GENERAL ELECTRIC REVIEW

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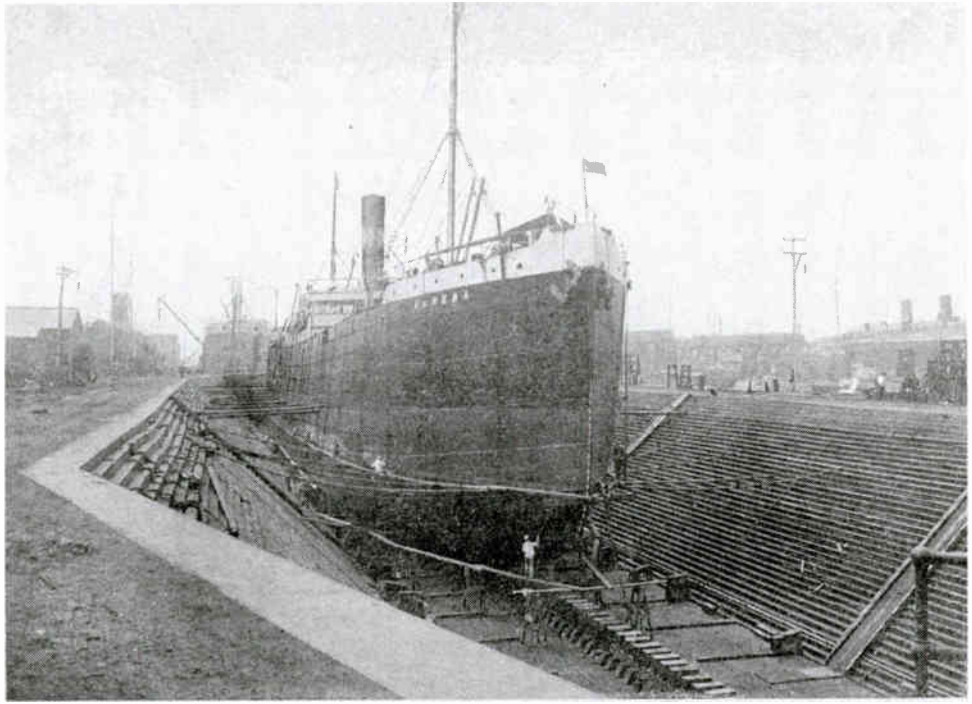


A Dry Dock of the John N. Robins Company, Erie Basin, Brooklyn
(See Page 513)

GENERAL ELECTRIC REVIEW

THE OSCILLOGRAPH

In order to properly design electrical apparatus, or, in fact, apparatus of any variety, the first essential is a knowledge of the phenomena in connection with which the apparatus is to operate. In the case of electrical phenomena, however, the acquisition of this knowledge has been fraught with difficulties, on account of the exceeding rapidity with which the phenomena vary. Thus no ordinary voltmeter, ammeter or galvanometer is capable of following the wave of a rapidly varying electric current or pressure and recording the wave form or making it observable, the inertia of the moving parts rendering their movements too sluggish.

The need of some satisfactory means of accomplishing such results was early recognized and a number of different instruments were invented with this end in view. These instruments were of two classes; in the first, which could be employed only with recurrent phenomena, no attempt was made to have a moving element keep pace with the variations of the phenomena, but during the repetitions deflections were obtained indicating the successive values, the curve being either automatically drawn by means of these deflections or plotted later from the resulting data. This "point by point" method was first described by Joubert in 1880; it is the method employed in the Hospitalier's ondograph, Rosa's curve tracer and the General Electric wave meter.*

Obviously the use of these instruments is restricted to those phenomena that are many times repeated; they cannot, of course, cope with so called transient phenomena; for this purpose recourse must be had to the second, or *continuous*, class of instruments—those containing a moving element having a natural period short enough to enable the element to keep pace with the variations of the phenomena examined. The first instrument of this class was devised by Prof. Elihu Thomson in 1881, and was followed by a number of others; and though none of these were adequate to modern practical requirements they were the forerunners of the present oscillograph.

This instrument—which is to electrical apparatus what the indicator is to the steam engine—was first described by Blandel in the *Comptes Rendus*, April, 1893. In its modern design it is made in two forms, the vibrating iron strip and the vibrating loop type. The latter, which is the form most frequently used, consists, fundamentally, of a pair of fine silver wires or ribbons stretched at considerable tension and placed between the pole pieces of a powerful electromagnet, the ribbons carrying a minute mirror on which a beam of light is directed. The current to be investigated is passed through these ribbons, which, due to the field in which they are placed, are thus caused to twist. The beam of light from the mirror is in consequence deflected in proportion to the degree of torsion of the ribbons at every moment. The movements of the spot of light may be viewed by a revolving mirror, thus showing the wave form of the actuating current; or, it may be allowed to impinge upon a moving photographic film, in which case a permanent record of the wave is made.

In the second form of this instrument, the conducting vibrating loop is replaced by an iron band, which does not carry the current under examination—this being passed through two auxiliary coils which are placed on either side of the iron strip and cause it to twist.

In order that the oscillograph may meet the demands put upon it by modern engineering, the following characteristics are essential: The moving element must have a natural period that is relatively small as compared with the periods of the wave forms to be

*For detailed descriptions of these instruments, together with the different forms of the oscillograph, see paper by Louis T. Robinson, Trans. A.I.E.E., Vol. XXIV, p 185, *et seq.*

investigated; it must have critical damping; the instrument's self induction must be negligible; it must possess sufficient sensibility to respond to small currents; and, finally, the working parts must be accessible and susceptible of repair with ordinary care.

The article by Mr. Robinson in the present issue shows what advances have been made along these lines, and to what a degree of perfection the instrument has arrived. It has passed out of that class of laboratory instruments that on account of their delicacy are restricted to the use of experts and has taken its place among practical commercial instruments. Through its perfection an instrument of incalculable value has been placed at the command of engineers. In scope and the universality of its application it is like no other instrument, the investigations and tests for which it may be employed being almost endless in their variety.

WASHINGTON, BALTIMORE & ANNAPOLIS 1200 VOLT D.C. RAILWAY

In this issue we publish a somewhat extended account of the 1200 volt equipment of the Washington, Baltimore & Annapolis Railway, which has replaced the original 6600 volt alternating current equipment.

It is of interest to note that the weight of the present cars shows a reduction of about twenty tons each as compared with that of the older ones, and that the same schedule speed is being maintained as formerly, while the seating capacity has only been reduced from sixty-six persons per car to fifty-four. This reduction in weight, after allowing for the change in seating capacity, is due to the inherent differences in the alternating current and direct current equipments, and the consequent elimination of the transformers, etc.

The use of lighter cars has effected a reduction of forty per cent in the power bills, while the same service is maintained. The cost of power reduced to a ton mile basis shows that a saving of about ten per cent per ton mile is effected in favor of 1200 volts direct current.

Formerly the authorities would not permit the heavy cars to operate over the city tracks of Washington, owing to the insufficient strength of the yokes employed in the conduit system; it is only since the introduction of the new equipments that the interurban cars have been able to obtain running rights over the Washington city tracks. This has resulted in very material benefits to the Washington, Baltimore & Annapolis Railway Company.

The detailed description of the 1200 volt switchboards will be read with interest by all those who have been waiting to see what would become standard practice in this direction, while the satisfactory manner in which the two 600 volt rotary converters have been operating in series to give 1200 volts at the trolley will dispel the doubts of those who were looking for trouble in this direction.

That the change from alternating current to direct current was effected with no interruption to the traffic is a matter of satisfaction and congratulation to all parties concerned.

CATENARY LINE MATERIAL

Until within the past half dozen years, during which time rapid development has taken place in electric traction, the overhead equipment of electric roads was well nigh uniform—as indeed was trolley equipment in general, being almost universally supplied with direct current at 500 to 600 volts; but, with the growth of interurban traction and the employment of large cars operated at high speeds, the former overhead equipment was no longer adequate to meet the requirements of the new service.

Among other things, the unequal elevation of the trolley wire at the center of spans and points of support introduced difficulties in current collection that were not manifested at the lesser speeds formerly employed. To meet this difficulty, the catenary type of construction was introduced, this being briefly a method of suspending the trolley wire in such a manner as to practically eliminate the sag. For this purpose, a cable or wire, called a messenger, is strung above the trolley wire. This cable hangs in a catenary curve, and from it, the trolley wire is hung at frequent intervals by means of hangers which are made of such varying lengths as to support the trolley wire as nearly horizontal as possible. In this way the sag, which is objectionable in the trolley wire, is transferred to the messenger cable where it can do no harm.

The article by Mr. Hoffman in this number discusses the various advantages and disadvantages of catenary suspension, and includes a valuable table giving the relative costs of the catenary and direct suspension construction.

THE OSCILLOGRAPH

By L. T. Robinson

General Electric Standardizing Laboratory

The oscillograph is no longer an experiment, or even a device that would be exhibited of itself as having any special interest. In the hands of a number of investigators it is already a standard instrument for every day use and is doing its daily work with accuracy, reliability and satisfactory speed.

The difficulties which for a time existed in connection with the successful repair and renewal of the various delicate parts of the instrument have practically been overcome and the instruments are now supplied in such form that they can be successfully handled and repaired by any one who possesses ordinary skill in the handling of instruments in general.

The oscillograph has been found useful in connection with viewing and recording waves of current, potential, and magnetic flux, as well as for investigating a great variety of transient phenomena such as the rise and fall of current in a circuit when a short circuit is made through a fuse, rise of voltage when opening the field of a direct current generator, the form of current wave or the wave of voltage on either side of rectifying apparatus, the waves in ignition circuits in gas engines both with magnetos and batteries, etc., etc.

The alternating current wave in telephone circuits can also be shown, as well as other waves of a similar nature which, by means of auxiliary apparatus, can be reduced to current or potential waves in an electrical circuit.

Various occurrences in connection with transmission lines during switching, or when disturbances are caused by lightning, have been successfully investigated by means of this instrument.

These are only a few of the many things that can be studied with the aid of the oscillograph; to make it quite plain what

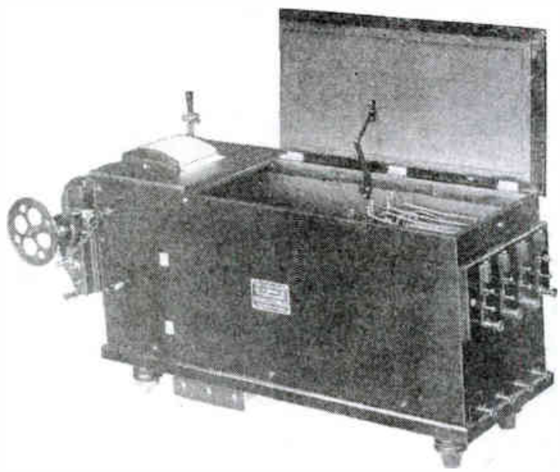


Fig. 1. Oscillograph in Case

can be done with the instrument, the period, sensibility, etc., that can be given to commercial instruments will be spoken of somewhat in detail.

The vibrating strip type of oscillograph with field supplied by an electro-magnet has a free period of oscillation of the moving system of about $\frac{1}{3000}$ of a second. With this period the resistance of the working element is, approximately, 1¼ ohms, and with the standard arrangement of parts gives a deflection of 1 mm. with from 0.005 to 0.007 ampere.

A reasonably large record of a wave—one that would be of suitable size for examination or analysis—would extend for 20 mm. on each side of the zero line, and would require a current of 1/10 to 1/7 of an ampere, or 12½ to 17 or 18 milli-watts of energy.

It is also possible to reduce the total resistance of the moving system to ¼ ohm and yet retain precisely the same characteristics of the moving element, as far as frequency, current sensibility, etc., are concerned. When these low resistance vibrators are employed, the only disadvantage which accompanies their use is that a little more time is required in restraining the vibrators, because the conductors leading into the

Fig. 2. Vibrator

moving strips must be attached by soldering near the bridges instead of to the ends of the strips as in standard arrangements. When the low resistance vibrator is used the energy consumed in a vibrator is reduced to 2½ to 3½ milli-watts.

The vibrators may be energized from shunts when larger currents are to be measured, and series resistances up to any required amount may be included in series with the vibrators when it is necessary to measure voltages of large value.

Current and potential transformers may also be made use of to extend the range of the instruments. If the requirements of the investigation demand the measurement of currents much smaller than those which may be directly measured by the vibrator, small current transformers may be made use of to step up the current before it is passed through the vibrators; remembering, of course, that the total energy required is not reduced below the 2½ to 3½ milli-watts that would be required for direct operation, but is slightly increased to the extent of the losses in the small transformers used. The amount of energy required may be more than that which is available in some places where oscillograph records would be of interest, but on the other hand it is not generally appreciated that the energy required for successful operation is as small as it is.

The standard arrangement of the oscillograph comprises a method for viewing waves as well as for photographing them on a drum around which a strip of sensitized film has been placed.

In general the viewing arrangements are not useful except in connection with phenomena which are repeated indefinitely at regular intervals in phase with some alternating current supply which may be used to operate the small synchronous motor that rocks the mirror to give the abscissæ on the viewing screen. Arrangements are provided whereby this viewing apparatus can be quickly removed from the path of the beam and the apparatus for making the photographic record brought into use.

In certain special investigations it may be desirable to use a long film drawn continuously in front of the light spot to receive the record, or an arrangement whereby a large drum could carry several feet of film. The usual length of film employed is one foot and this has come so near to satisfying all requirements that no other standard arrangement has been built. The film may be exposed for one revolution, beginning at the joint in the film, or instantly after one revolution, starting at any place.

The films may be rotated at a speed as high as 1200 feet per minute, it being quite

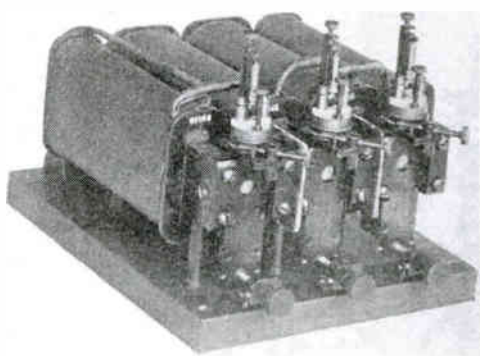


Fig. 3. Oscillograph Galvanometer

possible to obtain a satisfactory record of an irregular wave of 30 or 35 mm. amplitude each side of zero at this speed.

There is no question but that many investigations demand a much higher period than can be commercially obtained in the vibrating-strip type of oscillograph. Several attempts have been made to obtain this higher period in other designs—notably that in which the moving system consists of a vibrating band of iron. In this type, periods as high as 50,000 a second have been recorded. The highest period that could be called possible with the vibrating strip type is approximately 10,000 a second, and the dimensions of the parts, even at this frequency, would certainly be so small that the handling of the instrument would not be convenient. However, this apparent advantage in periods which may be secured by means of the single vibrating iron strip is generally of no practical advantage, because the field necessary to deflect a strip is considerable and must be produced by inductive windings through which the current to be investigated must be made to pass. The difficulty is that a current having a frequency high enough to require such a small period in the moving system could not well be passed through the inductive winding of such an oscillograph.

Fig. 4. Film Holder

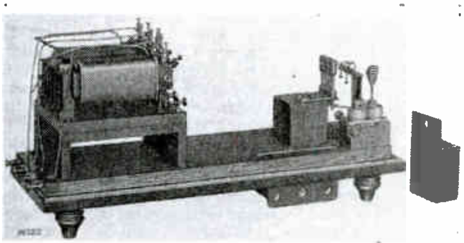


Fig. 5. Internal Arrangement of Oscillograph

It is also well to call attention to the fact that the period of the moving system and the speed at which the film can be operated are usually not the limiting features in obtaining photographic records. At the present time the limitations of oscillograph records at high speed and high frequency are found in the intensity of light which it is possible to get through any optical system, and the ability of any film to record the passage of the light spot. Careful attention to the details of the arc lamp and to the adjustment of all the parts in the light path will give a good record under the most severe conditions, but at the present time the question of light may be considered to be the limiting feature. In this connection the arc lamp may be briefly mentioned. Experiments have definitely shown that a large arc is not better than a small one for the purpose. For this reason the present practice is to use an 8 or 10 ampere partially enclosed arc regulated by hand. Automatically regulated, 25 or 30 ampere arc lamps have been used and still find some advocates, but there is no doubt that there is a general tendency to favor the hand-fed lamp of small ampere capacity. The latter is less expensive to operate, gives as good results as the automatic lamp when the latter is at its best, and the little attention required to feed the lamp by hand as the records are made is more than compensated for by the fact that any automatic lamp will sometimes regulate poorly, causing failure to get a proper record when the test can not be conveniently repeated.

With regard to the range of frequency that can be accurately taken care of with the oscillograph, experiments on machines of comparatively high frequency have shown that it can respond with accuracy to a frequency of about one-half that of the free period of the undamped vibrator. This means that with the ordinary standard type of instrument frequencies as high as 3000 may be recorded;

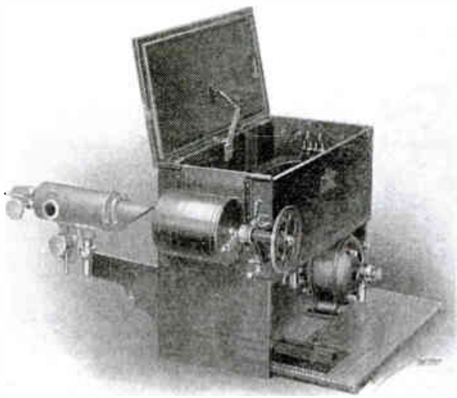


Fig. 6. Permanent Magnet Oscillograph

if, however, such a current or voltage has harmonics they will not be accurately recorded, but will usually be indicated up to the third and may be to the fifth harmonic, provided that these harmonics are quite prominent in the true wave. To obtain accurate measurements of the higher harmonics they should, of course, be regarded as the true frequency of the circuit. For example, on a 60 cycle circuit an ordinary vibrator should record correctly as high as the 40th or 51st harmonic, which, of course, is beyond what would usually be of interest. With the same degree of exactness, the 5th harmonic of a 600 cycle circuit could be recorded. As the recording of a 600 cycle wave at the highest film speed that can conveniently be obtained, namely, 20 feet per second, gives 2½ complete waves for every inch of the film, it may be seen that 600 cycles is about the limit in fundamental frequency that can be recorded where the form of the wave must be accurately known. At this point the mechanical limitations to the film speed, the free period which can be given to the vibrator, and the speed at which the photographic impression can be obtained are all fairly well in accord. If the speed of photographic impression could be materially increased there is every reason to believe that the other limiting features could be increased by a like amount.

The insulation within the instrument allows of the employment of potentials as high as 2300 volts between vibrators, or between any vibrator and ground. If higher potentials are to be employed, some method must be used which limits the potential between vibrators to not more than 2300 volts. Conditions where high voltage circuits must be used may be met by employing instrument transformers, or under certain conditions high resistances may be included in the vibrators, the whole instrument being near ground potential. It is also possible to insulate the whole instrument, together with a small storage battery for exciting the field from ground. This arrangement has been successfully employed in several cases.

In certain cases where it is difficult to insulate the exciting circuit of the electromagnetic field, and where there is no direct current available for field excitation, it has been found useful to provide oscillograph galvanometers with permanent magnets. These have been made with single vibrators and also with two vibrators, but the two-vibrator instrument can not have more than a few volts between the vibrating strip and the frame, or between the two moving elements. On account of the fact that the permanent magnet can not create as strong a field as that which can be obtained by means of the electromagnet, the sensitiveness is somewhat reduced in this form of instrument. The ampere sensibility is about 0.01 or 0.007, depending on whether two vibrators or one are included in the field of the permanent magnet. The resistance of the vibrator for the permanent type is the same as that for the electro-magnetic; in fact, the standard vibrators which are used in the electro-magnetic type may be used with the permanent magnet.

The galvanometer with permanent magnet may be arranged for use in the box provided

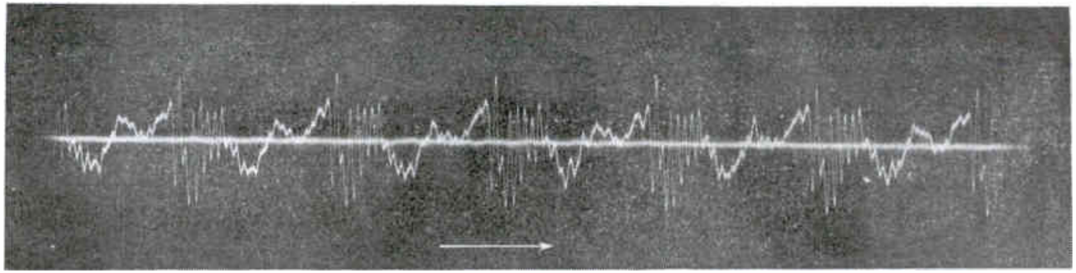


Fig. 7. Oscillograph Record of Current in Telephone Line Corresponding to Sustained Vowel Sound ("I," as in Machine); Voice Pitched at A 110
Above Record Shows About Six Cycles, Total Time Approximately .055 Seconds.

Record by John B. Taylor

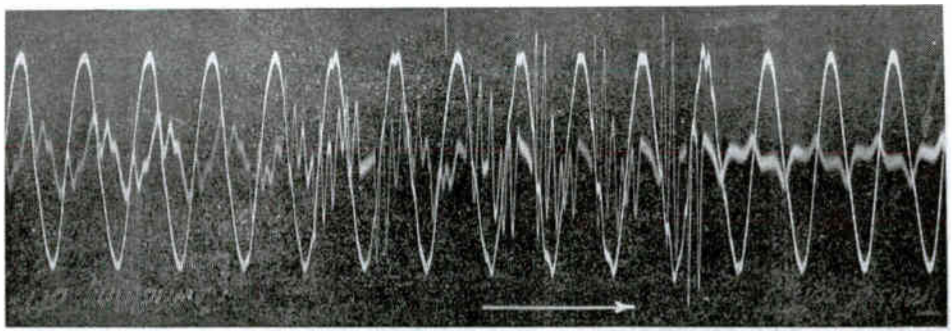


Fig. 8. Switching 100,000 Volt Line off Transformer, Showing Surge in Transformer. 25 Cycles

Record by G. Faccioli

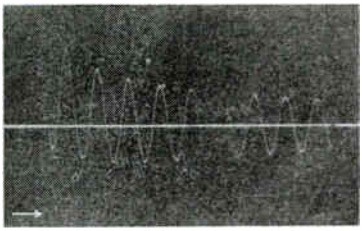


Fig. 9. First Rush of Current from an Alternator when Short Circuited, Showing Unsymmetrical Initial Wave of Current, Becoming Symmetrical after a Few Cycles. 25 Cycles

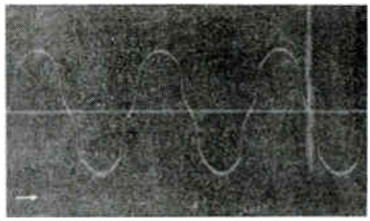


Fig. 10. Wave of Electromotive Force Obtained from Narrow Exploring Coil on Alternator Armature, Indicating Distribution of Field Flux. The Terminal Electromotive Force of the Alternator is Very Nearly a Sign Wave. 60 Cycles; About 17 Volts

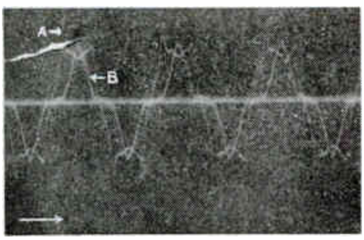


Fig. 11. The Waves of Voltage and Current of an Alternating Arc. (A) Voltage Wave; (B) Current Wave Showing Low Power Factor of the Arc without Apparent Phase Displacement. 60 Cycles

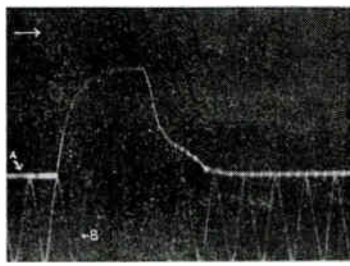


Fig. 12. Rupturing 650 Volt Circuit. (A) Current Wave, 60,000 Amperes Maximum; (B) 25 Cycle Wave to Mark Time Scale

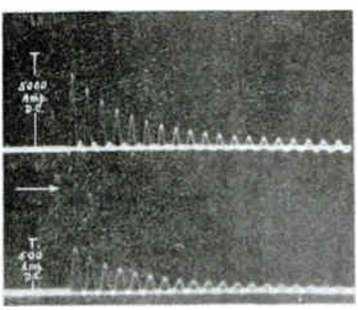


Fig. 13. First Rush of Current from Alternator when Short Circuited, Showing Unsymmetrical Current Wave as in Fig. 9: Also Wave of Field Current Caused by Short Circuit Current in Armature. Upper Curve, Armature Current; Lower Curve, Field Current

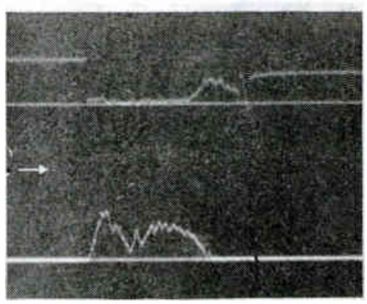


Fig. 14. Short Circuit Current on Direct Current End of Rotary Converter, 21,500 Amperes Maximum. Upper Curve, Direct Current Voltage; Lower Curve, Direct Current Amperes. Duration of Short Circuit About 1/10 Second

for the standard galvanometer with electro-magnet, and in this way may form part of the standard equipment. This would make the most complete kind of an outfit. The permanent magnet galvanometer is, however, usually assembled in a different box which has no synchronous viewing attachment, but which allows the wave to be viewed by means of rotating mirrors that can be turned by hand. The arc lamp for this outfit is made to pack in the box and the whole forms a semi-portable outfit which for some work is more convenient than the complete standard equipment. For laboratory use or for any sort of investigation work where a considerable variety of tests must be covered, the standard arrangement of box with electro-magnetic galvanometer will be found far more useful in its application.

As already stated, a construction for the moving part of the instrument that will admit of easy renewal and repair is very desirable. Reference to Fig. 2. will show that this feature has been very fully cared for, as there is a free space all around the vibrating strips and mirror on all sides, so that the mirrors can be readily attached to the strips or new strips put in place.

In most cases, the interpretation of results which have been recorded by the oscillograph requires definite knowledge of the manner in which the event recorded took place with reference to the time scale. It is usually most convenient to have this time scale read from left to right on any prints that are made, the direction of the time scale being indicated by an arrow, as shown in the records given. The practice should be avoided of having the arrow indicate the direction of the film in passing by the light spot or any other relative motion which may not be the same on all oscillographs and which might, under some circumstances, be different on a given instrument at different times.

It is also important when taking oscillograph records that are to be used for reproduction to use care in the adjustment of the optical system (the lamp, etc.) so that clear records may be obtained which may be reproduced as prints or halftones by direct process without being redrawn. It is usually possible to get negatives which will make good prints or reproductions and it is advisable at all times to use the necessary care to produce such negatives. If the record on the negative is drawn over before prints are made, a great deal of the original value of the record is destroyed. Aside from the fact that such doctored records usually do not appear well, it is seldom possible for any one to follow the line on a negative with ink without departing appreciably from the true path described by the light spot. This variation from absolute truth in the reproduced record may seem of no consequence to the person who is preparing the print, but the record of some important happening in connection with the test may be destroyed. Many phenomena of interest and value, that had no connection with the results which were being sought for, have been found to be clearly recorded on oscillograph films.

To illustrate the variety of work which can be done with the instrument the accompanying reproductions of records are given, together with a brief description of the conditions under which each was taken. These records, together with the detailed statements which have been made on the energy required to operate the instrument and the frequencies for which it is suitable, will give any one who is interested in the applications of the instrument a better idea of what may be done with it than could be had in any other way.

Fig. 15. Mazda (Tungsten) Lamp Showing Rapid Decrease to Normal Current as Filament Heats Up. 25 Cycles

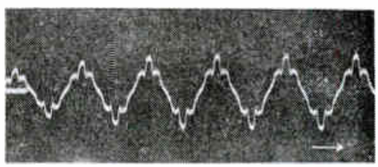


Fig. 16. Carbon Lamp, Showing Rapid Increase to Normal Current as Filament Heats Up. 25 Cycles

(The difference in wave form is due to the fact that the electromotive force waves of the machines on which the tests were made were different, and not to any action on the part of the lamps themselves.)

WASHINGTON, BALTIMORE & ANNAPOLIS 1200 VOLT D.C. RAILWAY

By John R. Hewett

The Washington, Baltimore & Annapolis Railway is of more than ordinary interest, both on the score of its having been converted from a 6600 volt single-phase to a 1200 volt direct current road, and on account of the class of service it is providing. The system comprises two divisions, the first consisting of a double track, high speed line connecting Washington, D. C., with Baltimore, Md. The plans for this portion of the system have been under consideration for a number of years, but the property only passed into the hands of the present company in 1905, and the work of electrification as a single-phase road was completed in two years from that date. The second portion of the system is a single track road connecting Annapolis Junction with Annapolis. The traffic to Annapolis is large, owing to the Naval Academy, which is one of the most important naval depots of the United States. This road was formerly known as the Annapolis, Washington & Baltimore Railway and was in operation as a steam road nearly eighty years ago. The equipment of this road is now similar to the double track road connecting Washington with Baltimore.

The map, Fig. 1, shows the route taken by both lines and also the location of the power house and substations.

Every detail of the road and its equipment has been designed with the view of giving a high class, high speed service. The city running necessarily takes up a disproportionate part of the running time, but the schedule on the interurban section, which is as high as 44 miles per hour, compensates for this and the run from terminal to terminal takes but 85

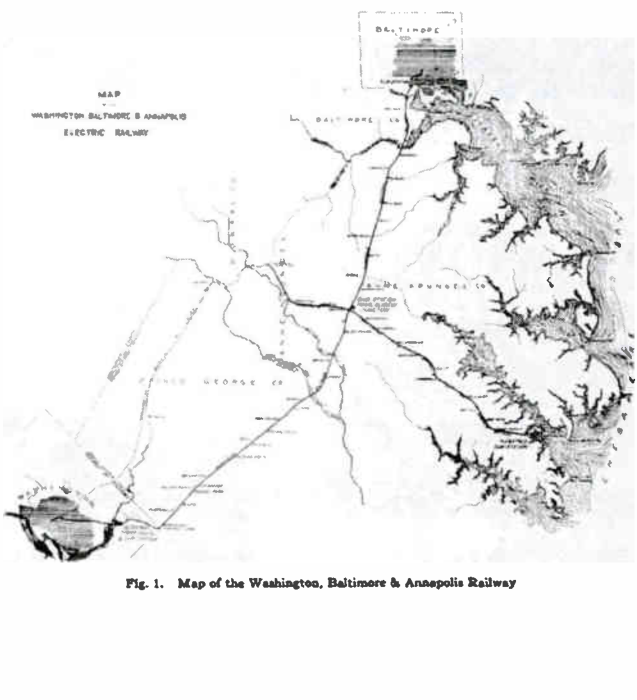


Fig. 1. Map of the Washington, Baltimore & Annapolis Railway

minutes. The steam road service between Washington and Baltimore is good, there being a very great number of trains per day, and it is therefore imperative that the electric lines should give an attractive schedule.

The electrical equipment of all the substations and cars was manufactured by the General Electric Company.

General Scheme of Electrification

Fig. 2 will give a good idea of the general scheme of electrification, and will also show the distances between the more important points.

The energy for operating the Washington, Baltimore & Annapolis Railway is generated by Curtis turbines in the Bennings power house of the Potomac Electric Power Company and is delivered to the Bennings substation at a potential of 6600 volts.

Figs. 3 and 4 respectively, are diagrams of the transmission lines and of the feeders and trolley. These together with the explanatory key to Fig. 2 render a written description in detail unnecessary.

Substations

There are five substations located at the following points: Ardmore, Naval Academy Junction, Baltimore, Annapolis and Bennings. The diagrams and map will show the relative positions of and the distances between these substations, as well as the manner in which they are connected electrically.

Bennings Substation

The function of the Bennings substation is to receive the power which is generated at the Potomac power house at 6600 volts, transform it to 33,000 volts, and distribute it at this potential to the duplicate transmission lines which feed the other substations of the Washington, Baltimore & Annapolis system. There are no 1200 volt feeders from this substation.

Ardmore Substation

The Ardmore substation is the only one which was

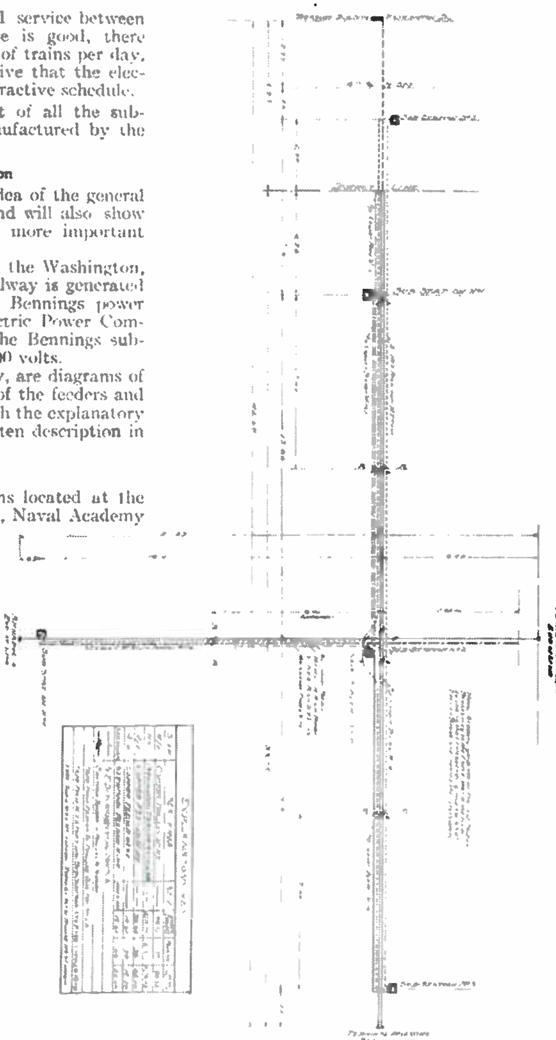


Fig. 2. Wiring Diagram of the Washington, Baltimore & Annapolis Railway

built for the 1200 volt system, the single-phase substations in each of the other cases having been altered to suit the new conditions.

This substation is a red brick structure and is divided into a machine room and a high tension compartment, the former containing the rotary converters, reactances and switchboard, and the latter the transformers, oil switches, lightning arresters, etc. Figs. 5 and 6 are interior views of these sections.

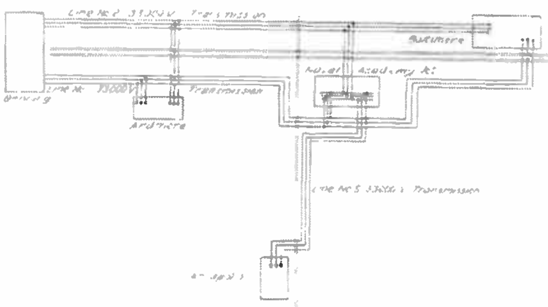


Fig. 3. Diagram of Transmission Line

Both of the 33,000 volt transmission lines are tapped into the Ardmore substation, and switching arrangements are provided to permit of either or both of the lines being used at the same time. The potential is stepped down from 33,000 to 370 volts and fed to the rotary converters, whence it is fed in both directions to the trolleys and feeders at 1200 volts.

Naval Academy Substation

This substation is situated near the car barn and is constructed with a reinforced concrete frame filled with red brick panels.

The substation proper is divided into two portions; namely, a common room for the transformers and rotary converters, and the high tension compartment. A small annex houses the boiler and pumping machinery that supplies the heating and sprinkler system for the car barns. An air compressor for car barn use is also installed here.

Both transmission lines are tapped into this substation and 1200 volt feeders extend from it in the direction of Washington, Baltimore, Annapolis and Annapolis Junction.

Figs. 7 and 8 are interior views of the machine room and high tension compartment respectively. One of the rotary converters is not shown in Fig. 7. Fig. 9 is an exterior view of the substation, while Fig. 10 was taken from the roof to show the manner of carrying the leads from the transmission line vertically down to the transformers. It also shows the horn gaps used in conjunction with the electrolytic lightning arresters.

Baltimore Substation

The Baltimore substation is a brick structure and is situated at the outskirts of Baltimore near Scott Street. The exterior of this building, and also a good view of the external high tension wiring, are shown in Fig. 11. The illustration on the first page

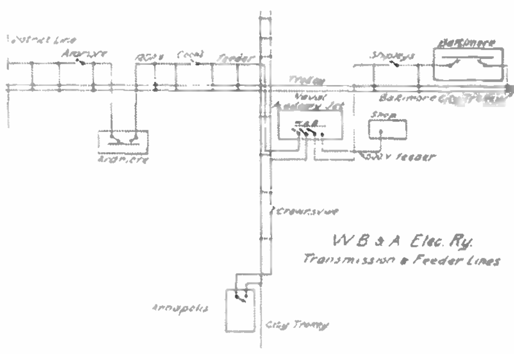


Fig. 4. Diagram of Trolley and Feeder Lines

of cover gives an excellent idea of the switchboard which controls the output of the substation. This board consists of two rotary converter panels and two feeder panels, the high tension alternating current panel being located at the opposite side of the machine room and shown in Fig. 12.

Annapolis Substation

The Annapolis substation is in the center of Annapolis and includes under one roof substation, express depot, waiting room and ticket office. This substation contains two 300 kw. rotary converters and three 160 kw. transformers.

The functions of this substation are considerably simplified since the change from alternating current to direct current, owing to the fact that the City of Annapolis permits the use of the 1200 volt trolley.

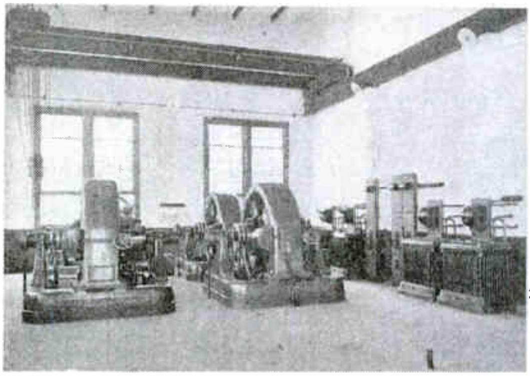


Fig. 5. Main Section Ardmore Substation

Substation Apparatus

The following table gives the number of rotary converters and transformers installed in the various substations. It should be noted that provision is made for two additional rotary converters and three additional transformers in both the Ardmore and Baltimore substations, while at Academy Junction one spare rotary converter is already installed and provision is made for the addition of a second.

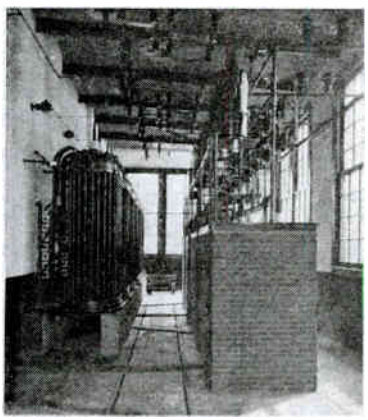


Fig. 6. High Tension Compartment Ardmore Substation

SUBSTATION APPARATUS

	Rotary Converters		Transformers	
	Number	Capacity Kws.	Number	Capacity Kws.
Bennings	1 1	500* 1000*	7 1 1	800 1100* 550*
Ardmore	4	300	6	160
Academy Junction	5	300	7	160
Baltimore	4	300	6	160
Annapolis	2	300	3	160

*Units marked thus are for operating the District line.

These rotary converters are all three-phase, four pole, 300 kw. units running at 750 r.p.m. and designed for a full load direct current of 500 amps. They are, practically speaking, standard 600 volt rotary converters with additional insulation to permit their operation in series to give 1200 volts. They are compound wound with their shunt fields excited from the individual machines and the series fields of each pair are connected in series on the grounded side. A speed limiting device and magnetic oscillator are provided on each machine, and the metallic graphic brushes employed on the alternating current side decrease the amount of carbon dust and make lubricating unnecessary, at the same time eliminating the wear of the rings. The direct current brush rigging is supported directly on the magnetic frame, in order to remove as far as possible from the commutator all metal on which an arc would hold in case a flashover should occur at any time.

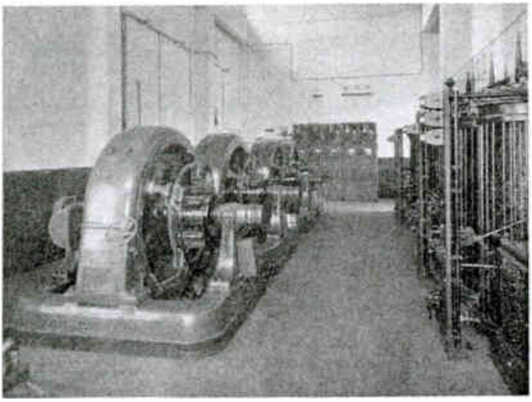


Fig. 7. Main Section Naval Academy Substation

These rotary converters have given the most excellent satisfaction in operation and no difficulty of any kind has been experienced with two machines operating in series.

The reactive coils each have a capacity of 45 kv-a., are oil cooled, and have standard starting switches with protecting covers mounted on the top.

All the transformers with the exception of those installed in the Bennings substation, which are of 800 kw. capacity, are 160 kw. Type H machines, similar in design. They are wound for 33,000 volts on the high tension side and for 370 volts on the low tension side. The primaries are Y-connected and are provided with four 2½ per cent taps, while the secondaries, which are double, are delta-connected and have 50 per cent starting taps.

The switching arrangements are of special interest, as the high tension direct current boards are of standard General Electric design, specifically made for 1200 volt work, two machines in series.

The direct current switchboard of the Baltimore substation is illustrated on the cover. This board consists of two machine panels and two feeder panels, each machine panel being for one pair of rotary converters.

The two 600 volt rotary converters are connected in series as previously stated, the series fields of both machines being connected between the armature of the low machine and ground. This arrangement makes necessary only one circuit breaker, one lever switch, and one ammeter and voltmeter on each panel. The lever switch is placed on the bus side of the circuit breaker so that when the switch is open it is possible to work on the circuit breaker without danger while the positive bus is alive.

The circuit breakers have standard carbon contacts

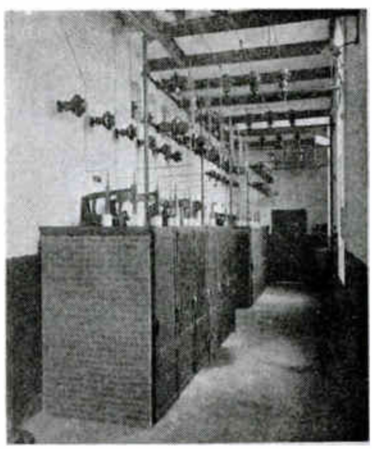


Fig. 8. High Tension Compartment Naval Academy Substation

with an increased length of break for 1200 volts, while the lever switch is made of standard 600 volt parts. Both the circuit breaker and lever switch have the current carrying parts mounted at the top of the panel out of reach, while their operating handles are on the lower panel. The mechanical connection between the handle and switch is made by an insulating rod. Fireproof arc chutes are provided around the circuit breaker and lever switch at the top of the panel.

The circuit breaker is arranged so that the handle always returns to the inward position, while the handle of the lever switch alongside it stands out when the switch is open. In order to distinguish between the two handles, which are identical in appearance, the circuit breaker is mounted inverted so that its handle points downward. For tripping the circuit breaker by hand an insulated trip rod is arranged to operate on the tripping pin of the breaker.

Fig. 10. High Tension Wiring on Roof of Naval Academy Substation

The rheostats are operated from the front of the board by means of a handwheel which turns a mechanism designed in such a manner as to permit of the regulation of the machines individually or collectively at will. The ammeters are of the d'Arsonval type and provided with insulated covers; the wattmeters are also insulated to suit the higher voltage. The voltmeters are standard 600 volt instruments of the permanent magnet type with 1200 volt scales, potential receptacles being provided so that the voltage of each or both machines may be read. Multipliers are used in the plugs so that the 600 volt instruments give the correct readings for the higher potential on the 200 volt scale.

The circuit breakers, lever switches and ammeters on the feeder panels are similar to those on the machine panels. The circuit breaker is con-

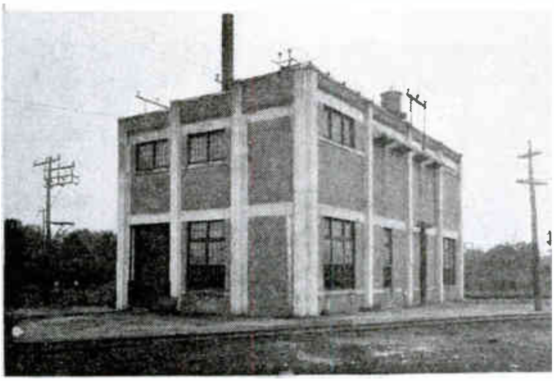


Fig. 9. Naval Academy Substation

nected to the bus and lever switch on the line side. One two-point 1200 volt potential receptacle on the line side of the lower switch allows of reading the trolley voltage before the feeder is cut in.

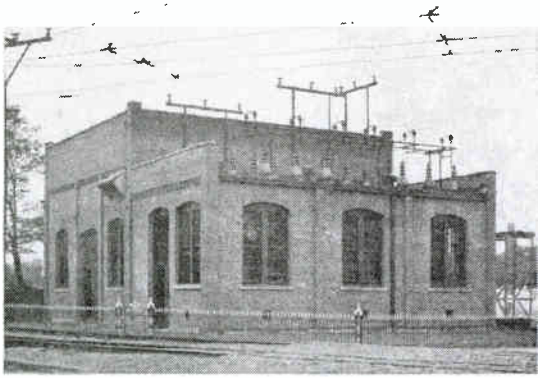


Fig. 11. Baltimore Substation

All the panels are made in three sections, 24 in. wide, the top section being 40 in. in height, the middle section 31 in., and the bottom section 28 in. All bolt heads on the front of the board are covered with insulating caps.

The rotary converters are started from the alternating current side, the starting switch being mounted on top of the reactance cover. Field break-up switches are mounted on the yokes of the rotary converters.

Cars and Equipments

The rolling stock consists of 17 straight passenger cars, 13 combination passenger and baggage cars, 1 express car and 3 freight cars or locomotives—33 equipments in all. Of these cars all were new when the 1200 volt system was installed, with the exception of three of the combination cars and two of the freight equipments, which were converted from single-phase to 1200 volt direct current.

Passenger Equipments

The equipments on the 30 passenger cars are all identical, each comprising four 75 h.p. motors and a full complement of Type M control, designed to operate on both 600 and 1200 volts direct current. These motors are of the commutating pole type and have given most excellent results in service. The schedule which the cars have to handle in this particular instance is very severe, but the motors have shown a wonderful record, especially in the direction of brush wear.

The control is of the relay automatic type, as arranged for train operation, and is intended to give full speed on 1200 volts and half speed on 600 volts. The local conditions call for many special features in the control apparatus. The operation in the city of Baltimore calls for 600 and 1200 volt single trolley, and the interurban run from Baltimore to the District line for 1200 volt single trolley. From the District line to 15th and H Streets in Washington there is a 600 volt

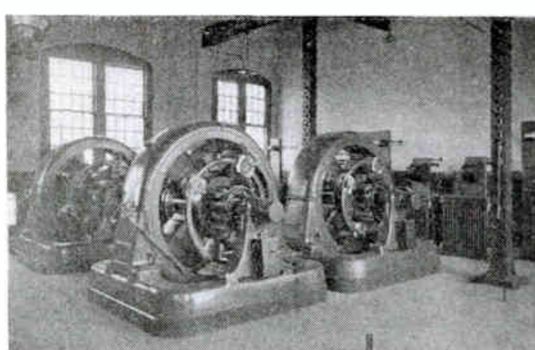


Fig. 12. Interior of Baltimore Substation

double trolley, while from 15th and H Streets to the Treasury Building, 600 volt double conduit plows are used. Hence the equipment is arranged to operate on 600 and 1200 volt single trolley, and on double trolley and double conduit plows.

The transfer of circuits from single trolley to double trolley is accomplished by using the negative trolley pole and hooks for switches as well as current collectors, and when a change from single to double trolley is made, all that is necessary to be done is to put the negative pole in contact with the second trolley. The transfer of circuits from trolley to conduit plows is made by a double-pole double-throw switch operated either by hand or air. This switch is provided with a magnetic blowout so that it can be opened when alive. When operated by air it is so interlocked with the controller that the control handle must be in the "off position" before the switch can be operated.

The air compressors for the air brake equipments have a capacity of 25 cu. ft. of free air per minute and are provided with the usual air compressor governors. These compressors are provided with motors wound for 1200 volts and are arranged to run at half speed on 600 volts.

The heaters and air compressors are operated directly from the trolley.

A dynamotor is provided for furnishing 600 volt current for the lighting circuits during 1200 volt operation, but on the 600 volt section of the road the lights are fed directly from the trolley. The transfer of these circuits is accomplished by a suitable relay directly under the control of the motorman.

Service Equipments

The service equipments comprise in general the same apparatus as the passenger cars, with the exception that the motors are of 125 h.p. each and the control is of the hand operated type.

Car Bodies

All of the car bodies were built by the Niles Car & Manufacturing Company. The straight passenger and combination passenger and baggage cars are similar in all important details, the only notable difference being that the smoking compartment in the combination cars is reduced in length to provide for a baggage compartment.

All the cars present a handsome appearance; they are painted a dark green and are double ended. The more important dimensions and weights are given below.

Length over all	50 ft.
Length over body	40 ft.
Width over all	8 ft. 9 in.
Height from sills to top of roof	9 ft. 4½ in.
Height from track to top of roof	12 ft. 9½ in.
Weight of car body	28,500 lb.
Weight of trucks (each)	10,000 lb.
Weight complete ready for service	78,000 lb.
Type of truck	Baldwin class 78–25 A
Distance between truck centers	28 ft. 8 in.
Wheel base of truck	6 ft. 6 in.
Diameter of wheels	36 in.
Seating capacity	54

The following table will show the more important details of the service equipments or locomotives, the first column of figures referring to the two converted equipments and the second column to the new one.

Length over all	54 ft.	50 ft.
Height over all	14 ft. 1 in.	14 ft. 1 in.
Width over all	9 ft. 6 in.	8 ft. 8 in.
Weight of body	30,000 lb.	27,000 lb.
Weight of trucks (each)	13,000 lb.	13,000 lb.
Weight complete	86,000 lb.	83,000 lb.
Distance between truck centers	33 ft.	26 ft.
Wheel base of trucks	7 ft. 6 in.	6 ft. 6 in.
Diameter of motor wheels	37 ft.	37 ft.

Figs. 13, 14 and 15 show respectively a three car train, a five car train and a freight train.

Overhead Construction

The overhead construction throughout the interurban section of the line is of the catenary 9-point suspension type. A double bracket construction has been adopted on the main line between Washington and Baltimore and a single bracket construction on the line from Annapolis Junction to Annapolis. The trolley wire is of 0000 grooved copper, while the messenger, which is of special high strength steel, consists of seven strands and has a diameter of ⅜ in.

The standard spacing of the poles is 150 feet but the distance varies at curves and on other special work. The poles are 35 feet in length, with a diameter at the top of from 6 to 8 inches. They are buried for a depth of 6 feet in the ground and are set at a slight inclination to the track.

The trolley is suspended 19 feet from the rail level between Washington and Baltimore and 22 feet from the track on the Annapolis Division. The distance between the two trolleys on double track work is 11 feet.

The brackets, which are of a T section, are 10 feet 6 inches in length and are attached to the poles by a flange and two lag screws.

All of the messenger insulators, straight line insulators, steady braces and hangers are of General Electric Company's standard pattern. The messenger insulators are of interest inasmuch as they have grooved petticoats, the function of which is to prevent the insulation from breaking so as to ground the line.

The theory which has been found to hold good in practice is that, should an insulator be damaged by gun shot or stone throw, it would not break in such a manner as to destroy the insulation of the line, but would be fractured at one of the grooves and there would still remain sufficient insulation to prevent a short circuit.

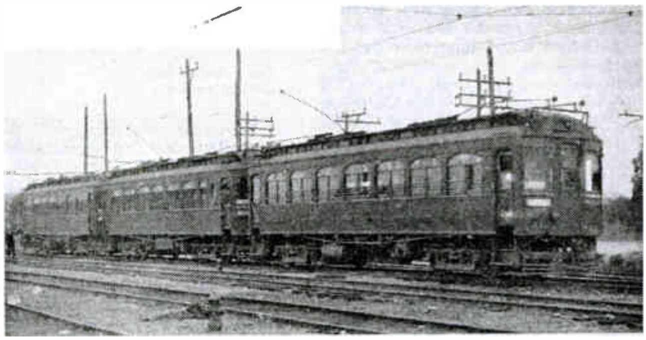


Fig. 13. Three Car Train

In the tunnels near West Port the trolley wire is supported by cross wires thoroughly insulated with fish tail and hickory strain insulators. The cross suspended wires are fastened to U bolts built into the cement structure and supported in the center by other U bolts. The messenger is insulated and anchored at both ends of the tunnel.

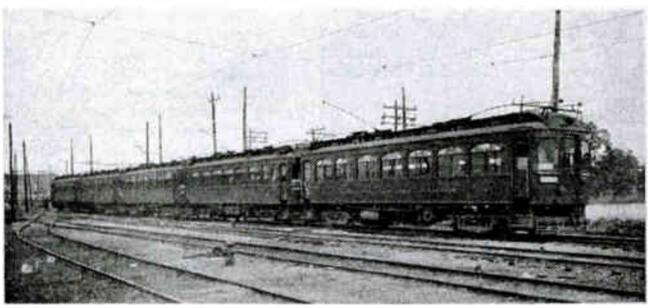


Fig. 14. Five Car Train

Section insulators are used where the 1200 volt trolley and 600 volt trolleys meet. The City of Baltimore now permits 1200 volt trolley as far as Lombard and Green Streets, and the City of Annapolis permits 1200 volt trolley running entirely around the town.

The general appearance of the catenary construction will be seen in Fig. 16.

Protection against lightning is afforded by a wire strung along the top of the trolley poles and grounded every fifth pole. Both sets of poles are protected in this manner on double track road. The ground leads are carried under ground and connected to the running rails.

Transmission Line

The transmission line is in duplicate (6 wires) between Bennings and Baltimore, and single (three wires) between Academy Junction and Annapolis. It consists of No. 2 aluminum wires strung on the same poles that carry the trolley. The potential is 33,000 volts at 25 cycles.

Telephone System

The road is equipped throughout with a duplicate telephone system, one line being used exclusively for giving train orders from the dispatcher's tower at Naval Academy Junction to cars at the terminal stations and to the different booths situated along the line. The telephone wires are carried on the same poles with the high tension transmission and trolley wires and are transposed every fifth pole.

Track

The line from Washington to Baltimore is of double track throughout and is provided with crossovers at intervals of about three miles. A telephone booth is situated at each crossover. The distance from the Baltimore terminal to the Treasury station at Washington is 40.54 miles and the total mileage of the system on a single track basis amounts to 88.87 miles.

The rails are of T section, weighing 80 lb. per yard and are laid in lengths of 33 feet. The gauge of the track is standard.

The Annapolis division, which is 20.05 miles long, is laid with similar rails for the major portion of the distance.

There is one curve of 8 degrees under the B.& O. Railway but excluding this there are no curves of over 4 degrees. The entire interurban section has a private right of way; the track is well ballasted with gravel and in every respect is excellent for high speed travel. Standard rail joints are used, and the 000 bonds employed are of the twin terminal type. Cross bonds are used for all special track work and at intervals of about half a mile.

A feature of specified interest from a railroad point of view, and one that greatly conduces to the maintenance of a high speed schedule is that there are only two grade crossings on the entire road between Washington and Baltimore, all the roads and public highways having been raised across the railway at considerable expense.

Car Barns

The car barns are situated at Naval Academy Junction and are provided with every facility for the upkeep of the rolling stock. The building is constructed with a reinforced

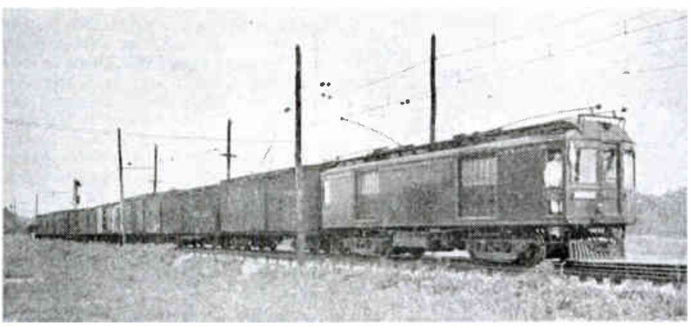


Fig. 15. Express Car and Freight Train

concrete frame filled with red brick panels. It is divided into a paint shop, washing and inspecting room, machine shop, carpenter shop, blacksmith shop, store room, locker room and offices. The machine shop is well equipped with lathes, drills, saws, etc., all of which are driven by General Electric direct current motors.

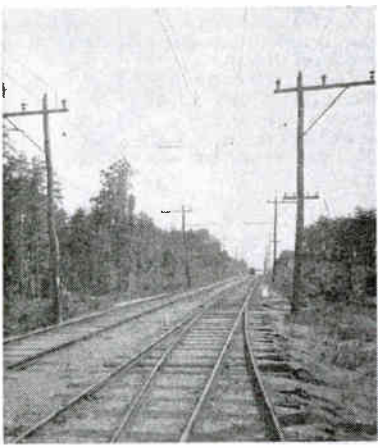


Fig. 16. View Along Right of Way

The heating system is very complete and the fire protection is exceptionally good; a pressure tower with a capacity of 50,000 gallons having been constructed for fire protection. The pits are heated to expedite the work of repairing and inspection during the winter months. A very efficient form of transfer table is used in the machine shop, with the aid of which a truck can be replaced in 28 minutes, this being a very creditable performance.

The potential used throughout the yards is 1200 volts and that in the car barns 600 volts.

It is perhaps worthy of note that a special oil house was built, since it was believed that a well equipped oil house is essential to high speed operation.

In addition to the above car barns a barn with a capacity of ten cars has been built at Lombard Street, Baltimore, to facilitate the maintenance of the schedule by a local storage of cars.

Terminal Facilities

The terminal facilities of the Washington, Baltimore & Annapolis Railroad are admirably situated in their respective cities and are of such a nature as to provide for the comfort and convenience of the traveling public.

The station at Baltimore is a red brick building located between Park Avenue and Liberty Street, and has entrances on both streets. It is also bounded by Marion Street. It consists of a waiting room and a ticket office with a track laid through one portion of the building. The administration offices of the company occupy the upper floor.

The Washington terminal is now near the Treasury building and nine ticket offices are provided in Washington between the old White House terminal and the Treasury. The White House depot, which was formerly used as a terminal for the Washington, Baltimore & Annapolis cars when a single-phase road, is now only used for the storage of cars.

At Annapolis the waiting room, ticket office and substation are all in the same building.

A waiting room is provided at Naval Academy Junction for the convenience of passenger changing cars at this point.

COMMERCIAL ELECTRICAL TESTING

PART XIII

BY E. F. COLLINS

TRANSFORMERS—Continued

THREE-PHASE AIR BLAST TRANSFORMERS

Special Tests

The order of tests on three-phase air blast transformers is the same as for the single-phase type. The mechanical construction of the coils is identical with that of the single-phase type; but as the air paths through the iron are longer, the air pressure required is slightly higher.

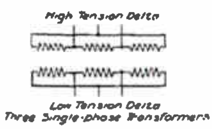


Fig. 53

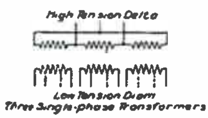


Fig. 54

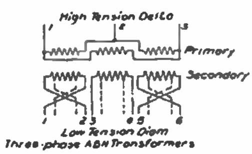


Fig. 57

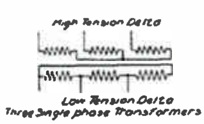


Fig. 55

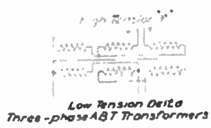


Fig. 58

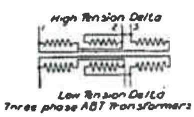


Fig. 56

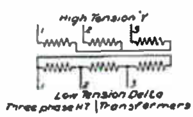


Fig. 59

Connections for Polarity on Three-Phase Transformers

Cold Resistances

The general instructions given for measuring the resistance of the single-phase type apply to three-phase transformers, but since the primary circuits are opened for the heat run, the resistance of each set of coils should be measured. If the secondary coils are permanently connected in delta, the resistance between each set of leads should be measured. If the secondary coils are arranged for diametrical connection, measure the resistance of each set of coils. Note on the record sheet how these readings are taken, so as to avoid confusion in measuring and recording hot resistances.

Polarity

The determination of polarity on three-phase transformers requires much care. The diagrams allow a comparison to be made of the various standard connections. Figs. 53, 54 and 55 are three-phase connections for three single-phase transformers, and Figs. 56, 57, 58 and 59 are connections for three-phase transformers.

In determining the polarity of three-phase air blast transformers, see that the primary and secondary coils are connected as shown. (Figs. 56 and 57.) Supply direct current to primary lines No. 1 and No. 2 to give the proper deflection on the voltmeter, then transfer the voltmeter lines to the secondary, connecting the line that was on No. 1 primary to No. 1 secondary, and the line that was on No. 2 primary to No. 2 secondary. Now break the primary current and if the polarity for this phase is correct, a positive kick will be obtained. Repeat this process for the two other phases and if they all agree with the first one, the polarity is correct. A sketch should be drawn on the record sheet, showing how the polarity test was made.

The polarity test on three-phase transformers also determines whether there will be a change of rotation of phase in transforming from one potential to the other. To determine the polarity of transformers connected as shown in Fig. 57, supply current to primaries 1–2 and take deflection on secondary 1–2; this should show reversed polarity. With current on 1–3 primary the deflection on 3–4 secondary

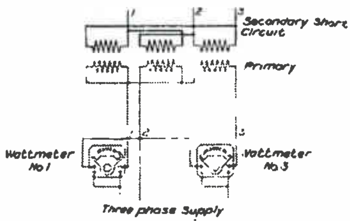


Fig. 60. Connections for Impedance Test

should be positive. With current on primary, the deflection on 5–6 secondary should be reversed.

Ratio and Checking of Taps

Whenever possible, a three-phase transformer should have ratio and taps checked on each phase separately. If this is not practicable, care must be taken to see that both primary and secondary voltages are read on the same phase. When these measurements can not be taken single-phase, three-phase voltage must be applied. If the ratio appears to be wrong, connect both windings in delta, apply full voltage to the secondary, and read the exchange current in the primary delta. This current should not exceed 6 per cent of full load current.

Impedance

For this test, connect the transformer according to Fig. 60 and follow the same general instructions as given for the air blast type. Calculate the current corresponding to the primary voltage of the transformer as follows: primary current $= \frac{\text{capacity in watts}}{\text{line voltage} \times \sqrt{3}}$

Connect in two wattmeters of the same capacity, as shown in Fig. 60. The ratio of the two potential transformers or multipliers should be the same. The algebraic sum of the readings of the wattmeters will represent the impedance loss of the transformer. The sign of the readings must be carefully noted, since the reading of one wattmeter may be reversed. To test for this, open line No. 1 and if the reading for wattmeter No. 3 is positive, the needle will drop to some value above zero. If the needle drops off the scale below zero, the reading must be recorded as negative. If the first meter tested reads positive, the sign of the other meter should be determined by this method.

An impedance curve should be taken from 50 per cent to 125 per cent full load.

In making the short circuit test on ABH (Fig. 57) transformers, each phase must be short circuited independently of the other. In taking readings, hold the current constant in one line from the testing table. Read the three-phase volts and the two wattmeters. Hold the voltage constant across one phase and read the current in the other phases.

Core Loss

In the core loss test, wattmeter readings are taken in the same manner as for the impedance test. The same precautions must be observed in regard to fastening up the primary leads so that there is no chance of danger. Take core loss curve from 50 per cent to 125 per cent normal voltage.

In ABH transformers, with the middle points of each phase connected together to form a neutral for a three-wire direct current system, some confusion may result as to the proper method for measuring core loss. If the neutral connection is broken (as is sometimes necessary for the heat run), the secondaries may be connected in delta and three-phase voltage applied. This voltage is the same as the diametrical voltage, or that of each phase. If the neutral can not be broken, the secondaries may be connected in Y, the neutral connection forming the Y point. In this case the voltage corresponding to the normal voltage of the transformer will be $\frac{\sqrt{3}}{2}$ times the diametrical voltage. It should be remembered that the middle set of coils should be connected so as to be reversed with respect to the other two, in order to obtain the proper magnetic flux in all parts of the core.

Hold the voltage constant and take readings as in impedance test. There will be a slight unbalancing of the magnetizing currents due to the unequal magnetic reluctances in the different parts of the core. For this reason the alternator for core loss tests must be operated at normal voltage so as to balance the three-phase voltage as nearly as possible.

Parallel Run

The parallel run checks ratio and polarity on a three-phase transformer in the same way that it does on a single-phase transformer.

Connect the secondary circuits of the two transformers in multiple, and the primaries as shown in Fig. 61.

Connect between *A* and *A′* and try the fuse wire from *B* to *B′*; if no spark is obtained, connect from *B* to *B′*, leaving the first connection, and try the fuse wire from *C* to *C′*. If no spark results here, the parallel run is satisfactory. The voltage must be taken off before any connections are changed.

Heat Run

The method described for three single-phase transformers is the one ordinarily used. If two or more transformers are to be run simultaneously, connect the transformers in multiple on the secondary side and the primaries all in series. The same general instructions for the heating of single-phase transformers will apply; in fact, each phase of a three-phase transformer must be treated as a single-phase transformer. Use as many thermometers on one three-phase transformer as on three single-phase transformers. A higher pressure is necessary to force air through the ducts

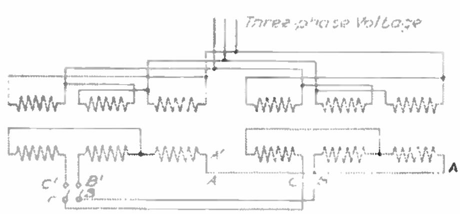


Fig. 61. Connections for Parallel Run, Three-Phase

in the iron of the three-phase transformer than in the single-phase, and the damper must be carefully adjusted.

In calculating the voltage required to supply the primary current for the heat run, the following rule may be used: If the primaries are connected in delta, multiply the impedance voltage by three; if the primaries are connected in Y, multiply the impedance voltage by $\frac{3}{\sqrt{3}}$. If overload is required, add 50 per cent for 50 per cent overload and 25 per cent for 25 per cent overload.

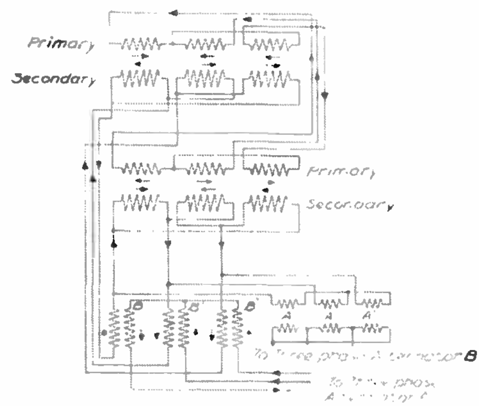


Fig. 62. Connections for Heat Run, Three-Phase

If it is impracticable to open the primary connection in order to take the heat run by applying three-phase voltage, to the secondaries and single-phase current to the primary, the following method may be used: Connect the transformers as shown in Fig. 62. Auxiliary transformers *A*, *A′*, *A″* are used to supply secondary voltage, and transformers *B*, *B′*, *B″* as series transformers to supply the impedance voltage to the secondary circuits. The voltage necessary to supply full load current is twice the impedance voltage of one transformer. The impedance voltage is the same percentage of the total voltage, irrespective of the circuit to which it is applied. The figure shows two three-phase alternators, one supplying core loss and exciting current, and the other the copper losses. When two alternators are used they must be run at nearly the same frequency, otherwise the superposition of the impedance voltage on the core loss voltage will impart a slight swing to the meter needles. Instead of the three transformers *B*, *B′*, *B″*, a three-phase transformer or an induction regulator may be used. If a regulator is used, all the losses may be supplied from one alternator.

Double Potential Test

If any repairs or alterations are required, such as making primary delta or Y connections permanent, or connecting up the secondary neutral, the double and high potential tests should be omitted until everything is completed. If double potential can not be obtained from a three-phase alternator on account of the high magnetizing current, the test can be made on one phase at a time. Double potential should always be followed by one and one-half times normal potential for five minutes.

High Potential

The high potential should always be applied after all changes have been made, such as tightening loose iron, connecting primary delta or Y. The polarity should always be tested after the delta or Y connection has been made.

Other tests, such as overload heat run, hot resistance, and air readings, are made in a manner similar to that followed for single-phase transformers.

OIL-COOLED TRANSFORMERS

The order of tests on oil-cooled transformers is the same as that for air blast transformers. The transformer should, if possible, be filled with oil at least four hours before starting the tests; If not possible, the cold resistance, polarity, ratio, checking of taps and impedance tests may be taken before. Under no condition, however, must an oil-cooled transformer of over 10,000 volts be operated at normal potential without being filled with oil, as the coils have only one taping, and the insulation may therefore break down.

Cold Resistance

If the transformer has not been filled with oil, a thermometer should be suspended inside the tank to measure as nearly as possible the temperature of the windings. If filled with oil, record the temperature of the oil. Always use a spirit thermometer to obtain the temperatures inside the tank. As the leads are not brought out in the same manner as in the air blast type, the circuits should be carefully checked before starting the tests.

Heat Run

The methods and connections used are practically the same as for air blast transformers, except that oil-cooled transformers should be started at an overload, so as to heat them up rapidly and thus shorten the run. Where practicable, they should be run with 50 per cent excess current for two hours, and 50 per cent excess voltage for three hours. In some cases the time of overload run must be shortened, though occasionally a longer time is required. When normal voltage is applied, the alternator must be operated at normal voltage.

During the heat run, a careful search should be made for oil leaks in the tank and oil gauges. If the transformer has been filled so full of oil that it is likely to overflow, draw off some oil. The leads coming from the transformer must not siphon the oil. In locating thermometers on the outside of the tank, place one at the top, about the height of the oil line, and on very large transformers, one near the bottom of the tank, always using the putty provided. As it is not possible to get the temperature of the core, the oil temperature must be carefully obtained. Whenever possible, place one thermometer near the center of the transformer so as to measure the temperature of the oil as it comes from the coils. The bulb of the thermometer should be about two inches under the oil. Place one thermometer in the oil about three inches from the side of the tank.

Oil-cooled transformers usually require a very long heat run, varying from six to fifteen hours, depending on the size. The heat run should be continued until the temperature rise is less than one degree in two hours. Do not make a short circuited heat run on an oil-cooled transformer if it can be avoided; if unavoidable, make a short circuited heat run on the coils to constant temperature, then take double potential for one minute, one and one-half potential for five minutes, and one and one-quarter potential for three hours.

High Potential or Insulation Test

Many oil-cooled transformers are built for 50,000 to 100,000 volts and require a correspondingly high insulation test. The wiring from the high potential transformer to the transformer to be tested should be arranged so that no one can possibly come in contact with it. It must be securely strung to prevent its falling on any one.

The voltage applied is controlled either by varying the field of the alternator supplying power to the low potential side of the testing transformer; or, if the power is taken from the constant potential shop circuit, by a single-phase potential regulator. The spark gap should always be used and, if the power is supplied from a separate alternator or is controlled by a potential regulator, a high resistance consisting of two or more glass tubes filled with clean water should be placed in series with the spark gap. This limits the flow of current across the gap at the instant of arcing over and prevents a sudden discharge of the transformer windings.

The transformer windings act as the plates of a condenser; if suddenly discharged, or brought to the same potential, adjacent turns may easily short circuit. The same phenomenon occurs when potential is suddenly applied to a transformer. To reach the interior of the windings, the charging current must either follow the conductors, or break down the insulation between adjacent turns. The end coils are therefore all strongly reinforced to prevent short circuits. The general instructions already given for high potential test on air-blast transformers also apply here.

Double Potential

On transformers built to operate at 50,000 volts or over, the double potential should be the last test applied, in order to discover if any breakdown has occurred between turns under the high potential test.

OIL AND WATER-COOLED TRANSFORMERS

Oil and water-cooled transformers are identical in construction to the oil-cooled type, except that, instead of being placed in corrugated tanks to radiate the heat, they are placed in smooth tanks and have a cooling coil immersed in the oil to carry away the heat generated by the losses. The cooling coils are usually made of wrought iron pipe made up in coils of proper size by the pipe manufacturers. In special cases, however, where salt water is used for cooling, copper pipes are employed to avoid the action of the salt on the cooling coils. In most transformers these coils are placed in the upper half of the tank, but sometimes the cooling coils are made of flattened brass or copper tubing, placed between the primary and secondary coils. In large water-cooled transformers with low secondary voltages, the secondary winding is made of flattened copper tubing, through which water circulates.

The tests on water-cooled transformers are the same as for other types, but special instructions are necessary for handling the water. The oil in the transformers should completely cover the cooling coils. The cooling coils are tested by the plumbers to several hundred pounds per square inch, but they should also be tested by the testing department at the water pressure available. Allow water to flow through the coil until no air is left; then close the overflow, allowing the pressure to rise. Note whether there are any leaks, and if not, close the inlet valve. If the pressure drops rapidly, a leak is present. If the outside plumbing and valves are tight, test the oil at the bottom of the tank for water by drawing some off in a test tube. If water is present, it will settle to the bottom of the tube. If water is found, the cooling coil must be taken out and repaired. If however, the pressure does not fall, leave the transformer under pressure for two hours. After all the tests are finished, the oil should be tested for water. With wrought iron pipe very little trouble is experienced.

Make all tests except the heat run according to the instructions already given for other types. At the start, run at normal rating without water until a rise of 20° C. by resistance is reached. The oil should have a rise of about 15° C. The ingoing water should be heated up to 20° C. by using a steam heater; this is about the average temperature found in practice. The water should then be adjusted so as to have 10° C. rise. Temperature readings should be made every fifteen minutes, in order that the quantity of water may be properly adjusted without loss of time. As soon as the transformers have nearly reached constant temperature, the quantity of water should be noted and a record made every half hour. The water may be weighed or measured.

The amount of water required is estimated as follows: One gallon of water will require about 2650 watts to raise it 10° C. in one minute, or one gallon of water raised 10° C. in one minute will carry away the heat generated by 2650 watts loss.

For a rough estimate, use one gallon of water for each 2500 watts loss—a small portion of the heat will be radiated from the outer surface of the tank. When the load is taken off the transformers for resistance measurements, always shut off the water. Complete the tests as on other transformers, making careful inspection for oil leaks. As the leads of many of these transformers are brought out through the cover, care must be taken, when making connections to avoid dropping tools on the porcelain bushings.

These transformers are usually made for very high voltages, and are often filled with oil that has been specially refined. The tank is exhausted of air while the transformer is hot, and the hot oil allowed to slowly flow in at the bottom of the tank. To heat up the winding of these transformers, put one-half the full load current through the primary winding, carefully measuring the cold resistance. Take readings every half hour and calculating the rise of temperature by resistance. When a rise of 50° C. is reached, decrease the current to maintain the temperature while the tank is exhausted of air.

In water-cooled transformers with secondary coils made of flattened copper tubing through which the water flows, the amount of water flowing through each section should be measured if all the sections are fed from the same water head. If each section has a regulating valve, these valves should be fully opened. Put on a low reading pressure gauge, hold the pressure constant by means of the valve in the main pipe and carefully measure the quantity of water from each section for a given time. Record the pressure and quantity per minute through each section. Never apply a pressure of over 10 pounds per square inch to a transformer of this type, as there is danger of opening the soldered joints. In taking overload heat runs, always use the same amount of water as for the normal load heat run.

Oil-cooled and oil and water-cooled transformers built for voltages above 75,000 have special high tension leads which are oil filled. These leads must be carefully filled with oil before potential is applied to the transformer, and they must be kept filled. They should be carefully watched for leaks.

(To be Continued)

THE CURTIS TURBINE*

By Charles B. Burleigh

The Curtis turbine was first introduced to the commercial public in its larger sizes, from 500 to 5000 kilowatts capacity, and since with the large turbines an excessive weight in moving member must be dealt with, these large machines were originally designed of the vertical shaft type. For this reason many have conceived the erroneous idea that the characteristics of the Curtis turbine necessitated the vertical form of construction; whereas in point of fact the Curtis turbine is equally well adapted for both vertical and horizontal arrangement of the shaft. In this respect the manufacturers of this turbine occupy a unique position in the turbine field in that they are prepared to offer, in accordance with the demands of local conditions both horizontal and vertical types. This being the case it may be of interest to discuss some of the characteristics of the two types and some of the limiting features of turbine design.

A comparison of the speed of the rifle bullet and the velocity of a jet of water will give the reader a partial conception of the problems that confronted the turbine designer, and presents a sufficient excuse for the delay in the development of a piece of apparatus that was conceived about 120 B.C.

With the hydraulic turbine it is the exception when the motion of the fluid is in excess of 200 feet per second, for the velocity of a jet of water at 150 pounds pressure per square inch (which corresponds to a head of 346 feet) is approximately 149 feet per second; while steam expanded from 150 pounds pressure per square inch to the pressure of the atmosphere attains a speed of 2950 feet per second, and if expanded into a 28 inch vacuum, can attain a velocity of 4010 feet per second.

In the impulse turbine, the steam expands in a separate nozzle or nozzles that are so arranged as to give it direction and bring it at expansion pressure and expansion velocity in contact with the buckets secured to the periphery of the rotating wheel, from which it rebounds, as an elastic body, with the same velocity as that with which it *strikes* i.e., with a velocity equal to the difference

*The calculations in this article are theoretical and disregard friction, losses due to angle of nozzles, etc., etc. *Editor.*

between the velocity of the steam and that of the buckets.

In other words, where steam that has been given a speed by expansion of 4000 feet per second, is brought in contact with the impulse bucket so secured as to be incapable of movement, it rebounds at a speed of 4000 feet per second.

Do not understand that the steam would not tend to actuate the stationary bucket, for it would, since the pressure on the bucket is greater when the bucket is stationary and is reduced as the bucket moves away from the steam, the steam pushing the bucket under the latter condition with a force which is proportional to the relative velocities of the steam and the bucket.

The steam delivered by the nozzle is moving so fast that it has no trouble in keeping up its push on buckets that are moving at a high speed. Thus as the velocity of the bucket is increased the steam is able to follow it, and up to a velocity equal to that of the steam itself tends to push it forward; if the speed of the bucket reaches that of the steam the latter would simply follow without pushing at all. It should be remembered that it is the relation of the velocity of the steam to the resistance offered by the bucket to movement of the bucket that determines the bucket's speed.

On the other hand, if the impulse bucket be allowed by the governor to move at a speed of 1000 feet per second, and the steam moving at a speed of 4000 feet per second be brought in contact with it, the steam will give up a portion of its energy to the bucket and leave it at a speed of 2000 feet per second, hence losing velocity by an amount equal to twice the wheel velocity.

Steam enters the bucket at velocity V_1, following the arc of the bucket, and, neglecting losses, the velocity which is left is V_2.

As stated, the energy of a moving body is one-half the mass times its velocity squared, thus the energy possessed by the steam as it goes into the bucket is $\frac{MV_1^2}{2}$, and since the mass of the steam has remained unchanged, its energy as it comes out is $\frac{MV_2^2}{2}$; the energy given up to the bucket is therefore: $\frac{MV_1^2}{2} - \frac{MV_2^2}{2}$. This has been given up to the buckets because the steam was pushing while the buckets were moving.

If the buckets had been stationary it would have simply changed the direction of the steam without material loss of energy, as it would have entered at a velocity of V_1 and left it at practically the same velocity; in this case no work would be done.

To take the full energy out of the steam, the wheel velocity must equal one-half the velocity of the steam jet; or as before, if the expanded steam moves at a speed of 4000 feet per second and is brought in contact with an impulse bucket moving at a speed of 2000 feet per second, thus losing velocity by an amount equal to twice the bucket velocity (2000 feet per second), its energy will all be given up to the bucket.

From the foregoing it is easy to determine the best speed conditions. When the bucket is stationary the push is greatest and the bucket's velocity is zero; and when the speed of the steam and that of the buckets are equal the bucket's velocity is greatest and the push is zero; at both of these extremes the work done is zero.

There is a point between these two extremes where the effect will be maximum. That point will be where the energy remaining in the steam after it has passed through the bucket will be the least.

Now let us assume that V_1 is just twice the velocity of the bucket; then, subtracting this bucket velocity from the steam velocity, we have as a remainder the relative velocity of the steam with respect to the bucket ($\frac{1}{2}V_1$), or the speed at which the steam overtakes the bucket. Consider for an instant that this relative velocity of the steam is the initial or actual velocity, and that the bucket is stationary; then, from what has been said, the steam would rebound from the bucket at a velocity equal to the initial velocity, or $\frac{1}{2}V_1$. However, the bucket actually has a velocity equal to the relative velocity, and the steam in striking rebounds *with respect to the bucket* at a velocity equal to the relative velocity, but with an *actual* velocity equal to zero. When, therefore, the velocity of the steam is twice that of the bucket, the steam delivers all its energy to the buckets.

In an impulse turbine therefore, such as the Curtis, with a given pressure range per wheel, the wheel velocity at best efficiency is only about 50 per cent of what it is in a reaction turbine, and 70 per cent of what it is in a combination turbine which alternates between impulse and reaction effect.

It is not possible to get efficiency with a single turbine wheel of the reaction type, while with a single wheel of the impulse type good efficiencies have been obtained by using extremely high peripheral speeds.

While hydraulic turbines are always designed with a single wheel, for the reason that the highest heads available produce in fluids velocities which correspond to moderate efficient wheel speeds, in the steam turbine it is not possible to make effective use of the total energy of the steam by a single wheel, and a number of wheels in series have to be used in order to efficiently utilize the extremely high velocities resulting from the steam expansion.

That is, the rotor velocity is reduced by subdividing the total pressure range into a number of successive stages.

In the combination impulse and reaction turbine each expansion or pressure stage requires a revolving wheel and a stationary guide wheel. The latter acts as a nozzle wheel in which the steam expands, acquiring a velocity equal to the velocity of the revolving wheel.

At the entrance into the revolving wheel this velocity is transferred to the wheel on the impulse turbine principle, and the steam in passing through the revolving wheel expands again, leaving it with wheel velocity; that is, the revolving wheel of the Parsons type is substantially an impulse wheel at the entrance and a reaction wheel at the exit side.

In the impulse turbine, in which the expansion of the steam is carried out separately from the transformation into mechanical rotation, a further and still more effective means of speed reduction is presented by the use of several velocity steps in each stage; that is, by imparting the velocity of the current of steam to a number of successive wheels composing a single revolving disc, by means of stationary guide wheels.

Since in a revolving wheel of an impulse turbine the steam velocity is reduced by an amount equal to twice the wheel velocity and a single wheel per stage must revolve at one-half the steam velocity, two wheels per stage must revolve at one-quarter the steam velocity and so forth. It follows, therefore, that the use of several wheels per stage is a most effective means of reducing the rotor speed; or inversely, when the rotor speed is given, of reducing the total number of revolving wheels. A two-wheel stage can thus take care of twice the steam velocity (or, four times the steam energy) of a single-wheel stage, and therefore, replaces four single-wheel stages. In other words, the speed reduction of the rotor is proportional to the number of wheels per stage; that is, to the number of velocity steps, but is proportional to only the square root of the number of stages; that is, the number of pressure steps.

The simultaneous use of pressure steps, or expansion stages, and velocity steps, or number of wheels per stage, leads therefore, to a construction requiring only a very small total number of wheels, which is carried out in the Curtis type of impulse turbine.

To illustrate: assume a total steam velocity from boiler to condenser of 4000 feet per second. Allowing a 10 per cent velocity loss, the available velocity would be 3600 feet per second, and two stages of three wheels per stage, or a total of six revolving wheels, would give a spouting velocity of the steam per stage of $\frac{3600}{\sqrt{2}} = 2550$ feet per second, and therefore a wheel velocity of $\frac{2550}{6} = 425$ feet per second.

With a wheel velocity of 425 feet per second, a single impulse wheel would efficiently utilize only $2 \times 425 = 850$ feet per second steam velocity, and $\left(\frac{3600}{850}\right)^2 = 18$ stages or successive steps of expansion would be required, that is, 18 revolving wheels, each with a set of expanding nozzles, etc.

With a wheel velocity of 425 feet per second, in a reaction type $\left(\frac{3600}{425}\right)^2 = 72$ successive expansions would be necessary; that is to say, if this condition could be realized, 36 revolving and 36 stationary wheels would be requisite.

In the Curtis turbine, two methods of subdividing the steam energy are available; pressure steps or stages, and velocity steps or wheels per stage. Obviously, a single pressure step or stage with a considerable number of successive wheels, or a large number of stages each with a single wheel, could be used, but either of these extreme arrangements would be inefficient, and the relative distribution of work between pressure steps and velocity steps depends upon considerations of efficiency.

The main losses in a steam turbine are:

(1) Wheel friction.

The wheels revolve in an atmosphere of steam, which has a remnant velocity several times greater than any tornado that ever devastated the country. This loss decreases with the decreasing number of wheels; hence it is a maximum, other things being equal, with the reaction type of turbine, and diminishes with a decrease in the total number of wheels; that is, with an increase in the number of wheels per stage.

(2) Bucket friction, or friction in the steam passages in revolving wheels and guide wheels.

This loss depends upon the relative velocity of steam and wheel, hence it is a minimum in the reaction turbine, where the average relative velocity is only half the wheel velocity.

In a single wheel impulse turbine, the relative velocity is equal to the wheel velocity, and increases with increasing number of wheels per stage, that is, an increasing number of velocity steps. It is this loss which finally limits the number of wheels permissible per stage.

(3) Nozzle losses—which at first decrease with decreasing pressure range (that is, decrease with decreasing work done per nozzle, or in other words, with increasing number of stages) but then increase again, due to the lesser accuracy of operation which results with very many successive nozzle wheels.

(4) Steam leakage from stage to stage.

Leakage losses are very much greater in the reaction turbine, where pressure differences exist between the intake and discharge side of each wheel and are dependent on the percentage of radial clearance and the bucket area. These leakages become small with impulse turbines, and disappear entirely in an impulse turbine using many wheels in a single stage.

If, therefore, we consider the losses as a function of the total number of revolving wheels, some losses—such as (1) and (4)—increase while others—such as (2)—decrease with increasing number of wheels; the problem of turbine design is to determine that intermediate point at which the total sum of the losses is a minimum, that is the efficiency is a maximum.

The foregoing conditions have been given the most careful consideration in the design of the Curtis turbine with the result that, irrespective of the shaft position, the smaller sizes from 7 to 35 kilowatts are of the single pressure step or expansion stage and multi-velocity step type. This construction eliminates entirely leakage losses (4), and greatly reduces nozzle losses (3), at the same time presenting extremely moderate wheel and bucket losses (1) and (2).

The former are further reduced to a minimum by the use of but one wheel having secured to its periphery (by a method later described) three rows of moving buckets, which function in the same manner as would three independent wheels and eliminate a large proportion of the skin friction. This arrangement, in conjunction with two rows of intermediates or re-directing buckets, constitute the interior equipment.

The intermediate sizes of turbines, from 100 to 500 kilowatts are of the double pressure step, or expansion stage variety and multi-velocity, or two or more wheels per stage type; while the larger sizes, from 750 kilowatt units upward, are usually for land purposes of the four or five pressure stage type and of the double velocity, or two-wheel per stage, design.

In the smaller sizes three rows of moving and two rows of intermediate buckets are employed; in the intermediate sizes four rows of moving and two rows of intermediates, and in the larger sizes eight or nine rows of moving and four rows of intermediates are used.

Perhaps a detailed description of one of the smaller size non-condensing units will best convey to the reader the extreme simplicity of the Curtis design. We will take for example a unit of 25 kilowatts capacity, which is designed to operate from 150 lbs. steam, exhausting against atmospheric pressure.

As previously stated in this size we shall select the single pressure step or single expansion stage, multi-velocity step type. With this design there will be no leakage losses, minimum nozzle losses and moderate wheel losses.

In our steam pipe, which must be large enough to properly supply the unit, we shall locate a metal screen to prevent boiler scale or other foreign matter from entering the machine.

We shall next provide a main admission valve for shutting off or turning on the steam to the steam chest. This chest must be sufficient to accommodate the several admission valves controlled by the governor, the position of which determines the amount of steam admitted to the machine.

Each of these valves controls the flow of steam through one or more expanding nozzles, which deliver the steam from the steam chest to the interior of the machine and are of such design as to expand it from boiler pressure to atmospheric pressure, thus giving to the steam a velocity of 2950 feet per second.

Atmospheric pressure of course, exists throughout the interior of the machine, and the steam delivered by the nozzle or nozzles is obviously of the same pressure, for which reason it is dependent upon the nozzle to give it direction; the nozzle angle is therefore carefully arranged to give that direction which will bring the steam in contact with the moving bucket without shock or sudden change of direction.

Since the area within the turbine and the admitted steam are of the same pressure, there is no more tendency for the steam to change its direction and attempt to escape into an atmospheric of its own density than there would be for a stream of water delivered by a hose nozzle into the atmosphere, to change its direction until it was brought in contact with some medium other than the atmosphere of such shape as would redirect it previous to its losing its velocity. For this reason you will appreciate that the efficient delivery of the steam by the nozzles to the buckets is in no way dependent on an exceedingly close proximity of the bucket to the nozzle, or in other words, fine clearance has no effect on efficiency.

The machine is equipped with some five or more expanding nozzles arranged successively, so that their delivery ends from practically a continuous opening some eight or more inches in length, separated by division walls, the width of the nozzle opening corresponding closely to the length of the bucket with which the steam is to be brought in contact.

The expanding nozzles are worked out in a bronze plate designed to bolt to the steam chest.

The governor of the machine, which in the smaller sizes is an extension of the shaft and rotates with it at shaft speed, thus doing away with the necessity of intermediaries, is of the flyball type.

In the intermediate and large sizes of turbines the valves permitting the entrance of the steam to the nozzles are controlled by a governor and consequently the volume of admitted steam is dependent on the load on the machine.

With a very light load on the unit but one of the valves would be open, controlling but one or two of the expanding nozzles, admitting a volume of steam corresponding to the area presented by the throat of the nozzle and delivering it to the interior in a short belt of a width approximately equal to the length of the delivery end of the nozzle or nozzles that are open.

As more load is imposed on the machine, successive nozzles are opened by the action of the governor and the admitted steam belt thereby lengthened until the extreme overload point is reached.

It will be seen that regulation is accomplished by lengthening or shortening the belt of admitted steam.

It will also be noted that all steam admitted to the machine flows continuously through the unit and that no losses occur due to alternate heating and cooling; further than this, under no condition of load does the belt of admitted steam surround more than a small fraction of the machine periphery.

(To be Continued

THE ELECTRICAL EQUIPMENT OF THE JOHN N. ROBINS CO. ERIE BASIN, BROOKLYN

By G. S. Rose

The shipyard of the John N. Robins Co., at Erie Basin, Brooklyn, is, in point of tonnage handled, the largest shipyard in this country devoted to repair work. The yard covers twenty-three acres and harbors five dry docks, the largest of these being capable of handling a vessel 600 feet in length. Three of these docks are of the floating type, the remaining two being of the graving construction.

The floating dock is submerged by allowing the water to enter its pontoon base and hollow sides. The vessel to be repaired is then floated in on top of the structure and the water pumped from the hollow portions, the dock rising and lifting the vessel out of the water. All three of these docks are emptied by electrically driven pumps located on the dock itself.

The graving type of dock consists of a walled slip, the base of which is below the level of the sea, with a movable dam or caisson at one end of the structure. To dock a vessel, the slip is filled with water to the same level as that upon which the ship to be repaired is floating. The vessel then enters the slip and the floating gate or caisson is securely fastened in place and made as watertight as possible. The water is then pumped from the slip, leaving the vessel high and dry. Fig. 1 shows one of these docks pumped dry and ready to be flooded to receive the ship, which may be seen floating on the bay in the distance. The supporting blocks which are pulled under the vessel to support it while being repaired can be seen along the base of the dry dock. The illustration on page 482 shows a vessel in dry dock with the supports in place. It is this graving type of dock in which we are particularly interested.

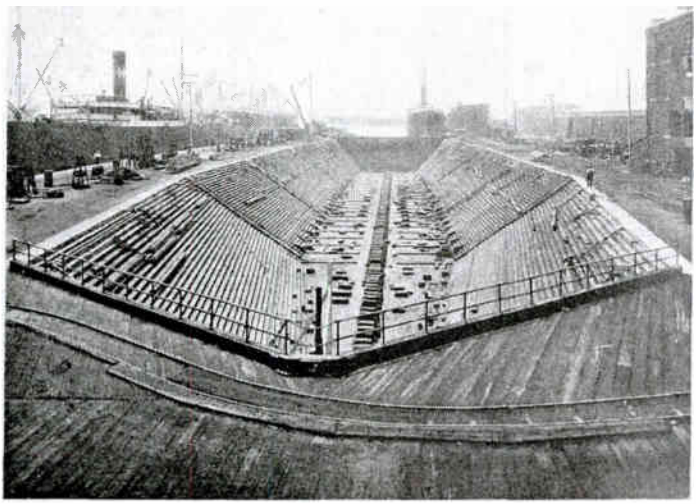


Fig. 1. Graving Type Dry Dock, Pumped Dry

In the shipyard considerable power is needed, not only to remove the water from the slips but to drive the machine shops, furnish the lighting and run the compressors for supplying air to the drills.

Three years ago Mr. Wm. T. Donnelly, a consulting engineer of New York City, was retained as engineer for this property. At that time the yard was supplied with power from one of the old type plants, consisting of a large boiler plant supplying steam to some twenty steam engines located in various parts of the yard; these engines, with one exception, being of the non-condensing type. Mr. Donnelly recognized the fact that the plant was out-of-date and uneconomical, and considered the installation of an up-to-date power plant with electrical distribution, with the alternative of taking power from a large central station. The results of this investigation confirm the claims made by large central stations, that they can furnish power for an installation of this sort cheaper than it can be generated in a smaller individual power plant. The operation of pumping the docks would give a very heavy peak load of short duration when compared with the average power consumed in the yard. This would mean, of course, a heavy initial expense involved in a plant large enough to handle the heavy peak loads; and besides, a very low load factor. For a large station supplying principally lighting service, with a load factor in the neighborhood of 35 per cent, a customer using approximately 265,000 kw-hrs. per month was indeed a prize. Arrangements were finally made whereby The Edison Electric Illuminating Company of Brooklyn contracted to supply The John N. Robins Co. with power at three-phase, twenty-five cycles, 6600 volts on a maximum demand basis.

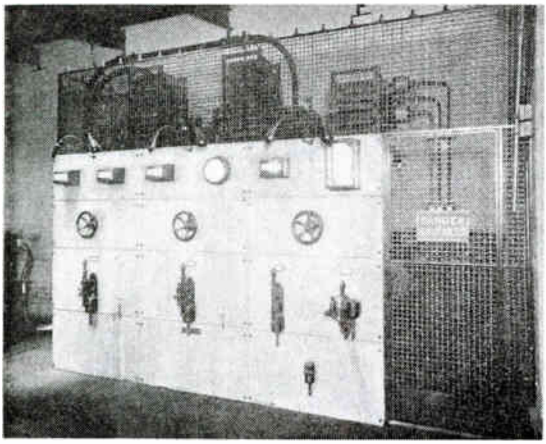


Fig. 2. Switchboard for Controlling Pump Motors

In changing to electric drive, a large distributing board was necessary to take the power from the Edison system and distribute it to the various parts of the yard. Space was a primary consideration and an unusually compact and complete switchboard was installed for this purpose. This board is of General Electric manufacture, the oil switches of which are of the well known "K" type, three-pole, single throw construction, mounted in cells directly back of the panel. Each switch is equipped with an inverse time limit relay, opening the switch when under overload. In addition to the protection against overload, an auxiliary shunt coil was added to the mechanism so that a switch may be opened by remote control from the point in the yard to which the feeder runs. In case of trouble around the yard, this arrangement allows the operator to disconnect his circuit by opening the main feeder switch, without having to get in touch with the operator at the main switchboard. Wattmeters are installed on all of the various circuits so that the amount of power used can be readily analyzed; these wattmeters, which are of the recording polyphase induction type, are designed for switchboard work and are of the very highest grade. A duplicate set of busbars was installed in order to make a flexible arrangement and at the same time allow the operator to work on one set of bars while the other is supplying power to the yards.

Two of the largest feeders from the distributing board run to the motors that are used to drive the vertical pumps which pump the water from the slips of the graving docks. These units consist of two 350 h.p., three-phase, 6600 volt, 25 cycle vertical type induction motors, each direct connected to a vertical type 30 inch centrifugal pump. These motors are designed with wound rotors and are furnished with starting resistance which is connected in series with the rotor winding when starting. This resistance increases the starting torque and limits the initial rush of current to the machine when it is connected to the line. The motors are supported on ball bearings located at the top of the machine and supplied with oil by means of centrifugal oil deflectors.

In the old system of direct connected steam-driven pumps, between two and three hours were required to remove the water from the graving docks; depending, of course, upon the size of the vessel in the slip. In changing to electric drive Mr. Donnelly figured on enlarging the water mains and increasing the amount of water which could be handled in a given time. The time required to empty the docks with the two motor-driven pumps is from one and one-quarter to two hours, depending upon the size of the vessel in the slip.

In addition to the two pumps that are used intermittently, a small vertical motor-driven pump, similar to the larger pumps, was installed to operate continuously and handle the leakage which is bound to accumulate in the slips. This vertical pump is driven by a 50 h.p., 440 volt, 25 cycle three-phase induction motor equipped with wound rotor and starting resistance. The motor is operated from a step-down transformer, it being undesirable to wind a machine of this size for 6600 volts.

A blue Vermont marble switchboard was installed to control the above motors and is shown in Fig. 2. This switchboard presents an unusually attractive appearance. The oil switches are of the same type as those used on the main distributing board, and in addition to being automatically opened under overload, they are equipped with automatic release for no voltage conditions. The load on the pumps increases inversely as the head against which they are delivering water and in order to indicate an overload condition before the oil switch is tripped, a relay is inserted which is so connected as to ring a gong and thus notify the operator. If the load on the pump is not relieved, the oil switch will be tripped. The controllers that are used to vary the resistance in the wound secondaries of the motors are interlocked with the switch mechanism so that it is impossible to throw in the oil switch unless all the resistance is in the rotor circuit. Ammeters are placed in the various circuits and a voltmeter is installed to indicate when the bus is alive.

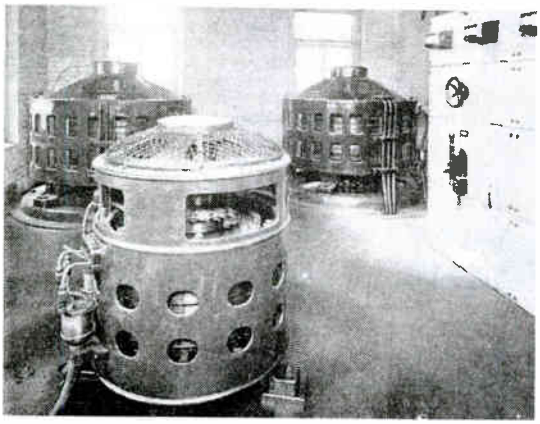


Fig. 3. Two 350 H.P. Induction Motors in Background
50 H.P. Induction Motor in Foreground

The shops of the yard have been changed from the old belt drive with long lines of shafting to motor drive with the group arrangement. The shops are very large and complete, and comprise a large machine shop with tools for handling cylinders and crank shafts of large ships, a smaller machine shop, a boiler shop with large rolls, a copper and sheet metal shop, a blacksmith shop equipped with steam hammers, and a carpenter shop complete with joiner and woodworking machinery. Power in all of these shops is supplied by the General Electric squirrel cage induction motors, started by means of compensators with self-contained oil switches.

The installation nicely illustrates the present tendency of large central stations designed primarily for lighting purposes to increase their load factor by soliciting power customers of the largest class.

CATENARY LINE MATERIAL

By R. L. Hoffman

The advent of increased speeds and operating voltages on electric railways demanded that radical improvements be made in the existing overhead system, with the result that the catenary form of construction was developed. The advantages of this method of suspension are found principally in its adaptability to longer spans in the cross span and bracket construction; for instance, spans of from 125 ft. to 175 ft. are possible with catenary construction as against 80 ft. to 100 ft. with direct suspension. (Fig. 9). Also, by the use of structural steel bridges or supports, spans of from 240 ft. to 300 ft. are practical. The line can readily be insulated for any practical operating voltage and the contact wire can be made as nearly level as good operation requires, dependent on the type of collecting device to be used. All rigid or hard spots are eliminated and vibrations in the contact wire produced by the passing collectors are free to travel in either direction this point. Catenary construction further provides safe clearances for the insulators and for the guy wires from the collecting devices, and by using copper in the messenger or supporting cable, the necessity of erecting an additional feeder cable is obviated.

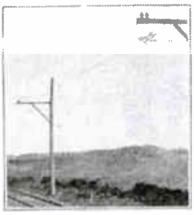


Fig. 1. One-Point Suspension

On 600 volt direct current lines the principal advantage of catenary construction is the elimination of trolley trouble at high speeds, owing to the flexibility of the construction; on interurban roads, therefore, the life of the wheel and contact wire is greatly increased. With the exception of the strain insulators, the material used for 1200 volt work is the same as that used for 600 volt work, and consequently lines operating on both potentials need carry only those repair parts common to both systems.

To make the table applicable for 1200 volt construction it is only neccessary to add a certain amount for additional insulation, which consists of the substitution or addition of proper strain insulators.

The following amounts should be added to give proper values for 1200 volt construction:

Direct suspension
- Bracket construction $40.00
- Span construction . . 40.00

Catenary suspension
- Bracket construction $10.00
- Span construction . . 10.00

COMPARATIVE COST PER MILE OF 600 VOLT TANGENT TRACK OVERHEAD CONSTRUCTION

Pole spacing { Direct Suspension 100 Feet; Catenary 150 Feet	Direct Suspension Bracket	Direct Suspension Span	Catenary—Three-Point Bracket	Catenary—Three-Point Span
Line material	$144.51	$98.85	$144.10	$100.54
4/0 grooved trolley wire	540.00	540.00	540.00	540.00
Steel anchor, guy and span cable	45.00	150.00	21.00	100.50
Messenger cable			91.80	91.80
8 in. by 35 ft. poles	265.00	530.00	180.00	360.00
Erecting poles	185.50	371.00	126.00	252.00
Mounting brackets	13.25		9.00	
Cross spans and back guys		212.00		144.00
Stringing wire and clamp	75.00	75.00	200.00	200.00
Install anchors	100.00	100.00	50.00	60.00
Misc. extras	150.00	150.00	150.00	150.00
	$1518.26	$2226.85	$1511.96	$1998.84
Curves plus 10 per cent	151.83	222.69		
Curves plus 15 per cent			226.80	299.84
	$1670.09	$2449.54	$1738.76	$2298.68

indefinitely. In direct suspension these vibrations are confined to a single span and are damped at the point of support, causing the wire to become fatigued and to break at

For similar installations, the first cost per mile of material as compared with direct suspension is approximately the same, while the labor item is greater for catenary construction.

The subsequent maintenance, however, is much less for catenary construction, as there is no wear on any of the supporting parts; and, since the contact wire is free to yield under the upward pressure of the collector, pounding and arcing with their injurious effects to the wire are eliminated, thus reducing to the minimum the possibility of a break.

Among the first efforts in catenary construction was a one point suspension with the contact wire supported from the messenger cable midway between the messenger supports, as shown in Fig. 1. This arrangement was somewhat similar in principle to direct suspension, except that the point of suspension had considerable flexibility which in recent installations has been shown to be desirable.

Further developments have brought out the three point suspension with the messenger supported every 150 ft.; the points of suspension for the conductor therefore being 50 ft. apart. The distance between the messenger and the contact wire at point of support is 22 in. and the sag in the messenger cable 16 in. A $\frac{7}{16}$ in. steel messenger cable having a breakage strain of 9000 lbs. is used, and the stress

Fig. 2. Three-Point Suspension

in messenger and contact wires is kept between 2000 and 2500 lbs. This construction has proven so satisfactory for wheel collector operation that it has been accepted as standard for interurban installations. (Fig. 2.)

The original installation of the 3-point suspension, which consisted of 180 miles of line, has proven very satisfactory from an operating standpoint. The hanger used consisted of a standard three-screw clamping ear and a malleable iron sister hook casting connected by a cold rolled steel strip ⅝ in. wide by ⅛ in. thick. The prongs of the sister

Fig. 3. Sister Hook Casting

hook casting were bent around the messenger cable as shown in Fig. 3. This same form of hanger has been used on a side bracket, double track, 150 ft., 9-point suspension for a high speed trolley with equally satisfactory results.

Later developments have brought about the 150 ft., 11-point suspension, the standard spacing of the hangers for this class of work being 13.6 ft. This construction has a very level contact wire and will give good results.

All of the foregoing constructions have been erected on ordinary wood or tubular iron poles.

A recent installation of 200 ft., 4-point construction with rectangular lattice iron poles for wheel collection has been built. (Fig. 4.) In this installation the distance between the wires was increased to 32 in., the same stress being retained in the messenger and contact wires as in the ordinary standard construction, making only a slight increase in cost per mile of material.

In order to give maximum flexibility to the contact wire, the loop form of hanger has been developed, having an average weight of 8 oz. (Fig. 5.) The stem of this hanger is formed into a long loop at the upper end, so that the contact wire is free to rise from the upward pressure of the collector without lifting the weight of the messenger cable. On 11-point construction several hangers on either side of the collector will be in action at one time. This hanger is intended for spans of 150 ft. or under, but it can be used on the 240 to 300 ft. spans by using two messenger cables, one directly over the other. The main messenger cable then supports the auxiliary messenger for one-third the distance from the main messenger support, and the contact wire is suspended from the auxiliary messengers with hangers spaced the same distance apart as for single messenger construction. No appreciable wear from the action of these hangers can be detected on either the steel or copper messenger cable. Another advantage of this arrangement in operation is that slack or stretch in the contact wire can be compensated for without the necessity of readjusting the hangers.

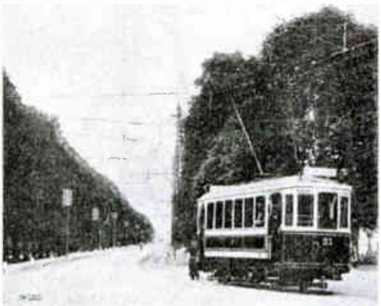


Fig. 4. Four-Point Suspension

Pull-Off and Curve Work

This is the most difficult and expensive part of catenary construction, as the necessity of holding two wires in position does not permit any saving in poles and fixtures, and the labor required is several times that of tangent work for a given distance. The ordinary bridle pull-off construction (Fig. 6) fulfills all the requirements and has some flexibility, and is generally accepted as standard. To obtain good results on curve work the supporting poles should be located on the outside of the track and pull-offs installed so as to maintain the contact wire within 4 to 6 inches of the center of the track. The longer the bridles can be made the greater the flexibility that can be obtained, and on high speed curves of large radius installed in this manner good operation has been the result. Several installations have used steady braces (Fig. 7) consisting of a long cylindrical wooden body and a clamping ear for clamping to the supporting brackets.

For pantograph operation this arrangement

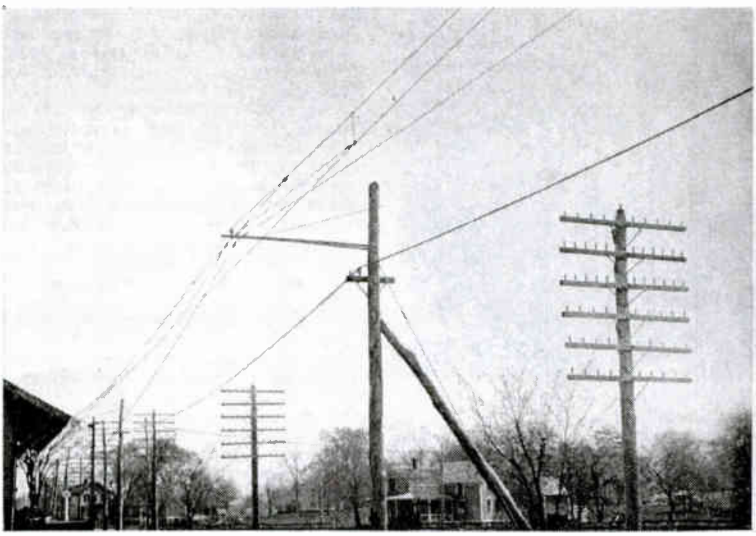


Fig 5. Loop Hanger

is satisfactory, but a considerable reduction in the pole spacing on curves is necessary. Where wheel collectors are used, frequent renewals have to be made, owing to the breaking of the wooden bodies by trolley poles slipping the wire. The point of greatest rigidity in the contact wire lies directly underneath the messenger support and the addition of the weight and tension of the steady brace at this point forms a hard spot.

Anchorages

Recent changes in the method of anchoring the line have resulted in flexibility at this point.

The former method of clamping a rigid hanger between the messenger and the contact wire is now replaced by an arrangement of separate anchor clamps. The messenger clamp is located at a point 10 ft. from the bracket and the contact wire clamp at a point 25 ft. from the bracket. The bracket to which the anchor wires are fastened is in turn anchored to adjacent poles.

Catenary construction on ordinary city electric railways having frequent turnouts and small radius curves should be avoided wherever possible, as local conditions are usually such that the line can not be put up and held with the required tension, owing to the difficulty of locating supports strong enough to hold the strains.

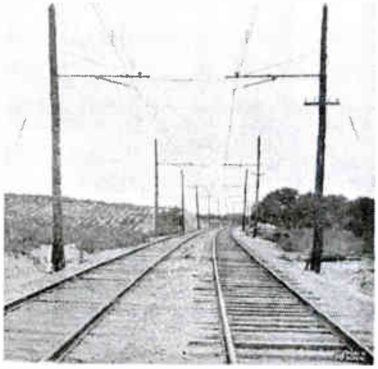


Fig 7. Catenary Construction Showing the Use of Steady Braces

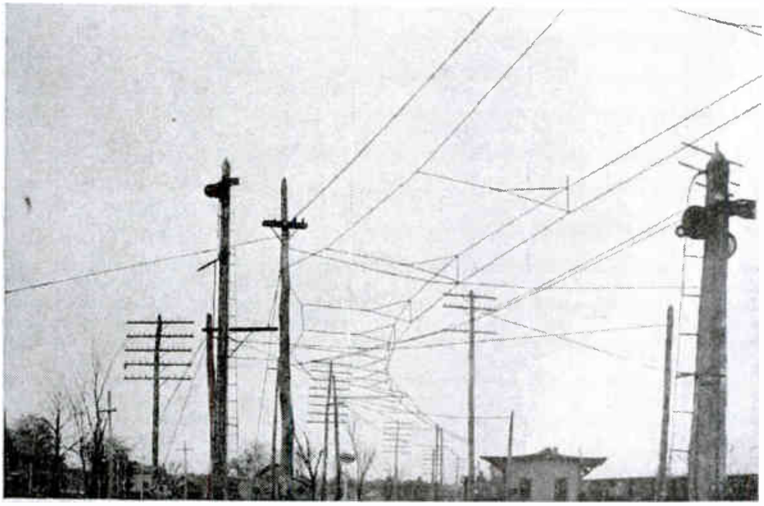


Fig 6. Pull-Off Construction

NOTES ON ELECTRIC LIGHTING

Part II

By Caryl D. Haskins

Manager Lighting Department, General Electric Company

In the first part of this article we decided that our generating apparatus should be three equal units, turbine-driven. We shall not consider the design of the machines—that is a text book matter.

Let us now consider for a moment some of the other apparatus in our station beside the generating units.

The switchboard, for example, is of vital importance to the good or poor operation of the central station. It is only the layout of the switchboard that we are going to discuss; a consideration of its units would carry us too far. First, we must have the one great essential, a panel for the generator—one which will control the generator in all its functions. Generally, there should be one panel for each generator. A generator panel, of course, must be provided with an ammeter, a voltmeter, and an indicating wattmeter. For the sake of economy, a single voltmeter may, in some instances, serve for several generators, and when so used may be placed at one end of the switchboard. Personally, I feel that the provision of a voltmeter on each panel is better practice. The indicating wattmeter is an important instrument on the switchboards of today, since almost every circuit in a generating station is running at a more or less variable power factor. The average switchboard should have certain other instruments, which may be termed minor instruments, as for example a synchronism indicator, which may take either the form of an actual instrument or consist of merely a pair of synchronizing lamps; or a frequency indicator, giving upon a scale, such as that of a voltmeter, the *frequency* of the machine, which means the *speed* of the machine. The latter is a very useful device especially in water power stations, where the speed of the prime mover may be variable. A power factor indicator, though less common, is very valuable, since it saves the comparison of volts times amperes with the reading of the indicating wattmeter; and finally we may find it desirable to use the recording or "curve drawing" instruments for giving us permanent records of voltage or current fluctuations, etc.

Fig. 1. Generator Side

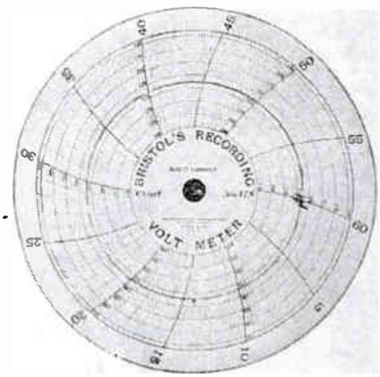


Fig. 2. Regulator Side

We must, of course, have one or more exciter panels in our switchboard for the control of the exciter sets.

Up to this point we have omitted a discussion of single-phase, two-phase and three-phase generation, and here again I must refer you to your text books. The analytical consideration of two versus three-phase service takes one into highly technical questions. Single-phase service is obsolete except for lighting circuits, while three-phase service is becoming daily more universal. Let us then decide arbitrarily that our lighting feeders are to be single-phase and our power feeders three-phase.

It is the practice in many stations to serve power through lighting feeders, but this practice has a grave disadvantage in that the power load often fluctuates severely, and sudden fluctuations in voltage are detrimental to good lighting. Today it is customary in good practice to install a feeder regulator in connection with each lighting feeder, that is, a regulator which will maintain the voltage of that feeder at normal. To show the value of this practice, I have brought these charts (Figs. 1 and 2) showing the variations in voltage on a circuit not equipped with a regulator, and the voltage regulator on the same circuit when equipped with a regulator. The general use of automatic feeder regulators is relatively a new thing; so new, in fact, that five or six years ago only about one station in five or six had them in service. Today, however, there is a large and growing demand for these regulators in central station work, for it is obviously desirable that every central station should have a uniform voltage at the lamps. The rate of installation of feeder regulators during the last four years has increased roughly about 400 per cent. In the old days we used to have voltage regulation of a crude kind by means of hand regulators. Today we have a piece of practically stationary apparatus which depreciates very slowly, and which may be regarded as automatic. Regulators are controlled through relays in a dozen different ways. Power circuits as a rule, do not require close regulation; they do not suffer serious consequences, as do lighting circuits, from voltage fluctuations.

My first experience in connection with the operation of a central station was about twenty-two years ago. The voltage at which the current was transmitted was not high—2400 volts direct current—but in those days we considered it very high. The switches installed were of the ordinary knife blade type and, of course, when we pulled them, we got a heavy arc. We therefore had a notice prepared, which was posted in a conspicuous place near the switch, and read as follows: "The operator will take the paddle in his hand and strike, etc., etc."

The paddle consisted of a good sized wooden handle into which was set a piece of 2-inch belting, and with this instrument we "struck out" the arc as we pulled the switch.

Today, of course, the practice is to break the arc under oil, in what are known as "oil switches." As its name indicates, the oil switch is so designed that when opened the arc which takes place is submerged in oil of a suitable character, thus securing promptly sure, and safe disruption. It is probably one of the most essential and highly developed pieces of apparatus in use today in connection with high tension generating systems. One of our leading scientists has compared the work performed by certain large existing oil switches under short circuit operation, with stopping the Empire State Express in fifty feet when traveling at the rate of a mile a minute, and to my mind this is an excellent way of expressing the "safety buffer" capacity of these devices. Potentials up to 110,000 volts are being handled with oil switches, and I know of certain oil switches that are now being designed and that will shortly be under construction, which will open circuits operating at 140,000 volts. Those of you who have had some experience in connection with high potentials in your work here will appreciate what it means to solve the problem of merely bringing in and out the circuits to such a switch.

Returning to the question of voltage regulation, I have already impressed upon you that it is of great importance that the voltage of the feeders for lighting purposes shall remain uniform. In this respect, alternating current has an enormous advantage over direct current. It will be readily understood that fluctuations in the consumption of energy at the ends of the feeders must, of necessity, result in a material change of "drop" over the entire circuit. It is therefore necessary that the applied voltage at the generating station should respond very readily to this fluctuating demand, in order that the actual voltage applied may remain substantially constant. In no minor feature is alternating current at a greater advantage over direct current than in this connection.

The regulation of direct current systems is, of necessity, accomplished by means of boosters, that is, motor-generator sets or storage batteries, or by rheostatic control. The booster, of course, means moving apparatus, substantially a motor driving a dynamo, its function being commonly to raise the voltage. Generally speaking, this method is undesirable for small plants.

The use of storage batteries for this purpose has troublesome disadvantages except on very large systems, where it becomes desirable. Rheostatic control, however, is worse than either. The use of rheostats serves to reduce the voltage only, with heavy loss of energy. Even for small plants, this method of regulating the voltage is generally condemned. There are but few rheostatic control systems in operation in this country today in central stations, even old ones. In many of the larger direct current stations voltage control is accomplished by means of buses of different voltages, that is, a bus of high voltage, one of low voltage, and another of intermediate voltage. I know of one large city in this country having five buses for this purpose. It does not require an expert to appreciate how complicated such an arrangement renders the switching system. Comparing rheostatic with inductive voltage control on a system of similar size, we find results about as follows:

	Watts Loss	
	Rheostat	Regulator
Full Load	0	335
¾ Load	1300	265
½ Load	2750	215
¼ Load	687	185
No Load	0	175

The induction regulator is, practically speaking, a stationary piece of apparatus; that is, it has no parts with considerable movements, and is so designed that energy is inductively impressed on the outgoing lines in plus or minus direction, as the conditions of regulation may require. This action is controlled automatically or by hand, as may be best or preferred, in such a manner as to raise or lower the voltage of the outgoing lines. The structure being practically stationary, the regulator is subject to but little depreciation and is therefore very much to be preferred to boosters, quite apart from the question of efficiency. Hand control, of course, is by observation on the part of the operator, while automatic control is accomplished by means of a motor, operated through a relay controlled by a contact making voltmeter.

Substations will be dealt with more fully in a later paper. We may say a few words today, however, regarding the various classes of substations.

We may classify substations thus:

(*a*) The static substation, which is by far the most common form. It may consist of one transformer, or a bank of transformers, and its function is to step the voltage up or down, as the case may be, to meet conditions.

(*b*) Motor-generator substations, where the change in voltage (more commonly a change from alternating current to direct current service) is accomplished by means of a motor driving a generator.

(*c*) Rotary substations, in which the rotary converter takes the place of the motor-generator set, performing the same functions.

Dense districts make direct current distribution desirable, and where this system is desirable, the motor-generator rotary is employed to translate the current from alternating to direct.

In comparing 100 kw. units we find that the average efficiency of the rotary at one-half load is about 80 per cent, and that of the motor-generator set about 76 per cent. At full load the efficiency of the motor-generator is 81 per cent, and that of the rotary converter, 87 per cent. Generally speaking, therefore, the advantage is with the rotary. The rotary, however, is a somewhat more delicate piece of apparatus. There are today probably about eight motor-generator sets in use for lighting service to every rotary, but the improvements in rotaries have been rapid of late and the ratio is fast changing in favor of the rotary.

In considering translating devices we must not forget the mercury arc rectifier, a comparatively new device, but one which has already done much for the art in connection with series arc lighting. It chances that at least one of the preferred arc lighting systems of today calls for direct current—direct current from central stations which have no direct current apparatus. The mercury arc rectifier solves the difficulty for such stations in a particularly simple and economical way.

Stated briefly, with the elimination of all complexities, the mercury arc rectifier consists of a vacuum tube with inleading and outleading terminals, containing mercury within it in such a manner as to permit of the starting of an arc (not in vacuum really, but through mercury vapor) between one pocket of mercury and another. Such an arc is peculiar physically, in that it permits, when once established, of the passage of electric current through it *in one direction but not in the other*. We may define the theory of the rectifier thus:

Mercury vapor, under ordinary conditions, is a non-conductor, that is, if mercury be placed in a test tube and submitted to the Bunsen flame, the vapors thrown off are highly non-conductive. If this same mercury vapor is "ionized," that is, if each atom of mercury vapor receives a definite electric charge (like a Leyden jar), and if these charged atoms are moving under the influence of the potential, then the vapor immediately becomes a conductor, but in one direction only. We can not state why this is so, but can only accept it as a physical axiom of recent discovery.

The functionings of the mercury arc rectifier are not, to many people, easy of immediate comprehension, but a German engineer, who was in this country last year, expressed the matter most clearly when he said, "It's yoost like getting a feash hook in your fingker."

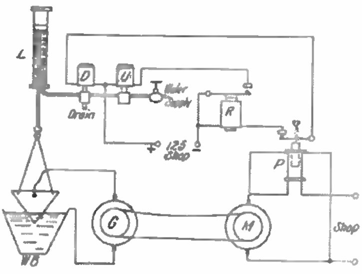
We have now taken a cursory glance at some of the essential features of the generating station. In the next paper I shall deal with the distribution and translation of the current, particularly with relation to pole lines and their construction, the conductors, insulators, and the governing conditions of voltage for various applications and distances; in short we shall deal with the questions of detail involved in getting the current from the generators to the point of use.

AUTOMATIC LOAD REGULATION BY MEANS OF WATER-BOX CONTROL

By Harold V. Green

The Testing Department of the General Electric Company recently made an endurance test upon a motor of special construction, the instructions calling for continuous daily operation under full load for a number of months. To conduct the test properly, it was necessary to devise some sort of automatic load control. A description of the mechanism employed is given below.

The motor was belted to a shop generator, this generator in turn being loaded on a water-box equipped with the usual water-box control. Because of the large field current taken by the generator, and also because of the unsatisfactory operation of a water-box with a fixed setting of the blade, the TD type



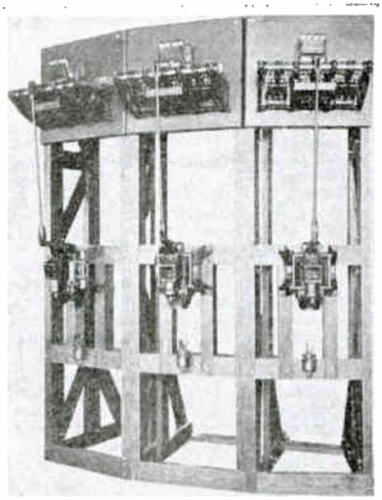
of voltage regulator was not applicable. It therefore became necessary to construct a regulator that would act upon the water-box blade through the medium of its remote electrical control. To fulfill this requirement a special regulator was devised which employed the use of the hunting regulator principle; the range of variation being kept so small as not to be appreciable. This regulator is shown in the accompanying diagram. A contact-making wattmeter, *P*, was placed in the motor circuit, and was so adjusted as to open its contacts at full load. The hydraulic lift, *L*, from which the water-box blade was suspended, was controlled through the electromagnetic valves *V* and *D*; *V* admitting water to the under side of the piston and *D* draining it. With all switches closed and the wiring arranged as shown in diagram, the valve *D* was in its open position and the water-box blade would descend by gravity. When full load on the motor was attained, contacts on *P* would open, thereby opening the circuit through the relay *R* which, in turn, would close the upside of the water-box control. Thereupon the water-box blade would ascend until its motion was arrested by the closing of the contacts on relay *P*, when the blade would again begin its downward travel and the cycle would be repeated. To prevent too rapid a cycle of operation the supply of water to the hydraulic lift was throttled at the inlet valve.

When properly adjusted this regulator was able to hold a load on the motor within one-half of one per cent. Observations of the behavior of the water-box blade showed that there was a movement of the blade up or down of about one-sixth of an inch, at intervals of approximately one minute, depending upon the stability of the shop voltage.

A LARGE ALTERNATING CURRENT CIRCUIT BREAKER INSTALLATION

By D. S. Morgan

The construction of a circuit breaker for use on heavy alternating current circuits presents a somewhat difficult problem to the designing electrical engineer. The distribution of the current uniformly throughout the various parts of the breaker and the avoidance of skin effect, energy losses in heating, etc., are the factors with which he has to deal.

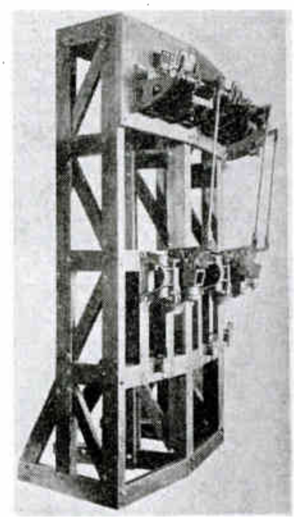


12,000 Ampere A.C. Circuit Breaker

The largest alternating current circuit breaker yet built is installed in the Worsted Mills of the American Woolen Company at Lawrence, Mass., and protects a 600 volt, 40 cycle turbine alternator. The breaker is a triple-pole solenoid-operated, Type C, Form K-2 breaker, and was built by the General Electric Company. It has a current carrying capacity of 12,000 amperes and will carry this current continuously without overheating.

If a circuit breaker for use on heavy alternating current circuits of 6000 amperes and over were built on the lines of usual direct current construction it would not satisfactorily perform its work, and would in service heat to a dangerous degree. To avoid this, special construction must be employed.

In the design of the circuit breaker in question, a large amount of radiating surface was provided and also an arrangement was made for the uniform distribution of the current in the various parts by subdividing the contact brushes and the studs of each pole into six sections, each insulated from the others. Each pole of the circuit breaker is operated by a separate solenoid mechanism so connected that the entire triple-pole breaker is controlled by a single control switch on the switchboard panel. The open and closed positions of the breaker are indicated by signal lamps located at the controlling switch.



12,000 Ampere A.C. Breaker. Side View

To obviate the necessity of opening an arc at the control switch, the circuit of the closing coils is opened on control relays located near the circuit breakers, the trip coils being opened by auxiliary switches operated by the breaker itself. The breaker is made automatic by the use of current transformers and relays. The circuit breaker, solenoids and control relays are mounted on specially designed hard wood supporting framework made to conform to the perimeter of the turbine to which the framework is secured. (See illustrations.)

Operation

The breaker has now been in operation for several months and according to reports received lately is operating satisfactorily. This, however, is not more than was expected, because before shipment, after being well tried out for purposes of adjustment and to discover any weak points in construction, the breaker was subjected to thorough mechanical endurance tests under conditions much more severe than it could possibly be expected to encounter in actual service.

THE TURBINE

By Harriet Monroe

Look at her—there she sits upon her throne
As ladylike and quiet as a nun!
But if you cross her—whew! her thunderbolts
Will shake the earth! She's proud as any queen,
The beauty—knows her royal business too,
To light the world, and does it night by night
When her gay lord, the sun, gives up his job.
I am her slave; I wake and watch and run
From dark till dawn beside her. All the while
She hums there softly, purring with delight
Because men bring the riches of the earth
To feed her yearning fires. I do her will
And dare not disobey, for her right hand
Is power, her left is terror, and her anger
Is havoc. Look—if I but lay a wire
Across the terminals of yonder switch
She'll burst her windings, rip her casings off,
And shriek till envious Hell shoots up its flames,
Shattering her very throne. And all her people,
The laboring, trampling, dreaming crowds out there—
Fools and the wise who look to her for light—
Will walk in darkness through the liquid night,
Submerged.
Sometimes I wonder why she stoops
To be my friend—oh, yes, who talks to me
And sings away my loneliness; my friend,
Though I am trivial and she sublime.
Hard-hearted?—No, tender and pitiful,
As all the great are. Every arrogant grief
She comforts quietly, and all my joys
Dance to her measures through the tolerant night.
She talks to me, tells me her troubles too,
Just as I tell her mine. Perhaps she feels
An ache deep down—that agonizing stab
Of grit grating her bearings; then her voice
Changes its tune, it wails and calls to me
To soothe her anguish, and I run, her slave,
Probe like a surgeon and relieve the pain.
But there are moments—hush!—when my turn comes,
Times when her slave commands, becomes her master,
Conquering her he serves. For she's a woman,
Gets bored there on her throne, tired of herself,
Tingles with power that turns to wantonness.
Suddenly something's wrong—she laughs at me,
Bedevils the frail wires with some mad caress
That thrills blind space, calls down ten thousand lightnings
To shatter her world and set her spirit free.

Then with this puny hand, swift as her threat,
Must I beat back the chaos, hold in leash
Destructive furies, rescue her—even her—
From the fierce rashness of her truant mood,
And make me lord of far and near a moment,
Startling the mystery. Last night I did it—
Alone here with my hand upon her heart
I faced the mounting fiends and whipped them down;
And never a wink from the long file of lamps
Betrayed her to the world.
So there she sits,
Mounted on all the ages, at the peak
Of time. The first man dreamed of light, and dug
The sodden ignorance away, and cursed
The darkness; young primeval races dragged
Foundation stones, and piled into the void
Rage and desire; the Greek mounted and sang
Promethean songs and light a signal fire;
The Roman bent his iron will to forge
Deep furnaces; slow epochs riveted
With hope and secret chambers; till at last
We, you and I, this living age of ours,
A new-winged Mercury, out of the skies
Filch the wild spirit of light, and chain him there
To do her will forever.
Look, my friend,
Behold a sign! What is this crystal sphere—
This little bulb of glass I lightly lift,
This iridescent bubble a child might blow
Out of its brazen pipe to hold the sun—
What strange toy is it? In my hand it lies
Cold and inert, its puny artery—
That curling cobweb film—ashen and dead.
But see—a twist or two—let it but touch
The hem, far trailing, of my lady's robe,
And lo, the burning life-blood of the stars
Leaps to its heart, that glows against the dark,
Kindling the world.
Even so I touch her garment,
Her servant through the quiet night. Even thus
I lay my hand upon the Pleiades
And feel their throb of fire. Grandly she gives
To me unworthy; woman inscrutable,
Scatters her splendors through my darkness, leads me
Far out into the workshop of the worlds.
There I can feel those infinite energies
Our little earth just gnaws at through the ether,
And see the light our sunshine hides. Out there
Close to the heart of life I am at peace.

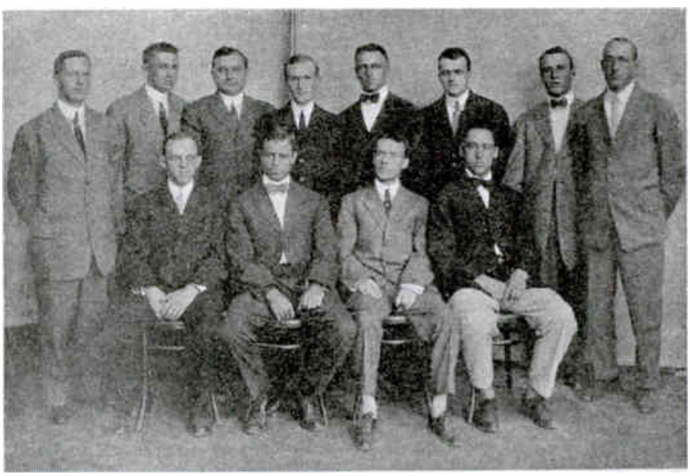
The Atlantic Monthly.

FIRST ANNUAL MEETING OF SWITCHBOARD SPECIALISTS

The switchboard specialist is the logical result of the need for the services of trained experts to deal with the control and distribution of the large amounts of electrical energy and the high voltages that are now being constantly developed.

In laying out a large station, particularly, great precautions must be taken to secure the proper switching equipment. The energy must be safely and economically controlled. The system must have proper flexibility and must be simple in arrangement so that no confusion will arise in operation. The switchboard must be so designed that extensions can be made without unnecessary expense or liability of shut-down and at the same time without danger to the workmen. In other words there must be at the command of the customer an expert who is so conversant with all conditions of switchboard practice in its various manifestations, that he is able to recommend in every instance the best equipment available, due consideration being given to all the essential points in the installation. But for the switchboard specialist in the field to be able to acquaint the customer with the best apparatus that can be supplied to fill his needs, it is necessary for the specialist to be fully informed concerning new developments in his line.

This can best be accomplished by bringing together at certain intervals the entire selling and designing forces of the manufacturing concern, with the purpose of giving a thorough consideration to all points both commercial and engineering that have developed since the previous meeting. The result will be two-fold: 1st, to acquaint the specialist with the recent developments in switchboard work; and, 2nd, to enable the designing engineer to become acquainted with the problems of switchboard engineering that have been encountered by the switchboard specialists during the last year, the new needs that have arisen, and the behavior of apparatus in actual service.



Switchboard Specialists in Attendance at First Annual Meeting

With these ends in view, the switchboard specialists of the General Electric Company held their first annual convention during the week commencing August 29th. The first four days of the week were spent in Schenectady, and on Friday and Saturday the conference was continued at Lynn.

In order to derive as much benefit as possible and to economize time, a comprehensive programme, laid out in advance, was rigorously adhered to, and the entire switchboard situation was gone into thoroughly. Shop trips to inspect apparatus were taken each day after the conclusion of the subjects scheduled for discussion.

The free interchange of ideas which took place at the convention must result in a decided help to all concerned, but especially to the customer since the better acquainted a salesman is with the appliance he sells, the more the benefits that accrue to the customer who follows his recommendations.

The accompanying illustration shows the specialists in attendance; they are, sitting left to right, C. C. Adams, T. S. Knight, C. M. Parker, F. W. Paterson: Standing, left to right, A. B. Lawrence, W. H. Heinz, Saul Lavine, G. A. Elder, H. H. Bodge, E. A. Harriss, F. E. Hause, H. H. Gardiner.

Specialists are located in offices of the General Electric Company at Boston, Chicago, New York, Pittsburgh, Philadelphia, San Francisco.

NOTES

During the months of July, August and September the following student engineers entered the Testing Department of the General Electric Company.

Albergotti, W. McA., Clemson College
Allen, H. E., University of Colorado
Ames, M. P., University of Vermont
Anderson, C. B., Purdue University
Anderson, J., Lehigh University
Andrews, H. L., Clemson College
Bacon, H. R., Sheffield Scientific School
Bahm, J. B., Louisiana State University
Bailey, E. H., University of Illinois
Balmson, G. F. R., Lehigh University
Becker, W. J., Union College
Beebe, L. H., Pennsylvania State College
Beekman, R. A., University of Missouri
Berg, A. L., University of Colorado
Bergland, W. S., Princeton University
Bell, H. A., Ohio State University
Bell, W. R., Worcester Polytechnic Institute
Benford, F. A., University of Michigan
Bennett, C. S., University of Kentucky
Bird, D. M., University of Nevada
Bird, Howard, Sheffield Scientific School (Yale)
Binns, C. A., Leland Stanford University
Bonnett, L. B., Syracuse University
Boos, H. C., Cornell University
Bossinger, H. C., Cornell University
Bower, G. W., Pennsylvania State College
Brockman, T. H., Tulane University
Bronson, J. T., Syracuse University
Brooks, G. W., Pratt Institute
Brown, H. D., Cornell University
Byerts, W. E., University of Nebraska
Camp, W. E., Oklahoma A. & M. College
Cann, L. B., Delaware College
Card, B. A., University of Kansas
Chadbourne, V. R., University of Maine
Chapman, F. W., Clemson College
Charest, J. G., Union College
Cheshire, J., Vanderbilt University
Clenn, E., University of Colorado
Cole, K. B. N., University of Arkansas
Corlette, L. H., Iowa State College
Corwin, H. G., Clarkson School of Technology
Cramer, H. P., Leland Stanford University
Crane, D. R., University of California
Crawford, H. V., University of Arkansas
Cumming, G. B., University of California
Curtis, L. F., Tufts College
Davis, A , Georgia School of Technology
Dennis, A. R., Union College
De Toledo, P. F., Union College
Deuel, H. R., University of Montana
Dickerson, A. F., A. & M. College of Texas
Dillinger, G. A., Union College
Doyle, E. D., University of Illinois
Dull, A. W., Purdue University
Edgell, W. T., Jr., La Fayette College
Edmonds, W. E., University of Kansas
Edwards, E. B., University of Michigan
Eliason, W. L., Delaware College
Farber, E., University of Kansas
Farrar, J. L., Lehigh University
Paulds, N. M., Oklahoma A. & M. College
Force, H. H., Ohio State University
Fosterling, C. W., Georgia School of Technology
Foust, C. A., Lehigh University
Fraukenfield, M. W., Virginia Polytechnic Institute
Fulmer, T., Clemson College
Gardner, G. N., Harvard University
Garza, J. I., University of Illinois
Gates, H. C., University of Michigan
Gifford, E. E., Syracuse University
Gill, J. H., University of Texas
Gill, M. F., University of Texas
Gold, R. G., Worcester Polytechnic Institute
Goldberg, W., Case School of Applied Science
Goodrich, G. P., University of Maine
Graeff, W. K., Pennsylvania State College
Grover, H. H., Union College
Hall, C. A., University of Maine
Hallock, H. F., University of Michigan
Hamman, A. M., Columbia University
Hansel, D. R., University of Pennsylvania
Harrison, E. M., Purdue University
Haspel, E., Tulane University
Hawkins, H. B., Virginia Polytechnic Institute
Heissler, L. J., Clarkson School of Technology
Henry, H. W., Rose Polytechnic Institute
Happerlen, J. A., University of Nebraska
Hoel, R. W., Pratt Institute
Hord, T. A., Jr., University of Texas
Horn, A. F. E., Delaware College
Horn, Max, University of Pennsylvania
Hoskins, H. A., W. Virginia University
Huston, C. B., University of Nebraska

Ingram, H. L., A. & M. College of Texas
Jeter, G. G., University of Illinois
Johnson, F. B., Iowa State College
Johnson, P., University of Nebraska
Jones, C. E., Georgia School of Technology
Jones, L., University of Colorado
Jump, G. H., Syracuse University
Keese, F. D., Syracuse University
Kelley, S. D., Union College
Keppel, W. M., Cornell University
Keyes, W. R., University of California
Kimball, W. G., Sheffield Scientific School
Kirkman, J., Cornell University
Knapp, L. H., Purdue University
Kriegsman, A. E., Union College
Lane, W. G., Iowa State College
Lapp, H. D., University of Michigan
Leavitt, J. H., Tufts College
Lewis, William, Lehigh University
Mack, E. D., University of Nevada
Madison, H. J., Rose Polytechnic Institute
McCarthy, E. T., Cornell University
McClintock, Paul, Tufts College
Mercer, J. M., Iowa State College
Metcalfe, V. E., University of Colorado
Miller, A. G., University of Missouri
Mills, G. P., University of Kentucky
Moore, D. H., N. Dakota Argicultural College
Moreland, C. M., University of Arkansas
Morris, G. S., University of Kansas
Myer, W. M., Pratt Institute
Neilson, W. B., Jr., Union College
Nixdorff, S. P., Cornell University
Noble, J. A., Iowa State College
Nuti, C. B., University of Wisconsin
O'Connell, W. T., Worcester Polytechnic Institute
Odell, I. N., Purdue University
Orbison, T. E., Cornell University
Owen, A. S., Cornell University
Paine, R. A., Virginia Polytechnic Institute
Parker, F. T., Leland Stanford Institute
Paul, W. E., Union College
Peabody, G. A., Rhode Island State College
Phelps, S. L., Purdue University
Phillips, W. R., N. C. College of A. & M. A.
Pierce, L. G., University of Illinois
Plankinton, J., Oregon Argicultural School
Plenge, H. D., Clemson College
Poindexter, P. W., Rose Polytechnic Institute
Ponsler, R. L., University of Kansas
Proctor, W. R., Purdue University
Propst, H. M., Oregon Agricultural College
Rank, F. A., University of Colorado
Rankin, H. McC., University of Michigan
Riggs, L. W., Cornell University
Rhode, W. C., University of Wisconsin
Rolnick, S., Ohio State University
Rose, T. D., University of North Carolina
Rusher, M. A., Cornell University
Sage, W. C., Purdue University
Schaller, W. F., University of Illinois
Schmidt, F. L. A., Case School of Applied Science
Shuler, E. H., Clemson College
Sears, R. P., Union College
Seymour, E. R., Case School of Applied Science
Shanklin, S., University of Kentucky
Shelby, J. B., University of Kentucky
Sherman, A. H., Union College
Shirley, A. A., Purdue University
Shirley, O. E., University of Illinois
Slutter, N. W., Union College
Smith, D. F., University of Nebraska
Smith, R. P., Harvard University
Snyder, T. I., Purdue University
So Relle, A. W., University of Michigan
Spurck, R. M., University of Illinois
Stafford, R. W., Colorado University
Stephens, L. T., Pennsylvania State College
Stilwell, E. D., University of Wisconsin
Storm, S. B., Tulane University
Stump, J. H., Rose Polytechnic Institute
Summers, J. A., Pennsylvania State College
Swope, R. B., Lehigh University
Sykes, C. S., University of Vermont
Taylor, A. L. R., University of Utah
Taylor, B. W., Ohio State University
Taylow, C. W., Tufts College
Thomas, E. E., Purdue University
Thomas, R. B., University of Kansas
Thornberg, C. E., University of Nebraska
Townsend, C. P., Clemson College
Tozier, E. S., Rutgers College
Treene, W. H., Cornell University
Twogood, E. N., University of California
Varderzee, G. W., University of Wisconsin
Van Meter, M. E., Iowa State College
Venn, J. G., Worcester Polytechnic Institute
Vivian, W. T., University of Nebraska
Wall, R., Leland Stanford University
Wanner, R. W., Pennsylvania State College
Ward, C. Q., Kansas State Agricultural College
Washburn, F. J., University of Vermont
Weber, E. R., University of Colorado
Webster, G. A., University of Maine
West, G. S., Tulane University
Wettengel, F. J., Iowa State College
Wheatlake, B. C. J., University of Illinois
Wheeler, R. H., Rhode Island State College
Whicker, M. N., Purdue University
Whitmore, P. J., Union College
Whyte, A. C., Stevens Institute of Technology
Williams, W. W., University of Cincinnati
Wilson, A., Cornell University
Wilson, J. E., University of Pennsylvania
Wilson, L. H., Clarkson School of Technology
Winne, H. A., Syracuse University
Winter, F. H., University of Kansas
Wood, H. J., Georgia School of Technology
Wolf, A. F., Tulane University
Zwiebel, O. J., Worcester Polytechnic Institute

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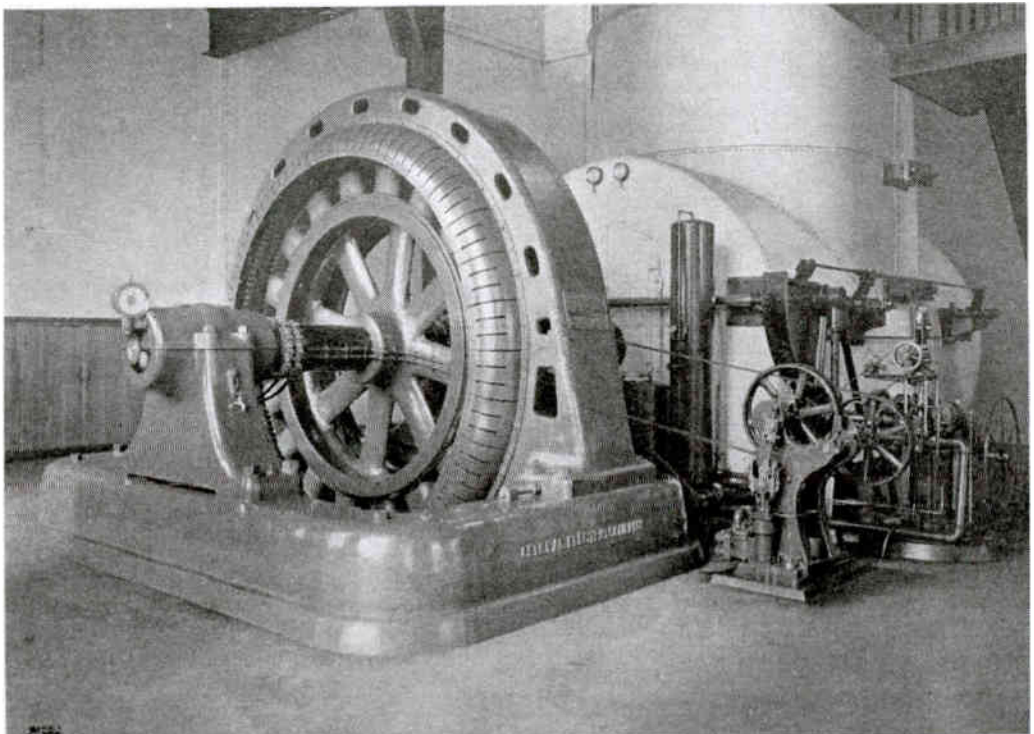

2000 Kw., 6600 Volt, 3-Phase Generator, Waterwheel-Driven, Moreau Power House

(See Page 569)