent Dead Group *IX* $12\frac{1}{2}\frac{MAM}{25^2}$ at 50 kv. Daily	Per Cent Dead Group *IY* $25\frac{MAM}{25^2}$ at 50 kv. Daily	Per Cent Dead Group *IZ* $50\frac{MAM}{25^2}$ at 50 kv. Daily	Per Cent Dead Group *JA* $100\frac{MAM}{25^2}$ at 50 kv. Daily
10	17	17	14	11	12	20
20	34	29	25	21	28	69
30	46	35	30	28	39	79
40	51	42	36	34	55	90
50	54	47	40	39	67	96
60	58	53	44	44	77	99
70	63	59	48	52	88	100
80	67	65	56	63	96	
90	74	74	69	79	98	
100	84	83	84	91	99	

was found that each curve was composed of portions of three accurate probability curves joined end to end. It is as though there were three causes of death, or perhaps three definite groups of ages. These three portions of the death-rate curve will be termed *A*, *B*, and *C*. Portion *C* represents those beetles which lived the longest in their group.

Table III gives the death rate per 100 in each group for *A*, *B*, and *C*.

TABLE II

PER CENT TRIBOLIUM CONFUSUM DEAD

Group	Approx. 50 per cent controls dead		Approx. 50 per cent x-rayed beetles dead	
	Sub-group (1)	Sub-group (2)	Sub-group (1)	Sub-group (2)
	39th day		56th day	
IV	47.7	54.2	52.8	60.0
IW	41.6	42.1	48.1	52.3
	39th day		74th day	
IV	47.7	54.2	59.9	70.3
IX	32.4	38.3	44.7	54.1
	39th day		67th day	
IV	47.7	54.2	58.6	68.2
IY	31.7	36.7	48.5	50.2
	39th day		38th day	
IV	47.7	54.2	46.8	53.4
IZ	52.9	54.5	50.1	52.4
	39th day		14th day	
IV	47.7	54.2	22.1	24.9
JA	88.5	91.7	43.7	46.8

TABLE III

Group	Daily Dose	Per Cent Which Died of "*A*"	Per Cent Which Died of "*B*"	Per Cent Which Died of "*C*"
IV	Control	44	26	30
IW	$6\frac{1}{4}$	32	36	32
IX	$12\frac{1}{2}$	26	26	48
IY	25	21	35	44
IZ	50	23	61	16
JA	100	64	17	19

Fig 2

It is evident that the smallest daily dose (group *IH*) decreases the death rate of "*A*" and that those beetles which are kept from dying of "*A*," die of "*B*." Deaths from cause "*C*" are practically unaltered. A larger daily dose (group *IX*) causes about half of those which would normally die of "*A*" to die of "*C*." A still larger daily dose (group *IY*) causes half of those which would have died of "*A*" to die of "*B*" and "*C*." A still larger daily dose (group *IZ*) acts much

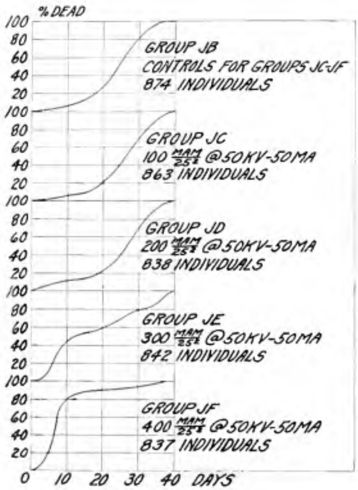

Fig. 3

like the previous dose in causing almost half of those which would have died of "*A*" to die of "*B*," but it differs from it in that some of those which would have died of "*C*" are prematurely killed. The largest daily dose employed (group *JA*) caused about a third of those which would have died of "*B*" and "*C*" to die of "*A*."

It is hard to interpret all this. It may be that life cannot exist except in the presence of a small amount of radioactivity. The radioactivity of the earth may not have been of the optimum value, so that some benefit was derived from the X-rays received each day. The following is an effort at an alternative explanation. The evidence given by group *JA* shows that the lethal action of X-rays is tied up in some way with cause of death "*A*." It is well known that the lethal action of X-rays is more marked on cells in the process of division than on those in the resting state. Therefore, small daily doses (larger than a certain minimal value) can kill off those few cells which happen to be in a state of division at the time of raying. The death of these few cells stimulates the production of more to take their places between the periods of raying. Therefore small daily doses, instead of increasing the death rate from cause "*A*," actually *decrease* it by stimulating the processes of repair. The whole individual beetle, therefore, has a smaller chance of dying from "*A*" and is compelled to die of either "*B*" or "*C*." When the daily dose is increased to such a value that the daily destruction of cells is equal to or greater than the production of new cells, premature death occurs, from causes "B" or "*A*" (see groups *IZ* and *JA*).

Experiment B: Prolongation of Life Due to Small Single Doses of X-rays

Five groups of approximately 850 individuals each were taken. These were known as groups *JB*, *JC*, *JD*, *JE* and *JF*.

Group *JB* was the control.

JC was given 100 $\frac{MAM}{25^2}$ at 50 kv., 50 ma.

JD was given 200 $\frac{MAM}{25^2}$ at 50 kv., 50 ma.

JE was given 300 $\frac{MAM}{25^2}$ at 50 kv., 50 ma.

JF was given 400 $\frac{MAM}{25^2}$ at 50 kv., 50 ma.

The beetles were rather old, so that the controls were all dead on the 40th day of the experiment. There were so few beetles still alive after the 35th day that the results of the last five days are not of the same order of accuracy as those of the first 35 days.

During the first 10 days of the experiment, group JC (100 $\frac{MAM}{25^2}$ at 50 kv.) had the same death rate as the controls. After the tenth day the death rate was considerably less than that of the controls. The two groups were divided into two equal sub-groups and although it was found that the idiosyncrasy was such that the sub-groups were not exactly alike, still, after the tenth day, the highest death rate of group JC was lower than the lowest death rate of the controls.

During the first 17 days of the experiment, group *JD* (200 $\frac{M.A.M}{25^2}$ at 50 kv.) had a higher death rate than the controls. After the 17th day, the death rate of group *JD* was less than that of the controls. After the 20th day, the death rate of *JD* was identical with that of *JC*. When divided into two equal sub-groups as described above, it was found that after the 22nd day the highest death rate of group *JD* was less than the lowest death rate of the controls.

During the first 29 days of the experiment, the death rate of group *JE* (300 $\frac{M.A.M}{25^2}$ at 50 kv.) was greater than that of the controls. After the 29th day, the death rate of *JE* was less than that of the controls.

The death rate of group *JF* (400 $\frac{M.A.M}{25^2}$ at 50 kv.) was at all times greater than that of the controls.

These results are shown graphically in Fig. 3. Fig. 4 contains an analysis of these same curves by means of probability paper, showing that, as in the case of experiment *A*, the curves are composed of accurate portions of probability curves placed end to end.

All of the foregoing results seem to be a direct confirmation of the curves given in the previous paper (loc. cit.). The effect of concentrated single doses is not nearly so marked as the effect of a series of small "homeopathic" doses. This seems to be much the same law as is already well known in serum therapy and in the action of certain drugs. In the case of serum therapy, this law has been shown to be identical with the law of absorption. If it could be rigorously shown that the effects of exposure to X-rays follow the same general law, we should conclude that the X-rays are responsible for the production of some substance, perhaps in the blood, which is later absorbed.

Summary

(1) It has been shown that the life of tribolium confusum may be prolonged by the use of a purely physical agent; i.e., X-rays.

(2) The prolongation of life due to a series of small daily doses is greater than that of larger doses given all at once.

(3) The lethal effect of an X-ray dose is less if it is split up into a series of small daily doses, than if it is given all at once.

(4) A method of graphical [illegible] results has been described by which [illegible] number of causes of death may be [illegible] from the death rates, and by which [illegible] of an external agent upon each of these may be studied.

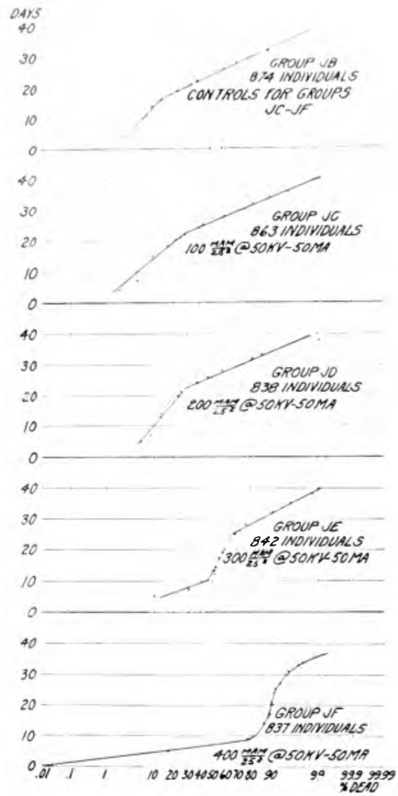

Fig. 4

(5) Using the same kind of organism throughout the whole experiment, the work reported in this and the previous paper (loc. cit.) has shown that, by merely varying the size of the dose, a purely physical agent (X-rays) may be made to produce at will (*a*) a stimulation, (*b*) a destructive effect which occurs only after a latent interval, and (*c*) an instant destructive effect.

Safety Rules for Men Handling Electrical Circuits or Apparatus

The safety rules published below are based on the long and vast experience acquired in the electrical field by the General Electric Company and have been thoughtfully and carefully prepared by that Company for its own employees. We do not feel, however, that the usefulness of these rules should be thus confined, and therefore publish them for their consideration and adoption by the electrical fraternity at large.—EDITOR.

Rules

These safety rules should be carefully read and studied. Employees may be called upon at any time to show their knowledge of the rules.

Warnings

Employees whose duties do not require them to approach or handle electrical equipment and lines should keep away from such equipment or lines.

They should cultivate the habit of being cautious, heed warning signs and signals, and always warn others when seen in danger near live equipment or lines.

Inexperienced Employees

No employee shall do work for which he is not properly qualified on or about live equipment or lines, except under the direct supervision of an experienced or properly qualified person.

If an employee is in doubt as to the proper performance of any work assigned, he should request instructions of foreman or other responsible person. *Don't take chances.*

Workmen whose employment incidentally brings them in the neighborhood of electrical supply equipment or lines, with the dangers of which they are not familiar, shall proceed with their work only when authorized. They shall be accompanied by a properly qualified and authorized person, whose instructions must be strictly obeyed.

Personal Caution

Employees about live equipment or lines should consider the effect of each act, and do nothing which may endanger themselves or others. Employees should be careful always to place themselves in a safe and secure position to avoid slipping, stumbling, or moving backward against live parts. The care exercised by others should not be relied on for protection.

Remember, personal caution is the greatest safeguard after all.

Clothing

Employees should wear suitable clothing while working on or about live equipment and lines. In particular, they should keep sleeves down and should avoid wearing unnecessary metal articles, celluloid collars, celluloid or metal cap visors or similar articles. Near live or moving parts loose clothing and shoes that slip easily on floors worked upon should not be worn.

Safety Devices

Safety devices provided to make the work less hazardous should always be used, but entire reliance should not be placed on them as any safety device may get out of order and become ineffective, therefore, such devices or tools should be first examined to make sure that they are suitable and in good condition.

Safety Belts

Employees should not work in elevated positions unless secured from falling by approved safety belts or by other adequate means.

Safety belts, whether owned by the Company or by the individual workmen, should be periodically inspected.

Eye Protectors

Suitable eye protectors should be worn by men working where an electric arc may be drawn, with resultant flash to eyes.

Approved safety goggles should be worn to prevent injury by flying particles when chiseling concrete, stone or brick for the support of wiring devices or electrical apparatus.

Rubber Gloves

Rubber gloves should be used only in special cases, and care must be taken to see that they are in good condition.

Danger Signs

Approved danger signs must be placed at all points where men may accidentally come in contact with live wires, and should also be placed at suitable places when men are working overhead, to prevent passersby from injury from falling tools, etc. Danger signs should be removed when the danger is past.

Manholes

When a cover is removed from a manhole, the hole must be properly guarded by railing, danger sign or red flag. An additional man stationed at the opening is often advisable.

Ladders

No imperfect or defective ladders should be used. All ladders should be provided with approved non-slip shoes to prevent slipping. On cement, tile or iron floors, or other smooth surfaces a board should be placed under the non-slip shoes.

Tools

No imperfect or defective tool should be used.

The handles of tools should be covered with rubber tape to prevent slipping and to reduce the possibility of short circuits across them. Such taping, however, should not be relied upon for protection of workmen from shock. Heads of cold chisels, center punches, etc., should be occasionally dressed and not allowed to become mushroomed. Avoid the use of measuring tapes of metal or with metal woven into the fabric, also brass-bound rules and steel scales.

Rubber Shields

When working on poles carrying lines of a potential higher than 600 volts, wiremen may use rubber shields across the wires to protect themselves while working on a selected wire.

Insulating Stands

Employees must be properly insulated from the ground by a linoleum or rubber mat, insulated stool, wooden slat platform, or other suitable insulating material when working on circuits or operating high tension switches, especially the disconnecting lever type.

Circuits

No repairs, alterations or examinations requiring handling of live circuits above 750 volts should be made, except in case of urgent need, and only when under the personal supervision of the foreman. All voltages must be considered dangerous by wiremen. Even though the voltage may not be great enough to produce a fatal shock, it may cause serious consequences by throwing workman from ladder or other overhead position. Except in emergencies, no employee shall work alone on or near live circuits above 750 volts in wet weather or at night.

Circuits should be made dead whenever possible before work is begun. Dead circuits should be treated as if they were alive. This procedure develops a caution that [illegible] sometimes prevent an accident caused by another person's error.

When working on series lamps, employees should make sure that they are well insulated from the ground and that the current is off.

All circuits should be tagged or lettered so that they may be readily identified.

Whenever circuits are opened for repair, alterations or examination, the control switch should be locked open and where switch construction permits, it should be padlocked. The disconnecting switches or cutouts should also be opened as an additional safeguard against accidental closing of circuit. The workman responsible for having the circuit opened shall place on a controlling switch a tag bearing his name and a notice that the switch shall not be closed until the tag is removed. No person other than the workman tagging the switch shall be allowed to close such switch. Whenever it becomes necessary for the person tagging a switch to leave before the work is completed, as may be the case in a long job, he shall go to the switch accompanied by the man who is to assume the responsibility, and remove his tag; his successor shall then attach a similar tag to the switch.

Where it is not possible on account of conditions to tag open switches, the wires should be short-circuited and grounded between source of power and point where work is being done, and kept so until work is completed.

As an additional safeguard, circuits carrying 750 volts or over should be short-circuited and grounded even if the rules previously stated are observed.

Wiring

All wiring must be done in accordance with Underwriters' Rules, National Bureau of Standards or local ordinances. Wires carelessly installed are dangerous and often are the cause of short circuits and fires. Ends of wires should not be left exposed after cutting. If wires cannot be removed altogether the ends should be well insulated.

The insulation on a wire should not be trusted for protection from shock. While the insulation may look perfect it may have deteriorated from age or exposure so it cannot be relied on.

When tapping live insulated wires, insulation should be removed from only one wire at a time. A second wire should not be exposed until the first tap is made and the joint insulated.

Connections between wires must be well made, the wires bound and soldered and the joint carefully insulated. When wires are held in contact by means of screws, care must be taken to see that the screws are set down tight. A slight movement of the wire while setting down screws will tend to make the joint tight.

Grounding

Employees should assume that all circuits are grounded and insulate their bodies properly against all wires.

Frames of motors, switch boxes, transformers, etc., must be substantially grounded.

To avoid possible shock due to grounding when work is being done in damp places, extra precautions must be taken to insulate the body. This can generally be satisfactorily done by using a dry plank or board to stand on.

Operating Switches

Switches should be left wide open when in open position, and fully closed when in the closed position.

Switches should not be closed in a hesitating manner or by tapping the blades against the contacts to ascertain if the circuit is on, but should be closed in a firm, positive manner, using sufficient force to make full contact of blades. A switch should not be closed without full knowledge of the condition of the circuit.

Fuses and Cutouts

Fuses should be pulled or replaced, using insulated fuse pullers. The live end of the fuse should be pulled out first and when replacing fuses the live end should be put in last.

The puller shown in Fig. I is standard for 2500-volt porcelain fuse plugs.

Power Plant and Motor Attendants

Do not allow oil cans, tools, dusters or wiping cloths to catch in moving parts of machines. In passing any switchboard or machine in operation, do not touch it unnecessarily nor allow metal tools or other metal objects to touch the apparatus or its connections. Do not use iron or tin oil cans near field magnets. Use only oilers, dusters, or wipers with insulated handles in or about commutators, switches, switchboards or other electrical equipment.

Resuscitation

The prone pressure method of resuscitation should be used in all cases of electrical shock. This method should therefore be thoroughly understood by all men handling electrical circuits or apparatus. See instructions on page 487.

Observance of Rules

The above rules cover some of the duties and precautions for the protection of wiremen and electricans; they must be observed by all men handling electrical circuits or apparatus.

Additional special instructions not to interfere with these rules may be issued by each Works if required to cover special conditions.

If the rules are not clear or it appears necessary for any reason to violate any of them, the superintendent or foreman of the electrical department should be promptly consulted.

Fig. 1. Porcelain Fuse Plug and Puller

RESUSCITATION FROM ELECTRIC SHOCK

Follow These Instructions Even If Victim Appears Dead

I. Immediately Break the Circuit

With a single quick motion, free the victim from the current. Use any *dry non-conductor* (clothing, rope, board) to move either the victim or the wire. Beware of using metal or any moist material. While freeing the victim from the live conductor have every effort also made to shut off the current quickly.

II. Instantly Attend to the Victim's Breathing

1. As soon as the victim is clear of the conductor, rapidly feel with your finger in his mouth and throat and remove any foreign body (tobacco, false teeth, etc.). Then *begin artificial respiration at once*. Do not stop to loosen the victim's clothing now; *every moment of delay is serious*. Proceed as follows:

(a) Lay the subject on his belly, one arm extended directly overhead, the other arm bent at elbow and with the face resting on hand or forearm so that the nose and mouth are free for breathing (see Fig. 1). Let an assistant draw forward the subject's tongue.

(b) Kneel straddling the subject's thighs, and facing his head; rest the palms of your hands on the loins (on the muscles of the small of the back), with fingers spread over the lowest ribs, as in Fig. 1.

(c) With arms held straight, swing forward slowly so that the weight of your body is gradually, but *not violently*, brought to bear upon the subject (see Fig. 2). This act should take from two to three seconds.

(d) Then immediately swing backward so as to remove the pressure, thus returning to the position shown in Fig. 1.

(e) Repeat deliberately twelve to fifteen times a minute the swinging forward and back— a complete respiration in four or five seconds.

(f) As soon as this artificial respiration has been started, and while it is being continued, an assistant should loosen any tight clothing about the subject's neck, chest or waist.

2. Continue the artificial respiration (if necessary, two hours or longer), *without interruption*, until natural breathing is restored, or until a physician arrives. If natural breathing stops after being restored, use artificial respiration again.

3. *Do not give any liquid by mouth until the subject is fully conscious.*

4. Give the subject fresh air but keep him warm.

III. As Soon as Accident is Discovered

Notify *[Physician's name here.]*

Rules Recommended by

COMMISSION ON RESUSCITATION FROM ELECTRIC SHOCK

Representing the

The American Medical Association
The National Electric Light Association
The American Institute of Electrical Engineers

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Editor Electrical World

Adopted by

GENERAL ELECTRIC COMPANY

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Fig. 1

Fig. 2

NOTES

An accidental electric shock usually does not kill at once, but may only stun the victim and for a while stop his breathing.

The shock is not likely to be immediately fatal, because:

(a) The conductors may make only a brief and imperfect contact with the body.

(b) The skin, unless it is wet, offers high resistance to the current.

Hope of restoring the victim lies in prompt and continued use of artificial respiration. The reasons for this statement are:

(a) The body continuously depends on an exchange of air, as shown by the fact that we must breathe in and out about fifteen times a minute.

(b) If the body is not thus repeatedly supplied with air, suffocation occurs.

(c) Persons whose breathing has been stopped by electric shock have been reported restored after artificial respiration has been continued for approximately two hours.

The Schafer or "prone pressure" method of artificial respiration, slightly modified, is illustrated and described in the above resuscitation rules. The advantages of this method are:

(a) Easy performance; little muscular exertion is required.

(b) Larger ventilation of the lungs than by the supine method.

(c) Simplicity; the operator makes no complex motions and readily learns the method on first trial.

(d) No trouble from the tongue falling back into the air passage.

(e) No risk of injury to the liver or ribs if the method is executed with proper care.

Aid can be rendered best by one who has studied the rules and has learned them by practice on a volunteer subject.

IN MEMORIAM

Edwin D. Mullen, conspicuous in the development of the electrical industry in America and for many years an official of the General Electric Company, died, in Philadelphia, on April 5, 1919, at the advanced age of eighty-one.

Mr. Mullen began his career in the '60s as a clerk in what is now the National Bank of North America, at Philadelphia, and from this subordinate position he rose to be a successful banker, broker, merchant and manufacturer.

EDWIN D. MULLEN

He first became prominent in the electrical industry in 1884, or shortly prior thereto, when he accepted the position of General Manager of the Thomson-Houston Electric Light Company of Philadelphia. This company owned the exclusive rights to the Thomson-Houston patents in New Jersey, Pennsylvania, Delaware, Maryland and the District of Columbia. Mr. Mullen retained this position until 1892, when the Thomson-Houston Electric Light Company of Philadelphia was incorporated into the Pennsylvania General Electric Company, with the late Charles O. Baird as President. Mr. Baird prevailed upon Mr. Mullen to become the active commercial head of this organization, and from a nucleus of ten or twelve employees largely through Mr. Mullen's efforts a powerful organization was developed.

In 1894 Mr. Mullen was made Manager of the Philadelphia District of the General Electric Company, and occupied this position until 1916, when he was retired by the company, with recognition of his loyal and valuable services.

In the earlier years of the electrical industry the introduction of electric light and power required the building and financing of central stations, and from the first Mr. Mullen was deeply interested in these developments and distinguished himself by his broad policy and his ability to maintain the most amicable relations between these public service utilities and the people whom they served. His first undertaking of the kind was the establishment of a small arc lighting plant at Philadelphia, which afterwards became the Philadelphia Arc Lighting Company, one of the largest underlying corporations of the Philadelphia Electric Company.

Many other important enterprises were created and financed by Mr. Mullen, among which were the Hudson Electric Light Company, Hoboken, N. J.; Thomson-Houston Electric Co., Newark, N. J.; New Jersey Electric Light Company, Bridgeton; New Jersey Electric Light Company, Long Branch; Pennsylvania Electric Company, Bloomsburg; Pennsylvania Electric Light Company, Milton, and the Pennsylvania Electric Company, Germantown.

Mr. Mullen's personality was forceful and ingratiating, and his charm of manner impressed all with whom he came in contact. A prominent characteristic was his great love for his family. His charities and practical assistance to others were frequent and extensive. The esteem in which he was held by a host of friends and acquaintances is indicated by this expression from one of his oldest business associates:

"I have had a very busy life myself, a very active life, and in my many years I have done business with thousands of men, but I have no hesitancy in saying that of the thousands I have known, of the thousands I have done business with, none has measured up to the standard of manhood which E. D. Mullen established when young, and which he steadfastly, unflinchingly adhered to throughout his career."