General Electric Company

Schenectady, N.Y.

SUPPLY DEPARTMENT

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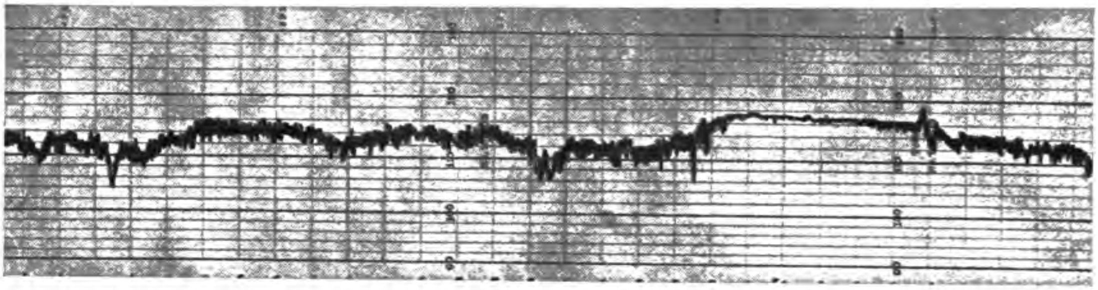
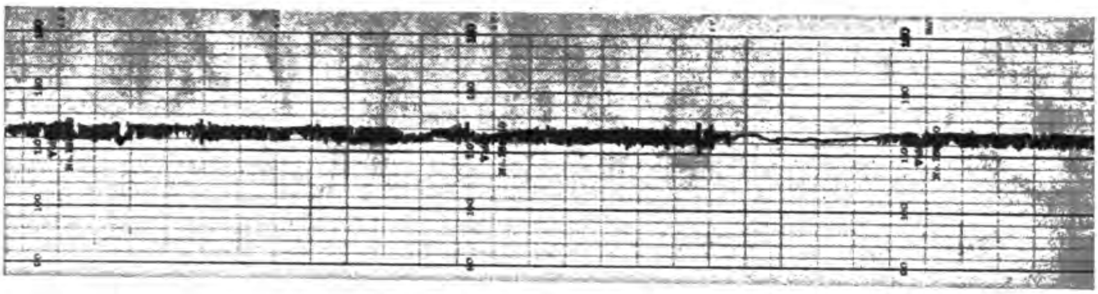
FEEDER VOLTAGE REGULATORS

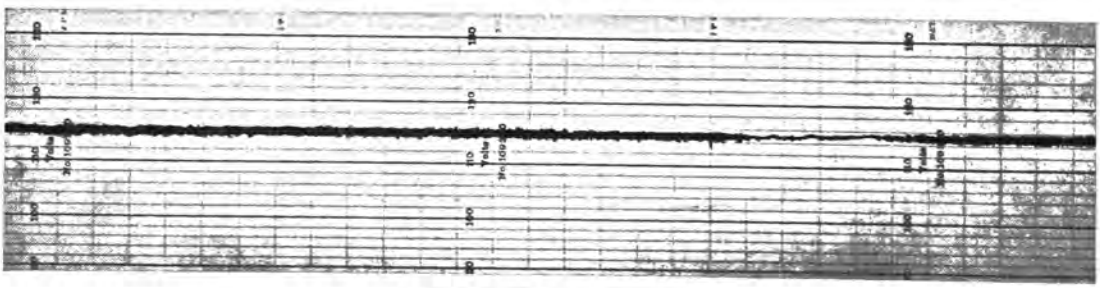
The tendency of modern generating and distributing stations toward the installation of large alternating current units increases the necessity for regulators for the control of individual feeders radiating from a common center. One feeder may serve a business district, while another from the same generator may serve a residence district, and



Generator Voltage



Feeder Voltage with IRS Regulator



Feeder Voltage with BR Regulator

Fig. 1

VOLTAGE CHARTS TAKEN ON AN UNREGULATED CIRCUIT AND ON CIRCUITS CONTROLLED BY AN IRS AND BR REGULATOR RESPECTIVELY, ALL THREE CIRCUITS BEING TAKEN FROM THE SAME GENERATOR AND AT THE SAME POINT

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since the amount of compensation required depends on the load, and since the peak of the load occurs at different times in different feeders, the regulation of the individual feeder is essential if good regulation is to be obtained on the entire system.

In order to meet different requirements and satisfy the varying conditions, the General Electric Company has designed and manufactures several types of feeder regulators, which have given satisfaction wherever they have been installed.

Feeder regulators may be classified as Induction Type and Switch Type, Single-Phase and Polyphase, Hand Operated and Automatically Operated. Each type will be described separately.

GENERAL PRINCIPLES

All feeder regulators manufactured by the General Electric Company are variable ratio transformers, or rather compensators, having two separate and distinct windings, primary and secondary, connected respectively across,

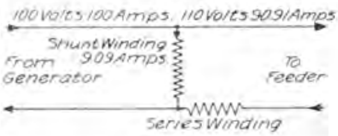


Fig. 2
REGULATOR BOOSTING

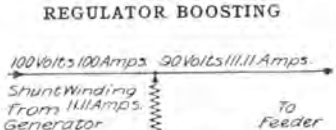


Fig. 3
REGULATOR LOWERING

and in series with, the feeder to be controlled. The product of the volts and amperes on the generator or busbar side is always equal to the product of the volts and amperes on the feeder side, less the small loss in the regulator itself.

This principle applies to both the single-phase and polyphase types of regulator, but for simplicity of illustration assume a single-phase regulator for a 100 volt, 100 ampere circuit having a capacity to produce a total range of 20 per cent in the voltage of the circuit, i.e., a variation from 10 per cent above to 10 per cent below normal, and further assume that there is no loss in the device itself. The values of currents and voltages may then be shown graphically as in Figs. 2 and 3, the former showing the values with the regulator in the maximum boosting position, and the latter with the regulator in the maximum lowering position. Intermediate values may be similarly shown.

With a regulator capable of a total variation of 20 per cent in the maximum boosting position, 9 per cent of the current flows through the primary and back into the line, and this amount is, therefore, deducted from the useful current in the feeder, but the feeder potential is thereby increased 10 per cent; whereas with the regulator in the maximum lowering position, the current in the shunt winding is reversed, thus increasing the useful feeder current by 11 per cent, but at the expense of lowering the voltage by 10 per cent.

This type of regulator should, therefore, not be confused with the "resistance" or "reactance" types of regulators, which can be used only for lowering the potential, and do so by actually absorbing voltage in the resistance of the device, either ohmic or reactive. Both the resistance and the reactance types of regulators consist of a single winding which is connected in series with the line to be controlled, so that the current on both sides of the device must necessarily be the same, and the product of this current by the voltage drop across the terminals represents either a dead loss or a very poor power factor. Moreover, the regulation depends entirely on the current in the feeder; whereas, with an induction regulator, the same amount of boosting and lowering can be obtained with any load, from no load to full load.

INDUCTION REGULATORS

Induction regulators are built single-phase or polyphase, and are designated by the type letters IRS for the single-phase, IRQ for the quarter-phase, IRT for the three-phase, and IRH for the six-phase designs. Although used principally for the control of lighting circuits, they are equally well adapted to power circuits, either single-phase or polyphase. Heretofore they have been used principally in connection with polyphase rotary converters, but at the present time the majority furnished are for the regulation of lighting feeders, particularly those of the three-phase, four-wire system, which constitutes in effect three individual single-phase feeders, each feeder requiring its own regulator.

Fig. 4
23 KW., 60 CYCLE, 2300 VOLT, SINGLE-PHASE, OIL IMMERSED, SELF-COOLED, AUTOMATIC TYPE IRS FEEDER VOLTAGE REGULATOR

In all induction regulators manufactured by the General Electric Company, with the exception of the Type MR, two windings are arranged on separate, circular, concentric sheet iron cores, one of which is stationary, and the other arranged so that it may be partially rotated within the former. The series or secondary winding is arranged in slots on the inside circumference of the stationary core, and the shunt or primary winding in similar slots on the outside circumference of the movable core, and the variation in the feeder voltage produced by the regulator is entirely due to the change in the angular positions of these cores.

This construction is shown in Fig. 7, which is a view of a partially disassembled single-phase induction regulator.

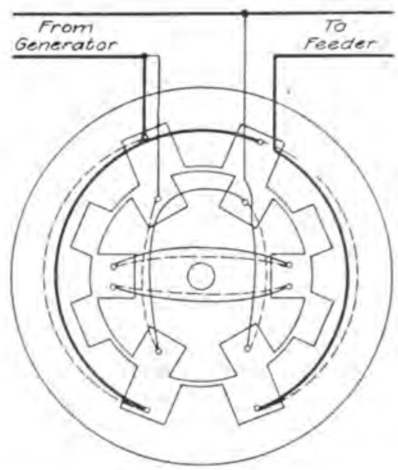


Fig. 5
ARRANGEMENT OF PRIMARY (ARMATURE) AND SECONDARY (FIELD) CORES AND WINDINGS IN SINGLE-PHASE INDUCTION FEEDER REGULATOR. ARMATURE IN MAXIMUM LOWERING POSITION

The windings on both stationary and movable cores are in effect polar windings. With a given pole of the primary opposite a similar pole of the secondary, the regulator will boost the line voltage, but will lower it if opposite a dissimilar pole; and the change from "boost" to "lower" is gradual as a given primary pole is rotated through the angle between a similar and a dissimilar pole of the secondary. The method of producing these results is, however, radically different in the single-phase and polyphase types, and each will, therefore, be discussed separately.

SINGLE-PHASE REGULATORS

The arrangement of the primary and secondary cores and windings is shown diagrammatically in Fig. 5. As there is only one excitation winding, the magnetizing flux is an alternating one and its direction is always parallel to that diameter of the movable core which passes through the center of the exciting coils, but its direction may be varied with respect to the stationary core, and, consequently, with respect to the stationary or series winding.

With the armature in such a relation to the field that the primary winding induces a flux opposed to that induced by the secondary, the voltage induced by the primary in the secondary is added directly to the line voltage, but is subtracted when the direction of the flux is the same; the complete range being obtained by rotating the armature through an angle of 180 degrees. As the core is rotated gradually, the relative direction of the primary flux, and, consequently, the amount forced through the secondary coils, is similarly varied and produces a gradually varying potential in the secondary from the maximum positive, through zero, to the maximum negative value. The induced potential is, however, always in phase with the excitation, and is, therefore, added directly to, or subtracted directly from the line voltage.

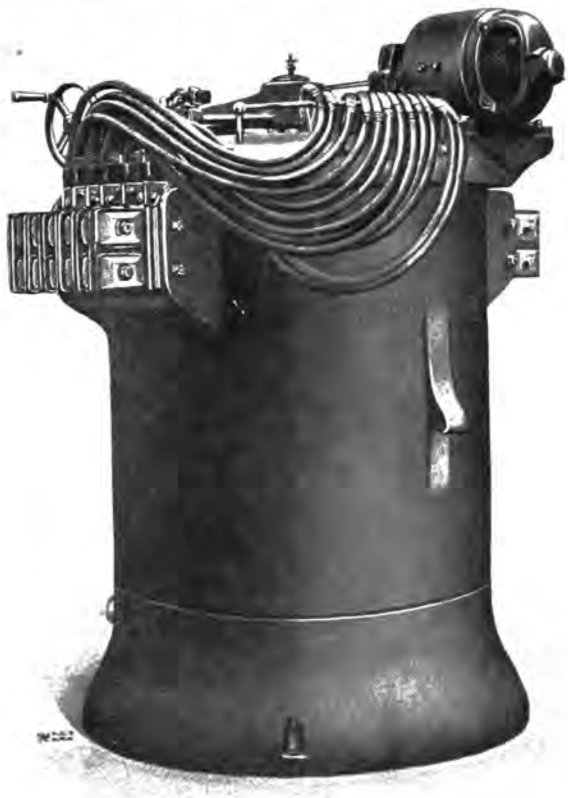


Fig. 6
300 KW., 25 CYCLE, SIX-PHASE, AIR-BLAST, MOTOR-OPERATED INDUCTION REGULATOR

The primary or rotating core contains two windings: the active or shunt winding connected across the line, and a second winding short-circuited on itself and arranged at right angles to the shunt winding. The object of this short-circuited winding is to decrease the reactance of the regulator, and its operation is as follows: As the primary and the short-circuited windings are both on the movable core and permanently fixed at right angles to each other, the flux generated by the primary passes on either side of the short-circuited coil, and is, therefore, not affected by it in any way whatever, for as long as no flux passes through this coil there is no current flowing in it. This condition is, however, only true when the armature is in the maximum boost or maximum lower position with current flowing in the series spondingly increasing flux would have to be generated. This voltage would become a maximum with the armature in the neutral position, due to the fact that in this position the shunt coils are at right angles to the series coils and therefore entirely out of inductive relation to them. The current in the secondary, therefore, would act as a magnetizing current, and a considerable part of the line voltage would have to be used to force the current through these coils. The voltage so absorbed would be at right angles to the line voltage, and the result would be a poor power factor on the feeder.

Fig. 7
DISASSEMBLY OF SINGLE-PHASE REGULATOR

winding, and in any position of the armature with no current in the secondary.

With the armature in the neutral, or no boost no lower position, the flux generated by the current in the secondary passes equally on either side of the primary coils, which cannot, therefore, neutralize the flux generated by the secondary.

If the primary core were not provided with a short-circuited winding, and were rotated from either maximum position so as to reduce the primary flux passing through the secondary, and if the line current remained constant, a gradually increasing potential would be required to force the current through the series windings, and a corre-

The short-circuited coil on the armature, however, which is in a direct inductive relation to the series coils when the armature is in the neutral position, acts as a short circuit on the secondary winding, and thereby reduces the voltage necessary to force full load current through this winding to only a trifle more than that represented by the resistance drop across the secondary and short-circuited windings. This short-circuiting of the secondary is gradual, from zero in the maximum boosting position of the regulator to the maximum short-circuiting in the neutral position; so that by the combined effect of the primary and the short-circuited coils the reactance of the secondary is kept to within reasonable limits, and consequently, produces no appreciable effect on the line, as may be seen by referring to the full-load boost and lower curves (Fig. 8) which are plotted from actual test results and not merely from theoretical calculations. The operation of the short-circuited coil does not increase the losses in the regulator, but rather tends to keep them constant for a given secondary current. In rotating the armature from either maximum to the neutral position, the current in the primary diminishes as the current in the short-circuited coil increases, so that the total ampere turns of the primary plus the ampere turns of the short-circuited winding are always approximately equal to the ampere turns of the secondary.

Although previously stated that Fig. 5 is diagrammatical, it shows in detail the exact arrangement of punchings and windings for both primary and secondary of the smallest size of single-phase regulator listed. The number of slots, and consequently the number of coils of both primary and secondary, are, however, increased in each successive size of punching, that is, for increasing capacities of regulators. By this means a very uniform radiation and impedance is obtained producing a uniform rise in temperature and reducing the power factor to a practical minimum for all sizes of regulators.

POLYPHASE REGULATORS

In the polyphase regulator, the excitation is produced by the combined action of shunt windings connected across the separate phases of the system. The shunt windings for the different phases must be identical in every way and arranged so that the various windings magnetize a given pole of the regulator in the same direction; that is, each pole is wound with as many distinct and separate windings as there are phases, and these windings are connected to the line in the same order as similar windings on the generator.

The magnetizing flux produced has a practically constant value, but does not have a constant direction. The magnetic field is a rotating one, not an alternating one as in the single-phase type, and the speed of rotation of the field per pole is the same as that of the generator.

All of the slots on the circumference of a polyphase regulator armature are filled with the windings of the various phases symmetrically arranged as stated, and the secondary or series winding is similarly arranged on the inside circumference of the stationary core; and the voltage produced in

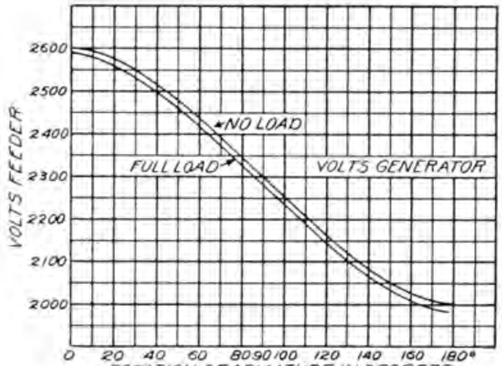


Fig. 8
CURVES SHOWING BOOSTING AND LOWERING OF FEEDER VOLTAGE BY INDUCTION REGULATOR

the secondary is due to the rotation of the flux produced by the combined action of the primaries. The voltages generated in the series windings of the various phases are, therefore, of the same value, and are constant for all positions of the armature, and the variation in the line voltage produced by the regulator is due to a phase displacement, which may be illustrated graphically as follows:

In Fig. 9, let EO represent the normal potential of one leg of the system, and let the radius of the arc ABD represent the constant voltage induced in the secondary of the regulator. With the primary coil of leg 1, for instance, directly opposite the secondary coil of the same leg, the voltage generated will be in phase with that impressed and will be represented by OD, and the regulator will lower by the maximum amount, making ED the feeder voltage. As, however, the primary is rotated out of this position, the secondary winding considered will be partially excited by the next winding on the armature, so that the voltage generated is not deducted directly from OE, but at an angle, as OC, and the feeder voltage is the resultant of EO and OC, or EC, which is equal to EX. Rotating the armature through an angle of nearly 90 degrees, or to OB, so that EB equals EO, the regulator is in the neutral, or no boost no lower position. Completing the full range of 180 degrees, leg 1 on the armature

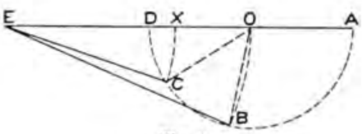


Fig. 9
CHANGE OF PHASE RELATION IN POLYPHASE INDUCTION REGULATOR

is again opposite leg 1 on the field, but opposite that part of the winding surrounding the dissimilar pole, so that the voltage OA is again in phase with OE, and the regulator is boosting. The resultant EA representing the feeder potential.

Due to the rotation of a similar field produced by the current in the series coils, the currents in the shunt windings are constant, regardless of the position of the armature, for a given line current, and the currents in the shunt windings are taken from the line or delivered back into the system as the armature is rotated from maximum boost to maximum lower in the same phase relation as represented by the secondary voltage generated. This condition is due to the fact that the current in the series winding (the line current) determines the direction of the current in the shunt winding in the same way that the voltage across the shunt winding determines the direction of the voltage in the series or secondary winding.

With the arrangement of the shunt windings necessary in the polyphase regulator, the impedance of the device is, therefore, comparatively small without the use of the short-circuited coil required in the single-phase device, and the total ampere turns of the primary are always equal to the total

Fig. 10
150 KW., 60 CYCLE, 4000 VOLT, THREE-PHASE, SELF-COOLED, FEEDER VOLTAGE REGULATOR

ampere turns of the secondary; this accounts for the currents in the shunt winding being out of phase with those in the series coils in any other than the maximum boost or lower positions.

POWER FACTOR

The power factor of a regulator of the induction type is not as high as in the standard General Electric Company dial switch types of regulator, but, as feeders seldom require a regulation exceeding 20 per cent, a regulator having as low a power factor as 85 per cent does not have any appreciable effect on the line. A regulator having this low power factor would have a magnetizing current and a reactance each exceeding 25 per cent, and assuming that the regulator is arranged for a 10 per cent boost and lower, and that the power factor on the line is 100 per cent, the effect of the regulator having this low power factor, with full load in the line, will only reduce the power factor of the

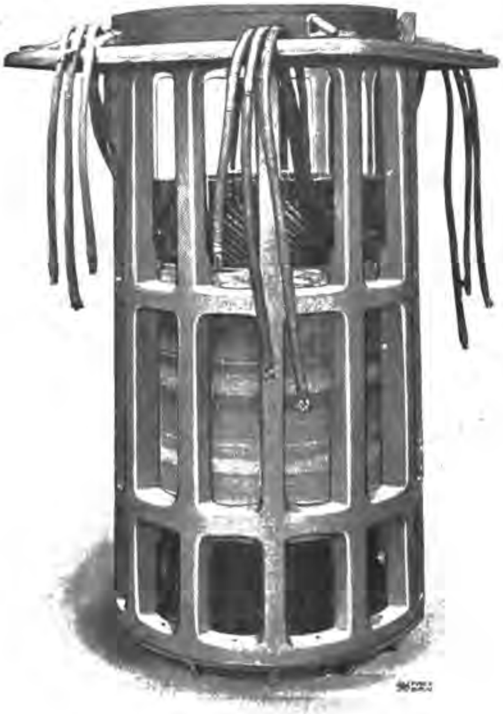


Fig. 11
FIELD OF 150 KW., 60 CYCLE, 4000 VOLT, THREE-PHASE, SELF-COOLED, FEEDER VOLTAGE REGULATOR SHOWN IN FIG. 10

load by a trifle over 0.1 per cent. On the other hand, if a regulator having a boost and lower of 5 per cent be considered, the power factor on the line would be reduced by one-half this amount, thereby changing a 100 per cent power factor line to one having a power factor of 99.9 per cent and 99.95 per cent respectively.

As the majority of regulators are used for controlling lighting circuits, which have a relatively high power factor, it will, therefore, be seen that the use of a regulator having a somewhat low power factor has a negligible effect on the system.

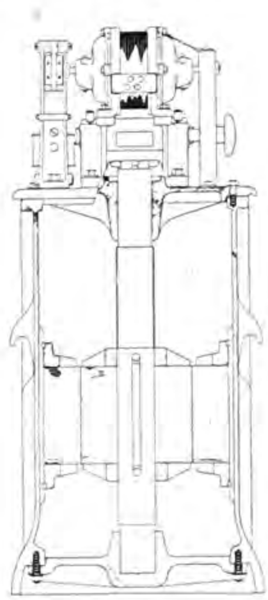


Fig. 12
ASSEMBLY OF SINGLE-PHASE REGULATOR SHOWN IN FIG. 4

EFFICIENCY

The efficiency of this type of regulator is considerably higher than the efficiency of other inductive apparatus of the same kw. capacity similarly constructed, the increased efficiency being obtained by the use of a small diameter of punching, with a correspondingly greater height of iron. In general, the full load efficiencies of the standard line of single-phase regulators listed, in sizes from 5¾ to 69 kw., for 2300 volt, 60 cycle circuits, vary from 93.5 to 96.5 per cent, and for the polyphase type from 92.5 to 96.5 per cent in corresponding size. This efficiency is based on the capacity of the regulator; that is, the loss in the regulator varies from 6.5 to 3.5 per cent of the kw. capacity of the regulator itself in the single-phase type and from 7.5 to 3.5 per cent in the polyphase, and is therefore, only a very small percentage of the capacity of the line.

MECHANICAL DESIGNS

The mechanical arrangement of this type of apparatus is shown in the accompanying illustrations. The primary punchings are assembled directly on the shaft in the smaller sizes, and on a spider mounted on the shaft in the larger ones. The secondary punchings are assembled in a substantial cast iron frame, which may form the case or tank of the regulator or which may be placed in a separate case or tank to increase the radiating surfaces. The former, which is the standard construction, is shown in Fig. 7 and the latter in Figs. 10 and 11. One end of the shaft carrying the primary punchings extends through the cover and is provided with a worm gear segment by means of which the armature is rotated, and the other end rests in a step bearing in the base of the secondary.

The construction of the redesigned regulator assembled in the square tank is well illustrated in Fig. 12, and it should be noted that there is a total of only three machined surfaces which determine the alignment of the stationary core and the top and bottom bearings for the movable core. Fig. 13 shows one of the special boring mills used to machine regulator tanks and with this mill all of the three surfaces of the tank are machined simultaneously. The design of the tank and the method of machining, as well as the use of exceptionally heavy bearings and shaft, insures an almost perfect alignment of primary and secondary cores, thus practically eliminating vibrations.

The connections of both primary and secondary windings are made by means of flexible cables, except in the case of large regulators for rotary converters, which have the secondary arranged with busbar terminals, as shown in Fig. 6.

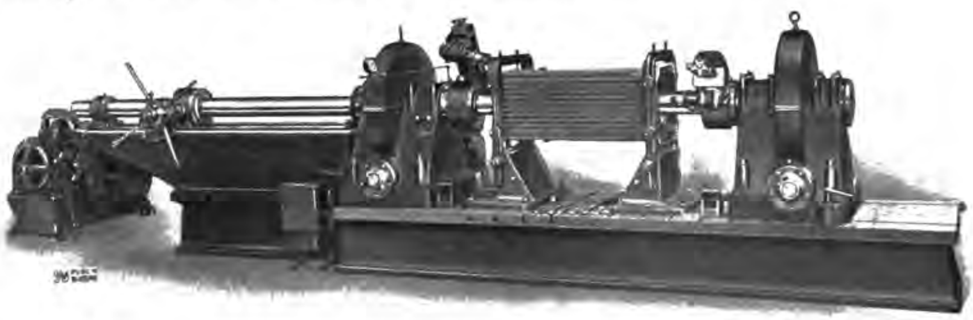


Fig. 13
ONE OF THE SPECIAL BORING MILLS FOR MACHINING REGULATOR TANKS

METHOD OF OPERATION

Regulators may be operated by hand, either directly or through a sprocket wheel and chain, by a hand-controlled motor, or automatically. If motor operated with hand control, the motor may be of the alternating current or of the direct current type, but preferably of the alternating polyphase type. If automatically operated, the operating motor should be of the polyphase type, as the single-phase alternating and the direct current motors are not well adapted for this purpose for the reason that the armature of a single-phase motor having the same characteristics as a polyphase machine, has approximately twice the weight, and consequently twice the inertia, which increases the over running of the regulator and its tendency to hunt, also the commutator and brushes of either a direct or alternating current motor require considerable attention. When motor operated the motor is controlled by means of a small double-pole, double-throw switch mounted on the switchboard or in any other convenient location. Closing the switch one way or

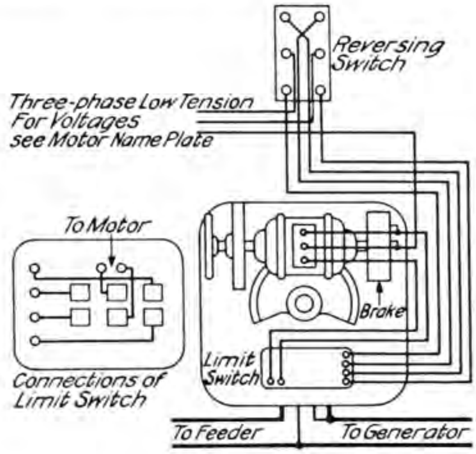


Fig. 14
CONNECTIONS OF SINGLE-PHASE INDUCTION REGULATOR OPERATED BY HAND CONTROLLED THREE-PHASE MOTOR

the other will start the motor so as to operate the regulator to obtain a boost or lower in the line voltage as may be desired, and when the correct line voltage is obtained the regulator may be stopped by opening the switch.

A limit switch is provided which stops the movement of the regulator by opening the motor circuit as soon as the regulator has reached either extreme position, but which automatically closes this circuit again as soon as the regulator armature recedes from the extreme position. The operation of either limit switch does not interfere with the movement of the regulator in the opposite direction, which the operator may produce by reversing the controlling switch.

All quick operating regulators, either motor-driven or automatic, are also provided with a brake to stop the motor as soon as the voltage has been properly adjusted. The brake magnet is equipped with an energizing coil, but is operated by gravity and is normally set. The energizing coil is connected across two of the motor terminals and releases the brake as soon as the motor is connected to the line, but sets the brake and stops the motor as soon as the circuit is broken.

Fig. 14 is a diagram of the connections of a single-phase regulator operated by a hand controlled three-phase motor, showing not only the connections of the regulator with reference to the line, but also the connection of the motor, limit switch and brake, and of the reversing switch for controlling the motor. The three-phase type is similarly connected.

In place of the hand operated double-pole, double-throw switch, the automatic type is provided with a switch which is electrically controlled by means of a relay or contact-making voltmeter connected across the feeder regulated. The switch consists of the usual

Fig. 15
RELAY SWITCH FOR AUTOMATICALLY OPERATED INDUCTION REGULATOR

six contacts, and is provided with two alternating current magnets arranged with their poles opposite each other and having a common armature, as shown in Fig. 15.

The contact making voltmeter, shown in Fig. 16, consists of a solenoid, and a laminated iron core which is supported partly by a spring and partly by the current in the solenoid, and which operates a lever provided with upper and lower contacts. The lever is connected to one side of a low tension alternating current circuit, the contacts are connected to the energizing coils on the relay switch, and the other terminals of these coils are connected to the other side of the circuit, as shown in the diagram of connections. (Fig. 18.)

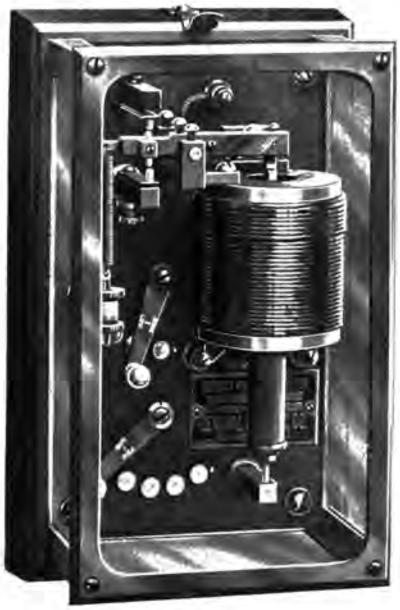


Fig. 16
CONTACT MAKING VOLTMETER

With the line at normal potential, the lever stands midway between the two contacts; but a variation of the line potential above or below normal causes the lever to close one or the other of the contacts, thereby energizing one of the coils of the controlling switch, which starts the motor in one direction or the other until the predetermined line voltage is again obtained.

If it is desired to compensate for line drop and maintain a constant potential at some distant point on the feeder, it is only necessary to provide the relay with a compensated winding connected in series with the line through a suitable current transformer. The compensated winding on the relay is arranged with two "dials," or multi-point switches, as shown in the diagram of connections (Fig. 17) so that a very close adjustment can be obtained within the limits for which the device is designed. This method of compensation takes care of the average conditions for both ohmic and inductive drops.

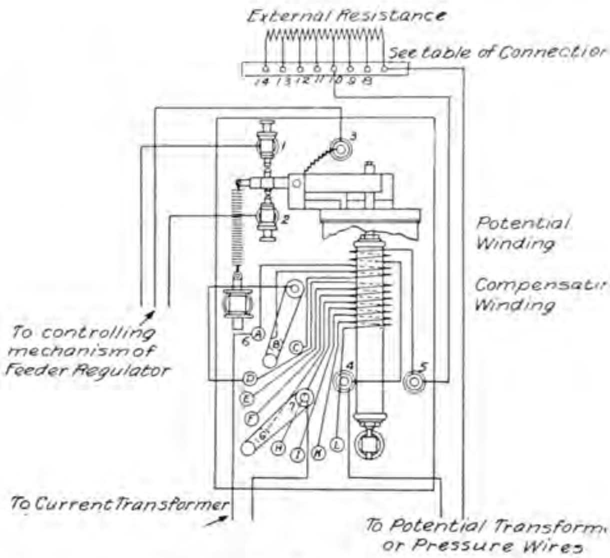


Fig. 17
CONNECTIONS OF CONTACT MAKING VOLTMETER

METHOD OF COOLING

Regulators varying in size from 5¾ to approximately 70 kw., 60 cycles, 2300 volts, either single-phase or polyphase, are generally furnished oil immersed, self cooled, as indicated in the tabulations, but the kw. capacity for which self cooling is advisable decreases with lower frequencies and higher voltages.

The self cooled regulators listed are constructed as shown in Figs. 7 and 12, that is, the secondary punchings are assembled directly in the ribbed spider or tank, for the reason that the losses are sufficiently low and the radiating surface obtained on the spider itself is ample to keep all internal parts within the temperature guaranteed. Regulators of larger sizes can be furnished in the self-cooled type if required, but are constructed as shown in Figs. 10 and 11, with an auxiliary tank having deep corrugations to give an increased radiating surface. Regulators of a higher capacity than those listed should be cooled by an air

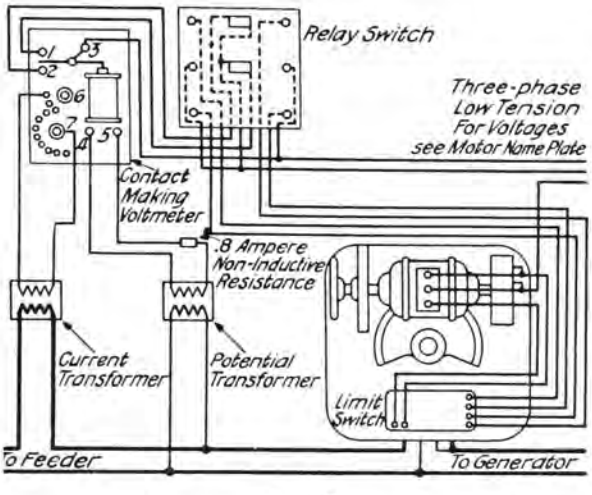


Fig. 18
CONNECTIONS OF AUTOMATICALLY OPERATED SINGLE-PHASE REGULATOR CONTROLLED BY THREE-PHASE MOTOR

blast, or by a water coil, and the sizes above 20 kw. can also usually be furnished for less cost with artificial cooling than self cooled. The polyphase artificially cooled type can be built either air blast or oil immersed water cooled, but the single-phase artificially cooled type for capacities up to 69 kw. can be furnished in the oil immersed water cooled type only. This method of cooling is necessitated by the fact that single-phase regulators up to 69 kw. capacity are designed with a two-pole winding, and as there is a greater tendency for the armature to vibrate with this arrangement, than when a greater number of poles are provided thereby making the armature more stable, the device must be oil immersed, as otherwise the noise might be objectionable The cooling coil for the circulation of water is in the top of the spider, and the internal arrangement of the regulator is such that, as heat is generated, an oil circulation is established through the center portion of the regulator and the water coils so as to effectually cool all parts of the regulator.

In the air blast type, the air passages are arranged so as to effectually cool all parts of the coils and core, and a damper is provided in the base so that when the regulators are not in use the air supply may be shut off.

SWITCH REGULATORS

These regulators are designated as the Type CR and the Type BR, the former being operated by hand and the latter automatically. They are the same in general principle and differ chiefly in the construction of the switch and mechanism.

They are of the oil immersed, self cooled, cover suspension type. The transformer part of the regulators is built up of the shell type of punchings and pancake coils, and the operating mechanism is assembled on the cover of the tank as shown in Figs. 20, 22 and 23. They are similar to the induction type only in that they have a primary winding

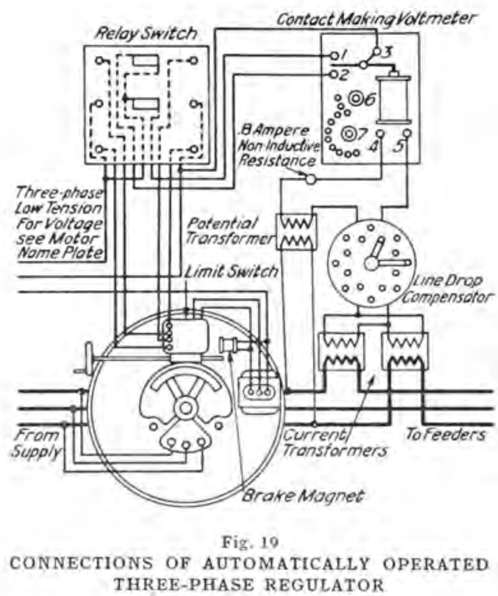


Fig. 19
CONNECTIONS OF AUTOMATICALLY OPERATED THREE-PHASE REGULATOR

connected across the line to be controlled and a secondary winding in series with the line.

The several coils of both windings are placed on a stationary sheet iron core. The secondary winding is provided with a number of taps connected to successive points on a dial switch, and the amount of boosting or lowering of the feeder potential depends on the amount of this winding included in the circuit controlled, and also on the direction of the voltage induced in the secondary.

Fig. 20
23 KW., 60 CYCLE, 2300 VOLT, 100 AMPERE CR FEEDER VOLTAGE REGULATOR

This type of regulator is therefore more economical than the induction type, for as the dial is adjusted from either maximum position to the neutral position the secondary winding is gradually cut out of circuit, and the copper losses reduced correspondingly; so that at the neutral, or no boost, no lower position, the only loss in the regulator itself is the core loss.

CR REGULATORS

CR regulators are arranged for hand operation by a handle attached directly to the dial switch, as shown in Fig. 20, or by a sprocket wheel or bevel gear so as to be operated from the switchboard gallery. Fig. 21 shows the diagram of internal and external connections and the operation is as follows:

Starting with the regulator in the position of maximum boost, that is, with the dial switch turned to the extreme left, it is possible to turn the dial switch to the right for two complete revolutions. During the first revolution the dial switch diminishes the amount of boost step by step, by cutting out in succession the several sections of the secondary winding. When the first revolution has been completed, the voltage on the feeder is the same as that of the generator, the secondary winding being entirely cut out of circuit. A further movement of the dial switch in the same direction automatically throws a reversing switch on the back of the panel; and on continuing the movement, the secondary winding is cut in again, step by step, but with reversed polarity,

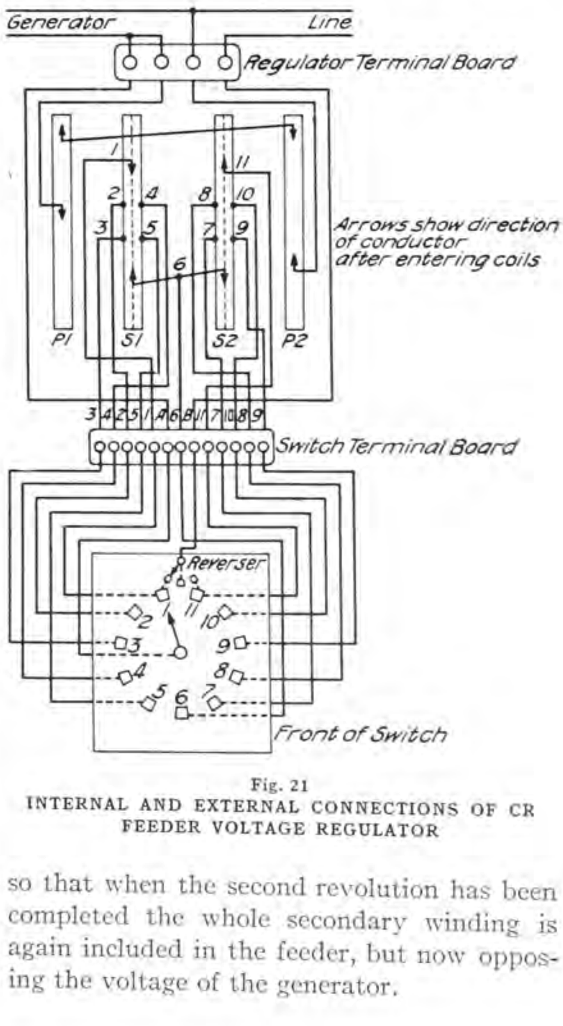


Fig. 21
INTERNAL AND EXTERNAL CONNECTIONS OF CR FEEDER VOLTAGE REGULATOR

so that when the second revolution has been completed the whole secondary winding is again included in the feeder, but now opposing the voltage of the generator.

Thus by one continuous movement of the dial switch, covering two revolutions in one direction, the complete range between maximum boost and the maximum lower of the feeder voltage is obtained. At either end of this range the dial switch is automatically arrested so that it is impossible to turn it too far.

Fig. 22
23 KW., 60 CYCLE, 2300 VOLT, 100 AMPERE BR FEEDER VOLTAGE REGULATOR

The dial switch is of substantial construction and operates from step to step with a "snap" movement regardless of the manner in which the operating handle is manipulated. This positive action is obtained by means of compression springs. An automatic bolt holds the switch blade on its contact point until the movement of the operating handle has compressed the spring sufficiently to carry the blade with a quick movement to the next contact, on which it is instantly locked again by the bolt. Owing to the quickness of the movement obtained, together with the special shaping of the contact blades, no flicker on the lamps is observed when the switch is moved from step to step.

The contact blades are of heavy copper with turned edges arranged to chill, by their mass, the momentary arc which occurs as the switch blade passes from point to point. Both the switch blade and contact blades can readily be removed and replaced, if after prolonged service it should become desirable to do so.

BR REGULATORS

The Type BR (switch type automatically operated) regulator is shown in Figs. 22, 23 and 24 and Fig. 25 shows the internal connections.

The advantages of the automatic BR feeder regulator over all other automatic types is that it can be made to respond to changes in the line voltage much quicker and with smaller consumption of power. In all regulating devices having a moving core, or coils,

Fig. 23
BR REGULATOR SHOWN IN FIG. 22 REMOVED FROM TANK

or both, the moving member not only has considerable inertia, which is prohibitive of instantaneous action, but it also exerts a considerable torque. In the BR type, however, the only moving part is a small switch arm having little inertia, and the only torque is the friction of a number of small switch contacts. The operating mechanism is so designed that the total movement from maximum boost to maximum lower may be effected in about five seconds. The automatically controlled regulator is operated with much greater frequency and rapidity than the hand controlled type and its moving member is subjected to constant reversals in rotation, so that the mechanism must be made as light as possible consistent with strength and rigidity and must be specially arranged to avoid burning of the contacts.

The "snap" movement so essential in the CR regulator is therefore dispensed with, and the same object is attained by providing the moving member of the Type BR regu-

Fig. 24
SWITCH OF BR FEEDER REGULATOR

lator switch with a series of fingers, the majority of which are always in contact, as indicated in Fig. 25.

Each finger is connected to a corresponding stationary collector ring by means of a suitable brush, and the collector ring is connected to the line through a preventive resistance. The individual fingers do not span the space between adjacent contacts, but the arrangement of the combination is such that with the center of the top finger on the center of one contact, the center of the bottom finger will be in the center of the next contact, the intermediate fingers being spaced so that the centers of all the fingers are on a straight line. The resistances which connect the several fingers to the line not only prevent excessive exchange currents as the fingers pass from contact to contact, but cause the changes in the line voltage to be gradual and not in steps. The moving member may therefore be left in any position whatever, and a very much closer adjustment of voltage may be obtained than in the hand operated switch type of regulator. This feature is essential, as it not only prevents hunting, but also decreases

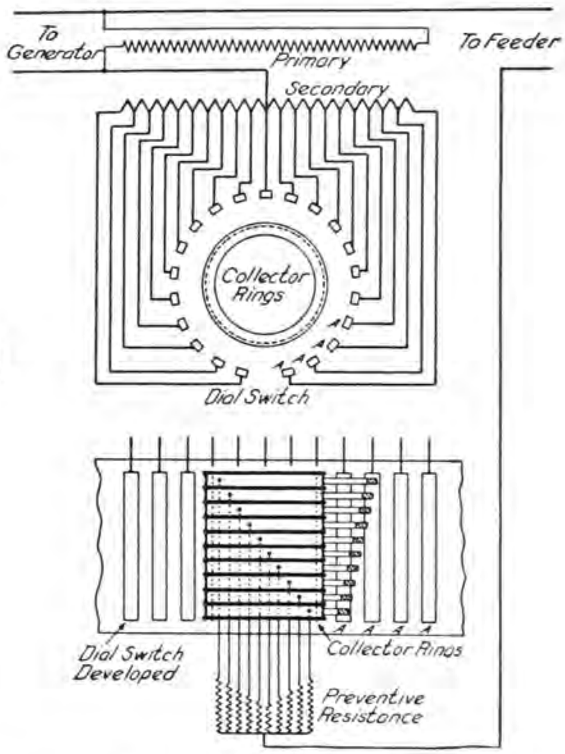


Fig. 25
INTERNAL CONNECTIONS OF TYPE BR REGULATOR

the number and extent of the movements of the regulator necessary to keep the voltage within the predetermined limits.

In order to simplify the operation of this regulator, the reversing switch provided in the Type CR is eliminated and a secondary winding capable of giving the entire range of control without any reversal of connections is provided. With this arrangement, the feeder is permanently connected to the center point of the secondary winding, and boosting is effected by moving the regulator switch to one side of the center and lowering by moving the switch to the other side.

The regulator is of the self-contained type, that is, the operating motor and mechanism is all mounted on the regulator cover. The operating motor is in continual operation and both motor and clutch coils are wound for single-phase, 110 volts, and for the frequency of the feeder circuit controlled. The operating motor is an improved type, having oil ring bearings, and is designed to run continually for long periods without attention. It is rated at 1/6 h.p., has ample capacity for the work required, is self starting under load and will run cool under all conditions. The clutches are positive in their operation, are made of hardened steel to resist wear and require no readjustment after they leave the factory. The two clutches are interlocked and the clutch coils are controlled by the contact making voltmeter direct; insuring a prompt adjustment of the voltage by the regulator.

The performance of this regulator is shown in Fig. 1 (page 1) which is reproduced from actual voltmeter charts. It will be noted that the frequent extremely rapid voltage variations on the generator side, accurately recorded by the sharply drawn lines of the Thomson curve drawing voltmeter, have been smoothed out by the Type BR regulator to an almost ideal extent.

Compensation for line drop is obtained by means of the auxiliary winding and dials provided in the contact-making voltmeter and connected with a current transformer, the same as with the induction type of regulator. (See Fig. 17.)

POWER FACTOR AND EFFICIENCIES

The power factor of both the Type CR and Type BR regulators is very nearly 100 per cent, so that the power factor of the feeder controlled is affected even less than with the Type IR.

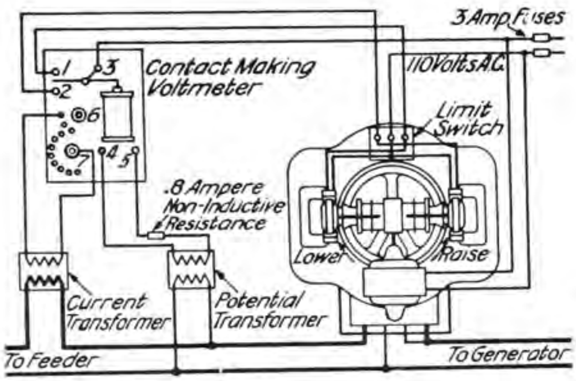


Fig. 26
EXTERNAL CONNECTIONS OF BR FEEDER VOLTAGE REGULATOR

The efficiency of the Type CR at full load varies from 95 per cent in the $5\frac{3}{4}$ kw. size to 97 per cent in the 46 kw. size, and this efficiency is based on the actual kw. capacity of the regulator; that is, the loss varies from 5 per cent to 3 per cent of the kw. capacity of the regulator, which is only a very small percentage of the capacity of the feeder.

The efficiency of the Type BR is slightly lower on account of the external preventive resistances. The efficiency varies for a given load, depending on the position of the individual fingers with reference to the tap connections of the secondary; being highest when the majority of the fingers are on the same switch contact and lowest when half of the fingers are on one contact and the other half on the adjacent contact.

SIZES

The following tables give the sizes as well as the weights and dimensions of the various standard regulators. Induction regulators can be furnished for any current or kw. capacity, but the size of the switch types is limited by the current which can readily be handled by the dial switches, and the use of Type CR or Type BR regulators for circuits of a capacity of over 200 amperes is not recommended.

Fig. 27
LINE DROP COMPENSATOR FOR AUTOMATIC REGULATORS USED ON LINES CARRYING VARIABLE POWER FACTOR LOADS

Regulators of a smaller kw. capacity than those listed can be furnished in an induction type designated as the Type MR. These regulators are designed for capacities of 1, 3, and 6 kw., 60 cycles, and are wound for 1150 or 2300 volts primary, and a boost or lower of 5, 7½ or 10 per cent as may be desired.

All regulators wound for 2300 volts can be operated on circuits varying 10 per cent either way from this voltage, with normal heating, provided the kw. capacity of the regulator remains as given in the tables.

LINE DROP COMPENSATOR

The potential drop in a feeder carrying an inductive load can be approximately compensated for by means of the series coil of the contact making voltmeter as previously stated, provided, however, that the power factor remains constant. For the proper compensation for a line drop due to a load of varying power factor, a line drop compensator as shown in Fig. 27, and which provides for the separate adjustment for both ohmic and reactive drop is, however, necessary.

This device is connected in series with the current transformer as shown in Fig. 19, two transformers and one compensator for a polyphase regulator and one of each for a single-phase.

It consists of a resistance and a reactance connected in series and each separately adjustable by means of individual dial switches. The compensation is obtained by connecting the potential transformer controlling the contact making voltmeter in series with any desired amount of the two adjustable members, so that the potential drop, due to the current from the series transformer, i.e., the line current, is deducted from the potential of the potential transformer. To compensate for varying power factor, it is therefore only necessary to adjust the dials for the resistance and the reactance of the line, and after they are once properly adjusted the regulator will maintain a constant voltage at any predetermined point on the feeder regardless of the power factor of the load.

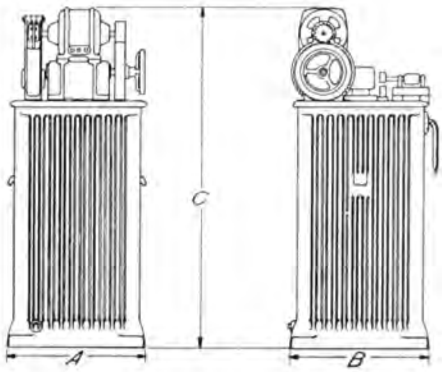
SELECTION OF REGULATORS

The switch type of regulator is built for single-phase circuits only whereas the induction type is built for either single or polyphase circuits. If, therefore, the first type is selected for use in a polyphase system, a separate regulator will be required for each phase, or for each phase the voltage of which is to be controlled.

Polyphase regulators change the voltages of all of the phases simultaneously and by an equal amount, depending on the excitation regardless of the load or the unbalancing of the line voltage between phases, whereas by using the single-phase type each phase can be controlled separately and a perfect balance obtained at the point of distribution on the feeder regardless of the unbalancing of the system. Polyphase regulators should therefore not be used on a badly unbalanced system either with regard to voltage or current, particularly as an unbalancing of the latter will tend to produce a still further unbalancing of the former, unless the regulator is especially designed to meet this condition.

Both the switch and the induction types can be furnished for hand or automatic control, but a longer time is required to adjust the voltage with the induction type because of the torque developed and because of the weight of the armature. This is well illustrated in Fig. 1, page 1, which shows three simultaneously taken voltage charts, the first on the generator, the second on a line operated from this generator and controlled by an induction regulator, and the third on a similar line operated from the same generator but controlled by a switch type of regulator. The load on the generator consisted of lighting and power, a considerable part of the latter being intermittent, such as crane and elevator motors. The results which can be obtained from a variable source of supply are well illustrated by the curves which show conclusively that while the induction type of automatic regulator is perfectly satisfactory for ordinary circuits, the switch type is the one most suitable for a rapidly fluctuating one and is the regulator by means of which the most satisfactory results can be obtained in operating a lighting feeder from a power or railway or any similar rapidly fluctuating circuit.

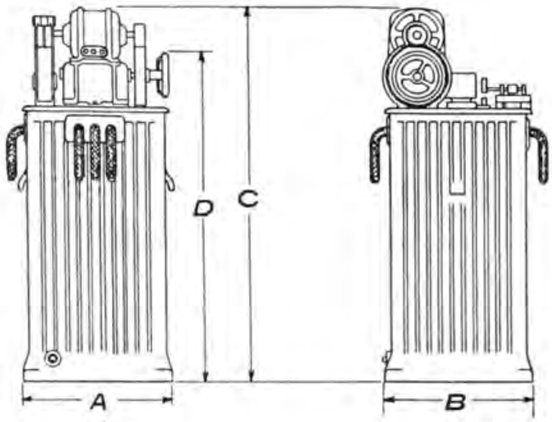
SINGLE-PHASE REGULATORS, MOTOR AND AUTOMATIC-OPERATED, TYPE IRS FOR 2300 VOLT, 60 CYCLE CIRCUITS



Feeder Capacity in Amperes	Increase or Decrease in Line Voltage at 2300 Volts		Kw. Capacity of Regulator	Dimensions in Inches			Weight in Lb.	
	Per Cent	Volts		A	B	C	Net	Ship.
50	5	115	5¾	17	17	42⅝	700	950
	7½	172	8¾	17	17	46⅝	820	1100
	10	230	11½	20½	20½	47¼	1265	1600
75	5	115	8¾	17	17	46⅝	820	1100
	7½	172	13	20½	20½	47¼	1285	1625
	10	230	17¼	20½	20½	51¼	1425	1800
100	5	115	11½	20½	20½	47¼	1265	1600
	7½	172	17¼	20½	20½	51¼	1425	1800
	10	230	23	20½	20½	55¼	1650	2025
150	5	115	17¼	20½	20½	51¼	1425	1800
	7½	172	26	20½	20½	59¼	1750	2150
	10	230	34½	24¼	24¼	63½	2600	3050
200	5	115	23	20½	20½	55¼	1650	2025
	7½	172	34½	24¼	24¼	63½	2600	3050
	10	230	46	24¼	24¼	68½	3100	3600
250	10	230	57½	29	29	79	3500	4250
300	10	230	69	29	29	33	4200	5000

4791–20 Feeder Voltage Regulators

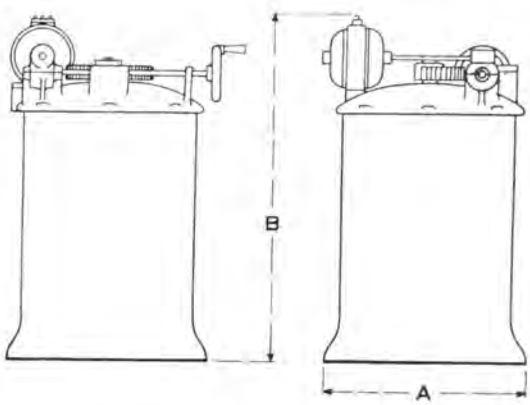
THREE-PHASE REGULATORS, MOTOR AND AUTOMATICALLY-OPERATED TYPE IRT FOR 2300 VOLT, 60 CYCLE CIRCUITS



Feeder Capacity in Amperes	Increase or Decrease in Line Voltage at 2300 Volts		Kw. Capacity of Regulator	Dimensions in Inches				Weight in Lb.	
	Per Cent	Volts		A	B	C	*D	Net	Ship
25	7½	172	7½	20½	20½	51¼	46	1425	1750
	10	230	10	20½	20½	51¼	46	1425	1750
50	5	115	10	20½	20½	51¼	46	1425	1750
	7½	172	15	20½	20½	55¼	50	1650	2000
	10	230	20	20½	20½	59¼	54	1875	2250
75	5	115	15	20½	20½	55¼	50	1650	2000
	7½	172	22½	20½	20½	59¼	54	1875	2250
	10	230	30	24¼	24¼	72¼	65½	2600	3050
100	5	115	20	20½	20½	59¼	54	1875	2250
	7½	172	30	24¼	24¼	72¼	65½	2600	3050
	10	230	40	24¼	24¼	76¼	69½	3000	3500
150	5	115	30	24¼	24¼	72¼	65½	2600	3050
	7½	172	45	29	29	79	72¼	3500	4200
	10	230	60	29	29	83	76¼	4200	5000
200	5	115	40	24¼	24¼	76¼	69½	3000	3500
	7½	172	60	29	29	83	76¼	4200	5000

* D = Maximum height for hand operated regulators.

POLYPHASE REGULATORS, TYPE IRH, FOR STANDARD SIX-PHASE 25 CYCLE ROTARY CONVERTERS



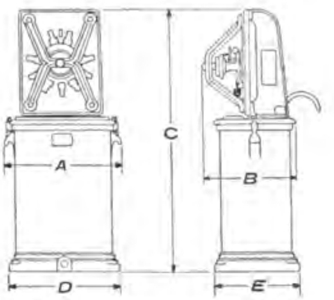
RANGE IN VOLTAGE 240 TO 280 D.C. TRANSFORMERS DIAMETRICALLY CONNECTED AND WOUND FOR A SECONDARY VOLTAGE OF 192

Kw. Capacity of Rotary Converter	Kw. Capacity of Regulator	Dimensions in Inches		Weight in Lb.	
		A	B	Net	Ship.
300	30	35	50	4000	4400
500	50	40	52	5000	5500
750	75	40	60	6000	6600
1000	100	54	64	8500	9350
1500	150	54	80	11000	12100
2000	200	59	86	14000	15400

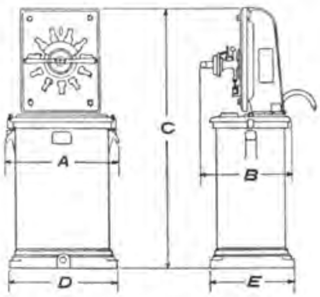
Regulators for rotary converters are usually furnished in the air-blast type; they can, however, be made oil- and water-cooled and the 30 kw. size can be furnished oil-cooled.

Regulators can be furnished for any frequency, for any range in voltage, and for any capacity of circuit.

SINGLE-PHASE REGULATORS, HAND OPERATED AND CHAIN AND SPROCKET OPERATED, TYPE CR, FOR 2300 VOLT, 60 CYCLE CIRCUITS



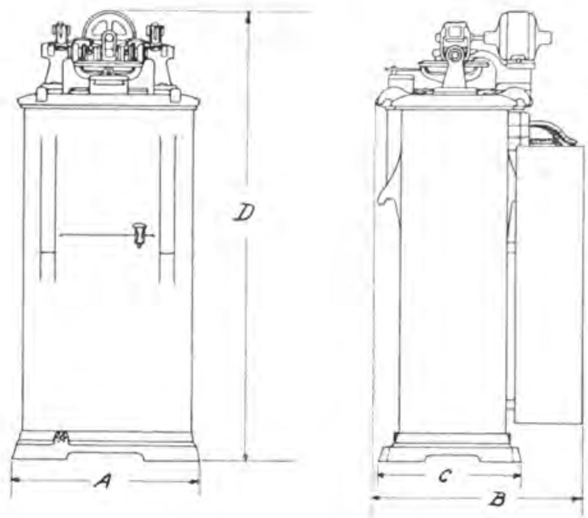
CHAIN AND SPROCKET OPERATED



HAND OPERATED

Feeder Capacity in Amperes	Increase or Decrease in Line Voltage at 2300 Volts		Kw. Capacity of Regulator	Dimensions in Inches							Weight in Lb.	
				A	B		C	D	E			
	Per Cent	Volts			Chain and Sprocket Operated	Hand Operated					Net	Ship.
25	10	230	5¾	23⅛	18¼	18¼	43	21	16		590	785
50	5	115	5¾	23⅛	18¼	18¼	43	21	16		590	785
	7½	173	8¾	23⅛	18¼	18¼	43	21	16		620	750
	10	230	11½	23⅛	19	18¼	50	21	16		720	897
75	5	115	8¾	23⅛	18¼	18¼	43	21	16		620	750
	7½	173	13	23⅛	19	19	50	21	16		720	897
	10	230	17¼	23⅛	19	18¼	50	21	16		780	910
100	5	115	11½	23⅛	19	18¼	50	21	16		720	897
	7½	173	17¼	23⅛	19	19	50	21	16		780	910
	10	230	23	23⅛	18¼	18¼	60	21	16		900	1150
150	5	115	17¼	23⅛	18¼	18¼	50	21	16		780	910
	7½	173	26	23⅛	18¼	18¼	60	21	16		900	1150
	10	230	34½	26¼	22½	21½	68½	27⅜	22⅞		1260	1510
200	5	115	23	23⅛	18¼	18¼	60	21	16		900	1150
	7½	173	34½	26¼	22½	22½	68½	27⅜	22⅞		1260	1510
	10	230	46	26¼	22½	21½	68½	27⅜	22⅞		1530	1760

SINGLE-PHASE REGULATORS, AUTOMATICALLY OPERATED, TYPE BR FOR 2300 VOLT, 60 CYCLE CIRCUITS



Feeder Capacity in Amperes	Increase or Decrease in Line Voltage at 2300 Volts		Kw. Capacity of Regulator	Dimensions in Inches				Weight in Lb.	
	Per Cent	Volts		A	B	C	D	Net	Ship.
50	10	230	11½	25¾	28¼	18¾	62	1350	1550
75	7½	172	13	25¾	28¼	18¾	62	1400	1600
	10	230	17¼	25¾	27	18¾	62	1475	1650
100	5	115	11½	25¾	28¼	18¾	62	1350	1550
	7½	172	17¼	25¾	27	18¾	62	1475	1650
	10	230	23	25¾	30	18¾	62	1725	2000
150	5	115	17¼	25¾	27	18¾	62	1475	1650
	7½	172	26	25¾	28¼	18¾	63	1725	2000
	10	230	34½	25¾	34¼	18¾	70½	2250	2450
200	5	115	23	25¾	30	18¾	62	1725	2000
	7½	172	34½	25¾	34¼	18¾	70½	2250	2450
	10	230	46	25¾	34¼	18¾	70½	2400	2600

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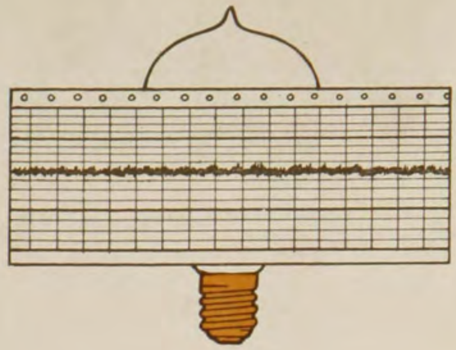

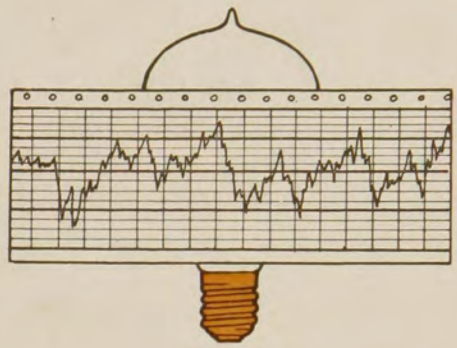

STEADY VS. UNSTEADY VOLTAGE

GENERAL ELECTRIC COMPANY

General Electric Company
Schenectady, N.Y.
SUPPLY DEPARTMENT

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STEADY VS. UNSTEADY VOLTAGE

For Incandescent Lighting on Alternating Current Systems

The maintenance of a constant voltage at the lamps determines in no small degree the economy with which a lighting system is operated, and it is as well the measure by which the customer primarily judges the excellence of electrical illumination. The life chiefly to the consumer, it is in fact of far greater value to the producer.

The modern system of using large alternating current generating units in a central station, distributing the power to substations, and then to centers of distribution, makes

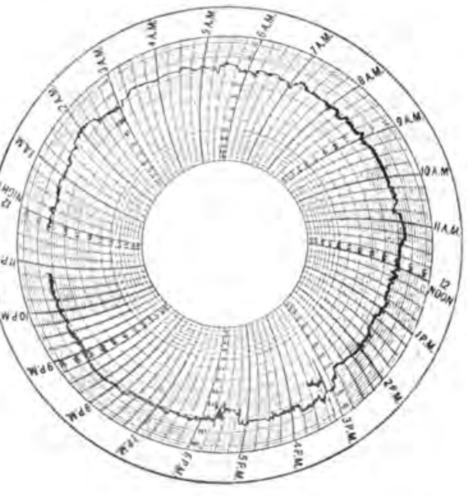


Fig. 3

Fig. 4

THE ABOVE CURVES WERE REPRODUCED FROM A PAPER BY MR. L. L. ELDEN, PRINTED IN THE APRIL, 1910, BULLETIN OF THE NATIONAL ELECTRIC LIGHT ASSOCIATION

In conclusion Mr. Elden says: "The subject of the regulation of incandescent lighting service is one which deserves careful consideration, whether the service be from a central station or from a private plant. That this is not always the case is well illustrated by the voltage chart Fig. 3, taken from the service of a well-known private plant showing a quality of service which would not be accepted from a central station company. Fig. 4 is a chart taken from the lines of a central station company 40 miles from the power house, on a circuit equipped with automatic regulators and operating a mixed load of incandescent lamps and motors."

and the candle-power of an incandescent lamp, change rapidly with comparatively small deviation from normal voltage, and the automatic regulation of this voltage at the station, is, therefore, of vital importance. While such regulation is apparently of benefit the maintenance of a constant potential at the individual lamp impracticable without the use of automatic potential and feeder regulators.

The generator should be controlled by a potential regulator so as to maintain a constant voltage at the bus or at the substation

**Supersedes No. 4619.*

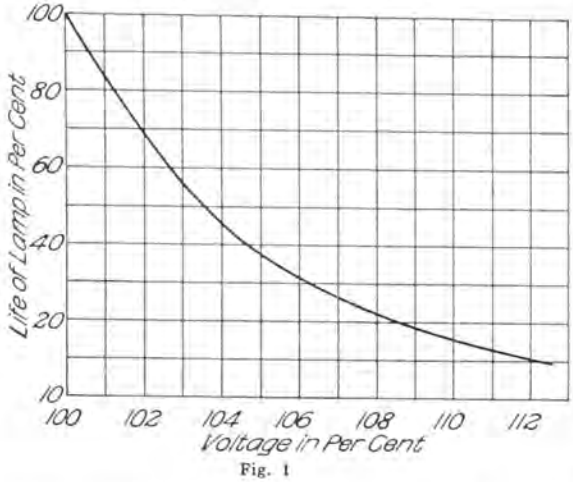


Fig. 1

independent of the changes in the load, and the various feeders emanating from the sub-station should each be controlled by feeder regulators arranged so as to automatically compensate for the drop in that feeder due to varying loads. Automatic feeder and voltage regulators are described in detail in separate bulletins specifically devoted to the different types.

By the use of these regulating devices a practically constant potential is maintained at the lamps with the following advantageous results:

1. Decrease of lamp renewals.
2. Increase sale of energy.
3. Steady illumination.
4. Increase capacity of feeders.
5. Better operating economy.

Lamp Renewals

The relation between the life of a lamp and the voltage applied is illustrated in Fig. 1. Assuming the lamp life as 100 per cent at 100 per cent voltage, it will be noted that the life decreases in a very much higher ratio than the increase in voltage. If the voltage is maintained at 2 per cent above normal the candle-power of the lamp is increased 11.6 per cent, the watts 4.2 per cent, and the life of the lamp reduced 33.6 per cent, resulting in a 50 per cent increase in lamp renewals. The consumer in this case receives excess candle-power without a proportionate increase in current consumed and the company is penalized by greater lamp bills. With voltages in excess of 2 per cent conditions are unfavorable to both company and consumer, but variations in excess of 2 per cent are by no means unusual occurrences in stations without means of regulation.

Assuming that the average lamp is operated at 4 per cent excess voltage for one-half the time and at normal voltage the remaining time, this condition would decrease by *one-third* the life of the lamp.

Assuming further that each connected lamp is used 600 hours per year, and in accordance with standard practice lamps are renewed when the candle-power reaches 80 per cent of normal value, taking the life of a lamp at 800 hours, the cost of excess lamp renewals resulting from such a condition is shown in the following tabulation:

Total Number of Lamps Connected	Total Renewals at Normal Voltage	Total Renewals Under Conditions Given	Cost of Excess Renewals at 15c. per Lamp
10,000	7500	11,200	$555

From the above it will be noted that under such conditions the loss due to renewals amount to considerable sums, as the number of connected lamps are increased.

Increase Sale of Energy

Fig. 2 shows the percentage loss in power of a lamp relative to the percentage of normal

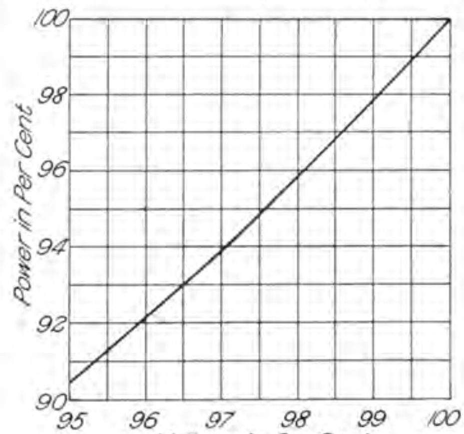


Fig. 2

voltage value applied to its terminals. A 4 per cent reduction from normal voltage reduces the candle-power 11 per cent, the watts by 4.3 per cent and increases the life 53 per cent. Such a condition is a disadvantage to the customer as the consumption of energy is not reduced in the same proportion as the candle-power. Furthermore, such a decrease in voltage is a direct loss to the station. It will be noted that the percentage of power consumed decreases as twice the percentage decrease in voltage, or in the ratio of 2:1. If the voltage, therefore, is 2 per cent below normal there is a consequent 4 per cent loss in power.

This fact may seem insignificant, but the figures given below show the actual loss without any compensating features to the company.

Assuming that each connected lamp is used 600 hours per year, and that the voltage is maintained at normal one-half of the time and 4 per cent below normal the remainder (which condition would probably occur at peak), the average loss in power for the total time is 4 per cent. On the basis of using 50 watt lamps and taking the average selling price per kw-hr. at 10c., the loss per year is as follows:

Total Number of Lamps Connected	Anticipated Revenue per Year	Loss in Revenue per Year Resulting from the Above Conditions
10,000	$30,000	$1200

From the above can be determined the loss in revenue with assumed conditions for larger numbers of connected lamps, and when it is considered that there is a loss of $60,000 with 500,000 connected lamps, there is very little use for additional argument to show the advantage of maintaining a constant voltage.

Steady Illumination

Feeder voltages may fluctuate gradually, remaining above normal a part of the time during the light load and falling below the normal line at peak. Even with such a gradual change in the voltage it is a disadvantage to company and consumer.

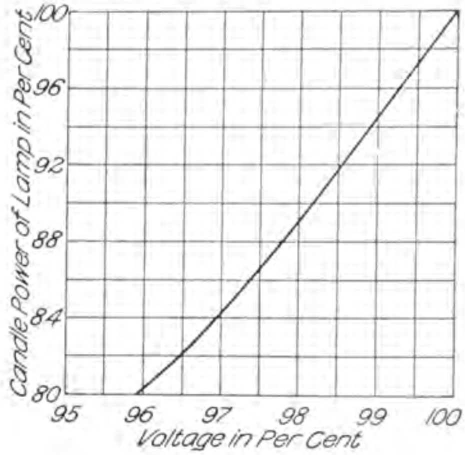


Fig. 3

It might be presumed that with voltage in excess of normal, the station profited by increased sale of power and at low voltage the customer received the benefit and in this way the two conditions would equalize. Careful study, however, has shown that such is not the case. With excess voltage the company does gain in revenue, but is penalized heavily by lamp renewals and the gain to the company reaches a maximum at 2 per cent above normal, while further increases in voltage result in decreased gain and a direct loss at a little over 4 per cent.

By reference to Fig. 3, it will be noted that the candle-power of the lamp varies at a much greater rate than the voltage applied to its terminals. On feeders where fluctuations take place rapidly as with combined lighting and power the illumination is extremely bad. In order to show how the illumination varies when the voltage is fluctuating, Fig. 4 has been prepared showing the candle-power in per cent corresponding to the voltage applied to the lamps.

This curve was taken from a fairly representative station without the use of automatic regulation. A customer receiving such service would have just cause for complaint. From a standpoint of service the station could not afford to give such a varying illumination and it is well to remember that good service is one of the chief business getters.

4793-4 Steady vs. Unsteady Voltage

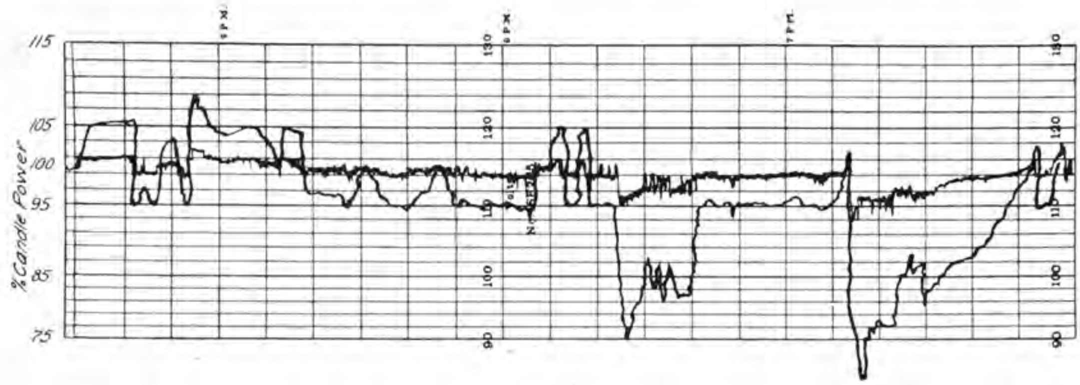


Fig. 4
NORMAL VOLTAGE 115 VOLTS
The Heavy Ragged Line is Voltage and Widely Varying Line the Candle-Power

Increased Capacity of Feeders

With the rapid increase in incandescent lighting it is practically impossible to keep the various feeders at their most efficient transmission capacity, and often the station manager is confronted by the condition that no more power can be delivered by a given unregulated feeder without serious detriment to the service. At such a time, the feeder regulator may be used to advantage to boost the voltage and overcome the excessive line drop, and will satisfactorily tide over the overload conditions until additional feeders are warranted.

Station Attendants

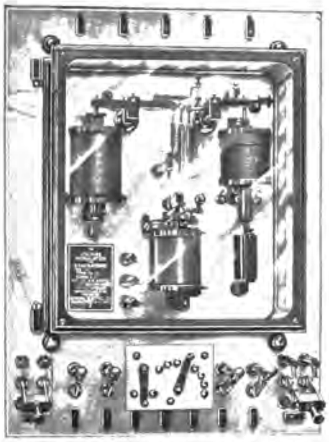
Both generators and feeders have in the past been regulated by hand, but this method of control is always dependent upon the personal characteristics of the station attendants and the nature and extent of their other duties.

The desired results can, however, be obtained by the use of automatic regulators. Always on duty to promptly and accurately compensate for any change in the load, automatic regulators may be depended upon for long service with minimum attention. By their use on the feeders, the individual circuits are controlled independently, each in accordance with its requirements; the personal errors of the attendants required by manually-operated apparatus will be eliminated and the station force may be either reduced or assigned to other operating duties.

SELECTION OF REGULATORS

Potential Regulators

It is possible to dispense with the regulator controlling the generator by supplying the individual feeders with regulators having a sufficient capacity to not only compensate for line drop, but also to compensate for the voltage variations in the generator. It is, however, more economical as well as advisable, on account of operating conditions, to control the generators by a voltage regulator such as shown in the accompanying illustration. This regulator is a relay device mounted on the switchboard and controls the generator voltage by opening and closing a shunt circuit across the resistance in the exciter field. The action of this regulator is very rapid and there is practically no fluctuation in the voltage. By its use, the kilowatt capacity of each regulator for the individual feeders is reduced as well as the number and amount of adjustments. The generator regulator has not only the advantage of reducing the wear on the feeder regulator mechanism, thus increasing the life of the apparatus, but it also decreases the amount of attention required, and simplifies the adjustments.



VOLTAGE REGULATOR TYPE TA

Feeder Regulators

Two types of regulators, designated respectively as the IR and the BR, can be furnished for automatically controlling the voltage of individual feeders. They are shown in Figs. 5 and 6 respectively, and a detailed description of each type as well as the methods of operation is given in other bulletins. Both types are controlled by a contact-making voltmeter, or relay, illustrated on this page.

Feeder regulators are transformers, or rather, compensators in principle, and disregarding the small loss in the device itself, the product of volts times amperes on the generator side is always equal to the product

CONTACT-MAKING VOLTMETER

of volts times amperes on the feeder side. Both types of regulators perform the same function and the principal difference in the results is in the rapidity with which they operate. The three curves on page 6 were taken simultaneously. The first is the generator voltage, the second, the voltage as regulated by a Type IR regulator, and the third as regulated by a Type BR regulator.

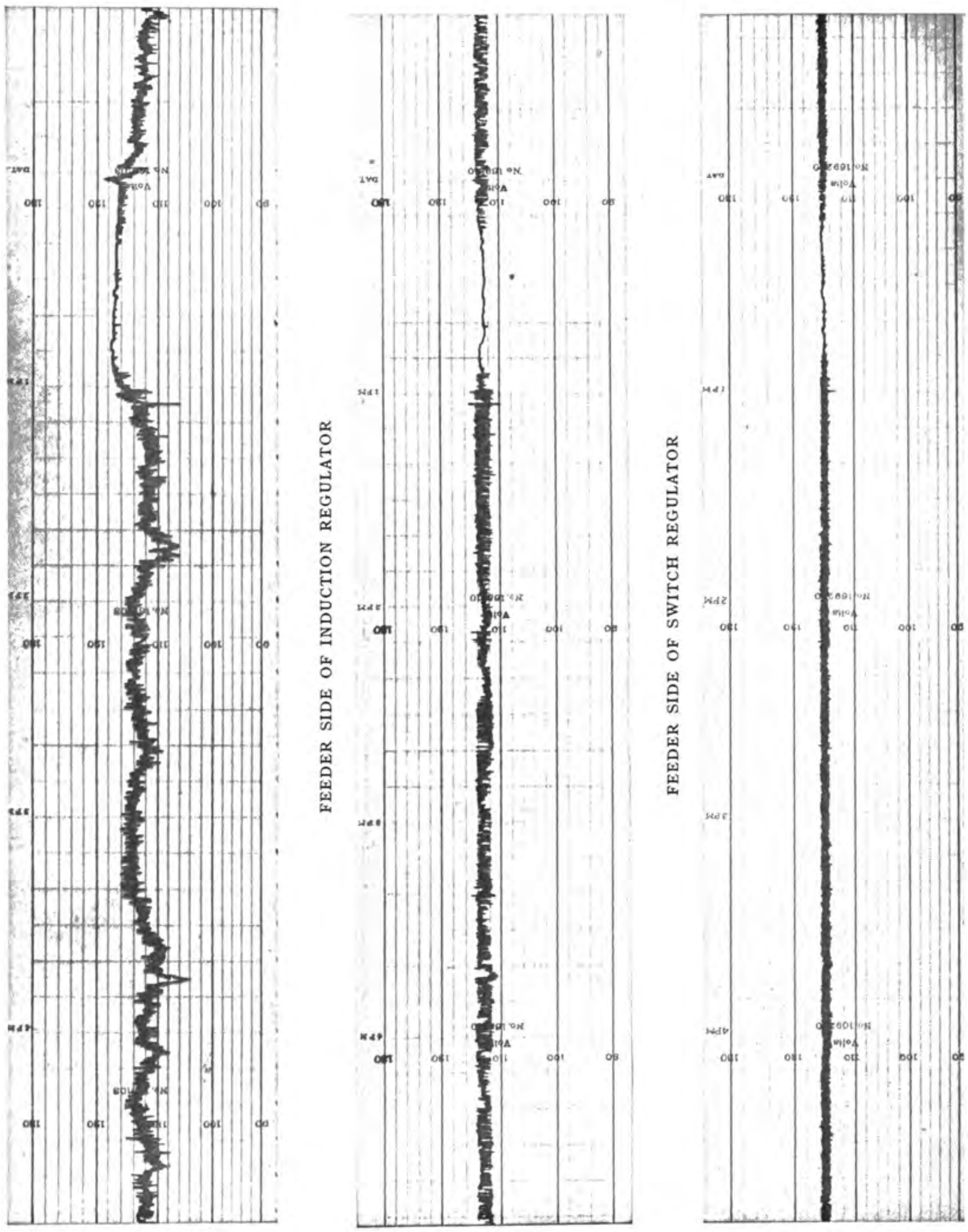
It will be noted that as long as the variations in the generator are gradual, either type of regulator will produce a fairly uniform voltage, but with abrupt changes in the

Fig. 5
TYPE IR FEEDER REGULATOR

generator voltage, such as are produced by a railway load, or in the starting of large induction motors, the Type BR or switch type is the most satisfactory.

The Type BR regulator consists essentially of a transformer with the secondary subdivided into a number of equal sections, and a dial switch with points connected successively to the different sections of the secondary winding. In this type of regulator the moving element is exceedingly light, and having little inertia it is particularly well adapted for very rapid adjustments. The

4793-6 Steady vs. Unsteady Voltage



GENERATOR SIDE OF REGULATOR

FEEDER SIDE OF INDUCTION REGULATOR

FEEDER SIDE OF SWITCH REGULATOR

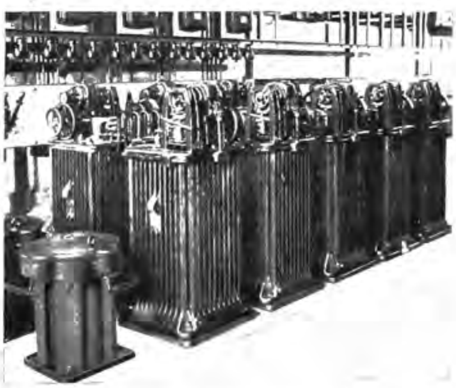
VOLTAGE REGULATION BY AUTOMATIC FEEDER VOLTAGE REGULATORS total time required for obtaining the complete range from maximum boost to maximum lower is about four seconds, and it will therefore compensate for very rapid changes in the line potential. It is, however, only built for single-phase circuits, and is limited by the current and voltage which can safely be handled by the switch. The capacity of the standard switch is 200 amperes and 220 volts boost or lower. As this represents a 20 per cent range on a 2200 volt, 440 kw. circuit, and it is seldom found advisable or necessary to run a single feeder of so large a capacity, the standard Type BR regulator will be found large enough for the majority of conditions. The BR is entirely operated from single-phase current.

The induction Type IR regulator is more rigid and substantial in construction, has a less number of moving parts than the switch type and no moving contacts. It is controlled entirely by means of alternating current and can be furnished for single or polyphase circuits. It can be built for capacities and voltages as great as that of any generator. Its efficiency is somewhat higher than that of the BR but the regulator is a little slower in operation, as it requires from eight to ten seconds for the entire range.

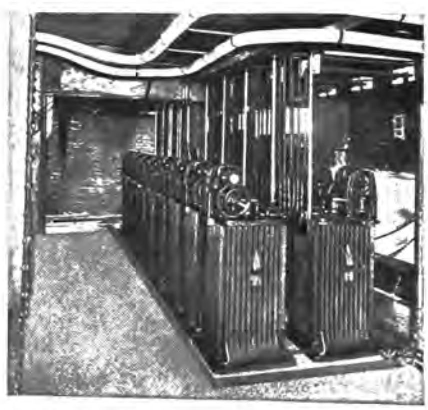
This type of regulator has windings and cores similar to an induction motor, and the armature not only has a considerable inertia, but also a torque depending on the kilowatt capacity. Both torque and inertia must be overcome by the operating motor, and it is, therefore, not always practicable to obtain

Fig. 6

with this regulator the same speed as with the Type BR or switch type. It will, however, be found entirely satisfactory for the majority of conditions.

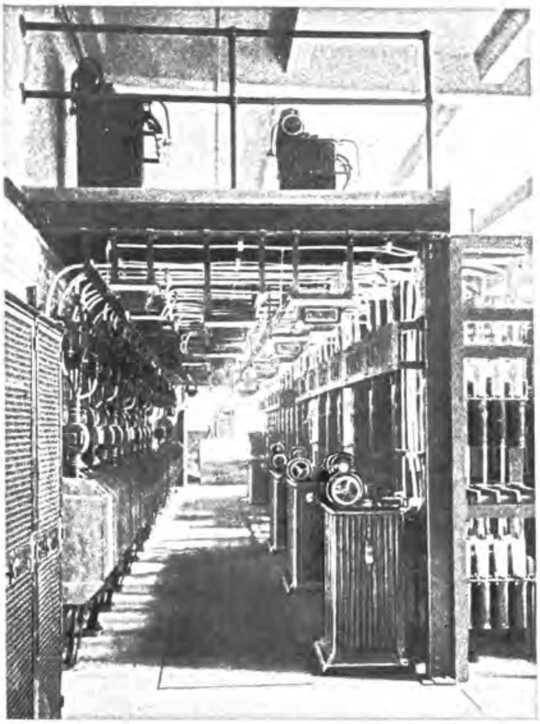


INSTALLATION PHILADELPHIA ELECTRIC CO.
G.E. CO. AUTOMATIC IRS REGULATORS

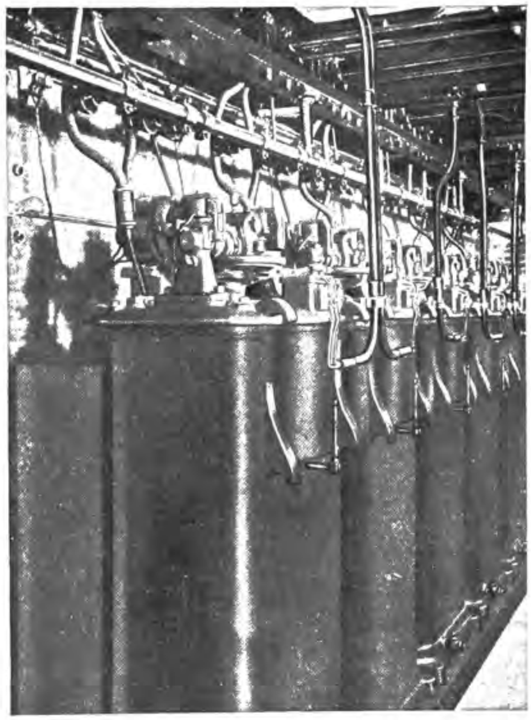


INSTALLATION PHILADELPHIA ELECTRIC CO.
G.E. CO. AUTOMATIC IRS REGULATORS

4793-8 Steady vs. Unsteady Voltage

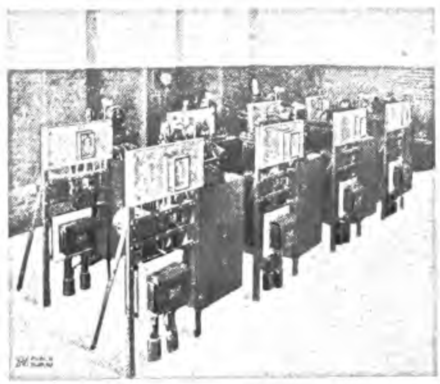


INSTALLATION BOSTON EDISON CO.
G.E. CO. AUTOMATIC IRS
REGULATORS



INSTALLATION UNION ELECTRIC CO., DUBUQUE, IOWA
G.E. CO. AUTOMATIC BR
REGULATORS

INSTALLATION PHILADELPHIA ELECTRIC CO.
SHOWING MOUNTING AUTOMATIC
RELAYS FOR IRS REGULATORS



INSTALLATION NEWBURG LIGHT, HEAT
AND POWER CO.
G.E. CO. AUTOMATIC BR REGULATORS

GENERAL ELECTRIC COMPANY

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Schenectady, N.Y.
RAILWAY DEPARTMENT

November, 1910 Bulletin No. 4794

*THE 1200 VOLT D.C. INTERURBAN LINES OF THE MILWAUKEE ELECTRIC RAILWAY AND LIGHT COMPANY

The Milwaukee Electric Railway and Light Company besides its extensive city service of street railways, lighting and other public utilities, owns and operates the more important interurban roads radiating from Milwaukee. It also furnishes both light and power for most of the towns served by these interurban lines. The size and importance of the system will be appreciated by referring to the accompanying map, Fig. 1.

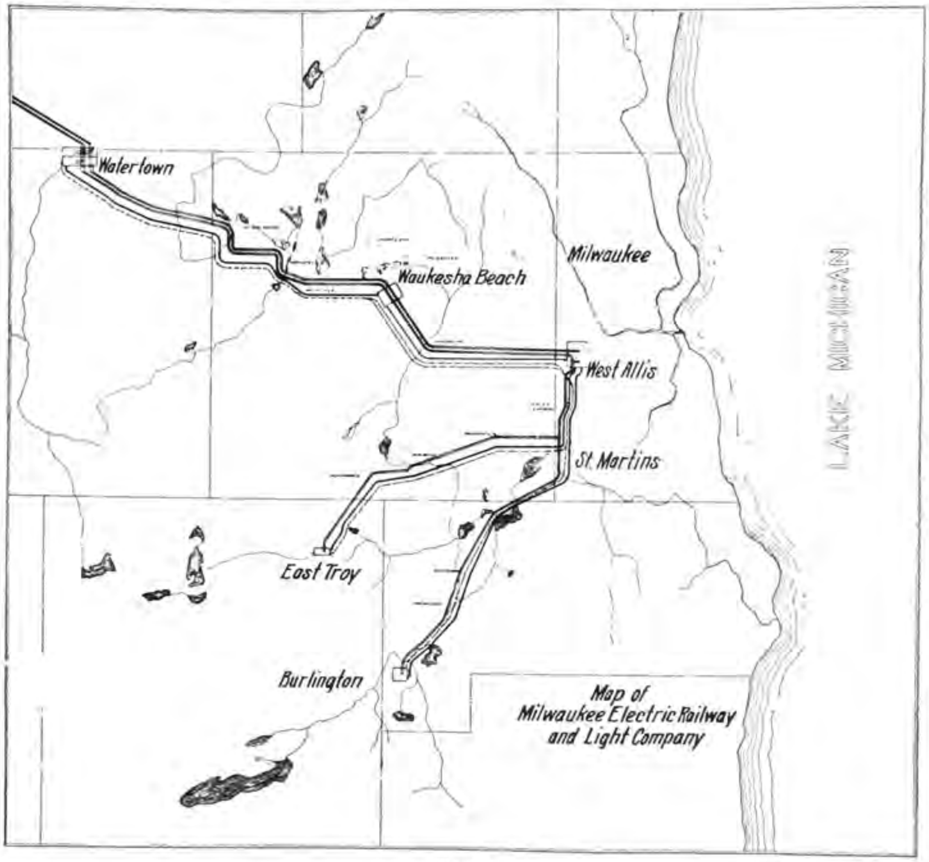

Fig. 1
ROUTE OF MILWAUKEE 1200 VOLT LINE

The interurban lines to be dealt with in the present article traverse remarkably beautiful sections of Wisconsin which are rich in lakes, rivers and other attractions which makes the summer schedule very severe at certain times, although generally speaking the country through which the roads pass is sparsely populated.

The three most important interurban roads are those running to Watertown, East Troy

* Reprint of Article by John R. Hewett in Electric Railway Journal.

and Burlington. Of these lines those sections between Waukesha Beach and Watertown, between St. Martins and East Troy and between St. Martins and Burlington, were formerly operated with a 3300 volt single-phase trolley but they have now been changed over for 1200 volt d.c. operation. In addition the track between West Allis and St. Martins

Fig. 2
INTERURBAN CAR

will be operated by 1200 volts in the near future and it is likely that the 1200 volt trolley will be adopted between Waukesha Beach and West Allis.

The following distances will show that at present there are 67.99 miles of road operating with the 1200 volt system: Waukesha Beach to Watertown 27.42 miles, St. Martins to East Troy 20.75 miles, St. Martins to Burlington 19.82 miles. It is also of interest to note that the distance between Milwaukee and Waukesha Beach is 23.86 miles, Milwaukee and Watertown 51.28 miles, Milwaukee and St. Martins 15.07 miles, West Allis and St. Martins 7.25 miles and West Allis and Milwaukee 7.82 miles.

GENERAL SCHEME OF ELECTRIFICATION

There are three main sources of power feeding into the transmission system. These are the two power houses in Milwaukee, one at Oneida Street and the other at Commerce Street, the third source is derived from the new hydraulic development of the Southern Wisconsin Power Company at Kilbourn which is about 70 miles from Watertown and over 120 miles from Milwaukee. Overhead transmission lines serve all of the interurban roads, while the energy is transmitted to and from Milwaukee and West Allis underground at 13,200 volts.

At present the tension of the system is 38,100 volts, but when some additions at present under way have been completed, the transformer connections will be changed from delta to Y and the potential will be raised to 66,000 volts at three-phase, 25 cycles. The 1200 volt d.c. substations that affect the interurban divisions now under consideration are as follows: For the Watertown road, at Watertown and Waukesha Beach and for the East Troy and Burlington roads, at East Troy, Burlington and West Allis. Feeders are strung on the trolley poles for the entire length of the interurban lines and are tied to the trolley wire at suitable intervals.

Fig. 3
INTERIOR OF INTERURBAN CAR

ROLLING STOCK

The initial rolling stock for service on these interurban roads consists of thirty cars, twenty-five passenger and five utility cars. Fifteen of these cars are new at the present date and were manufactured by the G. C. Kuhlman Car Company of Cleveland, Ohio, and are equipped with GE207 motors. The ten other passenger cars were constructed by the St. Louis Car Company and are now equipped with GE205 motors, whereas they formerly had single-phase apparatus. The remaining five cars used as utility rolling stock have GE205 motors.

The electrical equipments of all these cars are so similar, being all four motor equipments, that they can be described collectively after the different ratings of the GE205 and GE207 motors have been stated. The former is a 75 h.p. unit, while the rated capacity of the latter is 125 h.p. Both motors are of the General Electric commutating pole type and and is operated from either end by a lever in the motorman's cab. This switch has a dual function; first, it changes the motor connections from series to series-parallel during 1200 volt operation, and from series parallel to parallel during 600 volt operation, thereby giving full speed at both voltages; second, it transfers the auxiliary circuits (excepting the compressor circuit) from the trolley to the 600 volt tap of the dynamotor during 1200 volt operation and vice-versa during 600 volt operation.

The balance of the electrical equipment is substantially 600 volt apparatus with additional insulation to withstand the greater electrical potential. The current is collected by a standard type of trolley pole and wheel and passes through a circuit breaker, contact-

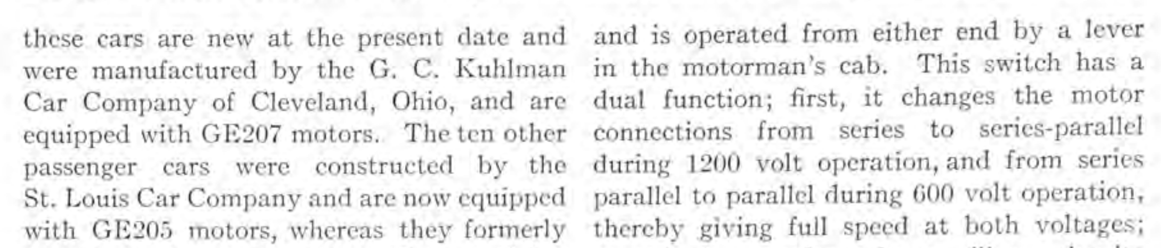

Fig. 4
PLAN OF INTERURBAN CAR

are designed for operation on both 600 volt and 1200 volt trolleys. The GE207 equipments are furnished with sixty tooth split gears and twenty-two tooth steel pinions, while the GE205 equipments have gears with fifty-three teeth and pinions with twenty-one teeth, giving gear ratios of 3.05 and 2.525 respectively. The motors are connected two in series when running on 1200 volts.

The control is the type "M," non-automatic design. As is usual with this type of equipment a dynamotor is used to supply current at 600 volts for the control and lighting circuits during 1200 volt operation. In this instance the compressor motor is insulated for 1200 volts and is run on both voltages with a decreased speed on 600 volts. The commutating switch is placed under the car ors, reverser and commutating switch to the motors. This circuit breaker, the contactors and reversers are electrically operated, and as stated are of standard 600 volt construction.

The car bodies of the fifteen new cars have many features of special interest. Fig. 4 shows a plan from which it will be noticed that the arrangement is somewhat unusual. In general the two ends are symmetrical, the rear compartment always being used as a smoking compartment and the front serving for seating passengers and taking baggage when there is any to be handled. This front compartment is practically an observation end. These cars are of the semi-steel type. The deep plate side sills are girders and form the principal members of the underframing which extends from side door to side door on both sides of the car. There are no bulkheads in the car, the load of the car ends being carried by four-inch channel center sills and two diagonal trusses constructed of four-inch I-beams. All the other smaller members of the underframing are steel.

The floor is a composition laid on keystone galvanized iron flooring. The surface of this composition is five-eighths-inch above the iron flooring and covers the entire floor and platforms. It somewhat resembles cement in appearance. The covers of the motor trap doors are filled with the same composition.

Figs. 2, 3, and 5 show respectively the exterior of one of these cars, an interior view and a car hauling three trailers.

SUBSTATIONS

The substation at Watertown is situated on the banks of the Rock River and besides housing the 1200 volt railway apparatus it contains two frequency changer sets for the lighting and power business of Watertown; in addition to these machines there is one 300 kw. generator driven by a hydraulic turbine to take care of the day lighting and power load

Fig. 5
MOTOR CAR AND THREE TRAILERS

of Watertown. Fig. 6 is an interior view of this substation, showing the railway apparatus in the foreground and the frequency changer sets and waterwheel unit in the background.

The West Allis substation is very large. It takes care of both city lighting and 600 volt city railway apparatus, and also contains apparatus for generating current at 1200 volts for the system being described. The energy from Kilbourn is received over the transmission line and transformed by six 2000 kv-a.,

The more important data concerning these cars are as follows:

Length overall	53 ft. 5 in.
Length over corner posts	40 ft.
Extreme width	8 ft. 7 in.
Height from rail over roof boards	11 ft. 6 in.
Distance between truck centers	28 ft. 4 in.
Weight of car body and trucks	48,000 lbs.
Total weight	80,000 lbs.
Seating capacity	64
TRUCKS	
Type	Brill M.C.B.
Wheel base	6 ft. 1 in.
Diameter of wheel	36 in.
Weight, exclusive of motor	14,000 lb.

66,000 volt, 13,200 volt O-I-W-C transformers. Figs. 8 and 9 are two exterior views of the West Allis substation and in the latter it will be seen that car house and office facilities are provided under the same roof.

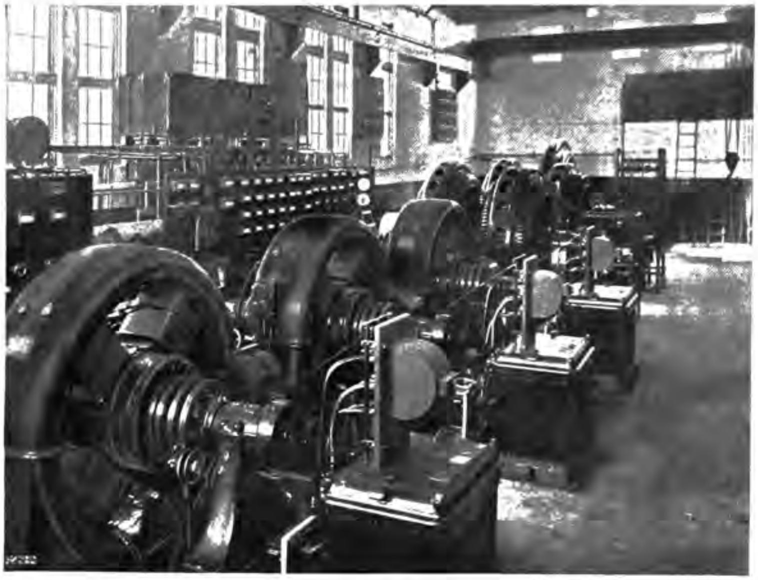

Fig. 6
INTERIOR OF WATERTOWN SUBSTATION

The Waukesha Beach substation and those at East Troy and Burlington are typical 1200 volt substations. Their layout and functions are the same with the one exception, that at Waukesha Beach where 600 volt current is fed in the direction of West Allis and 1200 volt current towards Watertown. Both the 600 volt and 1200 volt feeders are fed from the same rotary converters, which are connected in series. As these three substations are practically identical in design and are used solely for railway work, one description will cover all of them. Fig. 7 shows the exterior of the Burlington and Waukesha Beach substation. The building is of very neat design and is constructed of cream-colored brick with concrete floors. Fig. 10 shows a plan of the East Troy and Burlington substation, while Fig. 13 gives sectional views which apply to all three substations. This latter illustration with but slight modifications would also apply to the Waukesha Beach substations. Figs. 12, 14 and 15 are interior views of the Waukesha Beach substation. The buildings are each divided into a high tension compartment and a machine room. The former, containing the lightning arresters, oil switches, etc., is very roomy and provides ample spacing between all high tension leads.

The leads from the high tension transmission line are brought into the substation through vertical roof bushings in the high tension compartment roof and pass through double-throw, triple-pole switches, then through choke coils, K10 automatic oil switches and disconnecting switches to the primaries of the transformers. The secondaries of these transformers are double. The leads from the secondaries go to the reactances and thence to the collector rings of the rotary converters. The rotaries are 600 volt machines connected two

Fig. 7
EXTERIOR OF BURLINGTON AND WAUKESHA SUBSTATION

in series to give 1200 volts for the trolley. The lightning arresters are tapped from the high tension leads immediately after they have passed the double-throw triple-pole switches. They are of the G.E. aluminum cell type and have horn gaps.

The number of rotary converters and transformers installed in each substation is shown in the accompanying table, which also gives their capacity. There are three rotaries in the Waukesha Beach substation, two of which are connected in series to form a pair giving 1200 volts while the third serves as a spare.

SUBSTATION APPARATUS

	Rotary Converters		Transformers	
	Number	Capacity Each	Number	Capacity Each
Watertown	4	300 kw.	6	200 kw.
West Allis	2	500 kw.	6	185 kw.
East Troy	4	300 kw.	6	200 kw.
Burlington	4	300 kw.	6	200 kw.
Waukesha Beach	3	500 kw.	9	185 kw.

NOTE.—There are also two 500 kw. rotary converters and six 185 kw. transformers installed in the existing substation at West Allis.

Fig. 8
EXTERIOR OF WEST ALLIS SUBSTATION

ROTARY CONVERTERS

The twelve 300 kw. rotary converters are General Electric four-pole machines. They run at 750 r.p.m. and have a full load direct current of 500 amp. The five 500 kw. rotary converters are six-pole units with a speed of

Fig. 9
EXTERIOR OF WEST ALLIS SUBSTATION

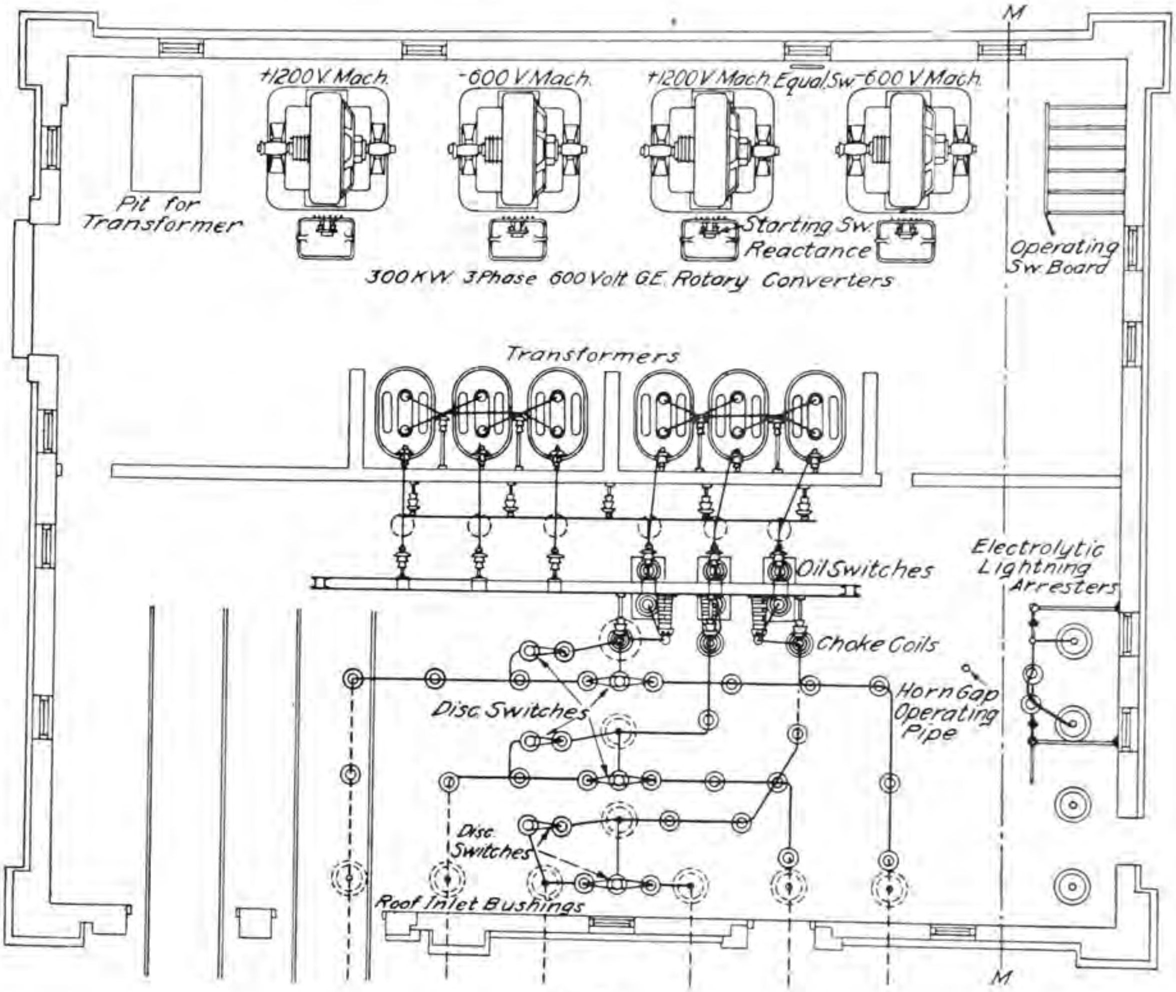

Fig. 10
PLAN OF EAST TROY AND BURLINGTON SUBSTATION
(For Section See Fig. 13)

500 r.p.m. and have a full load direct current capacity of 834 amp. A number of short circuit tests were made in the factory which showed that the effects of flashovers on the brush rigging and commutators was no more serious than in the case of 600 volt machines. There is no tendency to hunt and the factory tests also showed that these rotaries can stand very severe overloads.

The potential of each machine is 600 volts and two units are connected in series to give the desired 1200 volts. In all essentials the machines are standard 600 volt units with additional insulation. They are compound wound with the shunt fields excited from the individual machine, and the series fields of each pair connected in series on the grounded side. Each machine is provided with a speed limiting device and a magnetic oscillator, while metallic graphite brushes are used on the a.c. side, making lubrication unnecessary and decreasing the amount of dust from brush and ring wear. The d.c. brush riggings are all supported from the magnetic frame so that there will be no metal around the commutator on which an arc could hold should a flash-over occur from a short circuit. The projecting ends of the commutator clamping

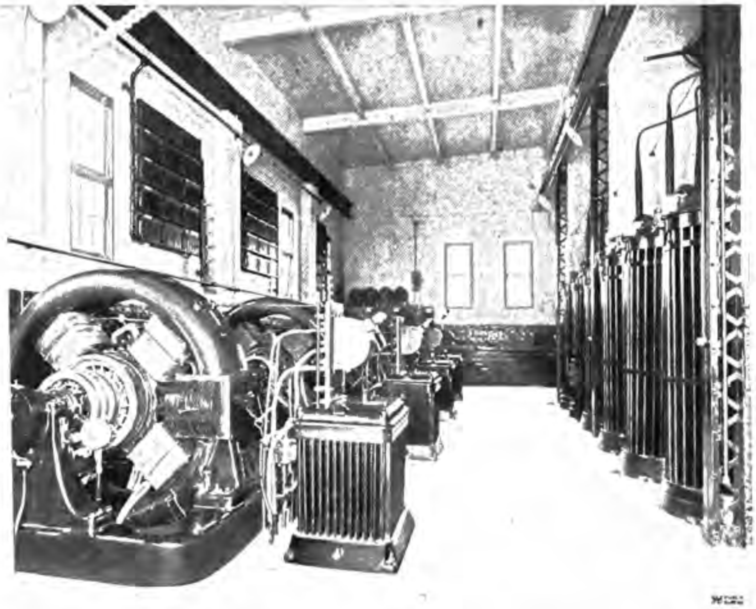

Fig. 11
INTERIOR OF WAUKESHA SUBSTATION

rings are entirely insulated and the metal shell and bolts of the collector rings which are usually exposed are covered with insulation.

The reactive coils used with the 300 kw. rotary converters have a capacity of 45 kv-a. and those used with the 500 kw. machines are 75 kv-a. They are all oil-cooled and have standard starting switches with protecting covers, mounted on the top. (See Fig. 11.)

TRANSFORMERS

The eighteen 200 kw. transformers are General Electric single-phase units of the oil-cooled core type with primaries multiple wound for 38,100 volts when delta-connected, and 66,000 volts when Y-connected. The secondaries are wound with two distinct windings for supplying the rotaries in series, each winding giving 370 volts; 50 per cent starting taps are provided in the secondary windings. These transformers are used in conjunction with the 300 kw. rotary converters, there being three single-phase transformers to each pair of rotary converters.

The nine 185 kw. transformers used in conjunction with the 500 kw. rotaries at Waukesha Beach, have the same arrangement of primaries as above, but the secondaries are wound for 430 volts and have 1/3 and 2/3 starting taps. The six transformers installed in the West Allis substation are also single-phase, 185 kw. units, but the primaries are wound for 13,200 volts and the secondaries for 430 volts. These secondaries also have 1/3 and 2/3 starting taps.

OIL SWITCHES

The high tension oil switches (see Fig. 12) in all of the substations described are of the K10 type, which is a top-connected switch designed for open wiring. It is made up of single pole elements and may be operated either by hand or by solenoid. This switch requires no masonry cells, each single pole element incorporating

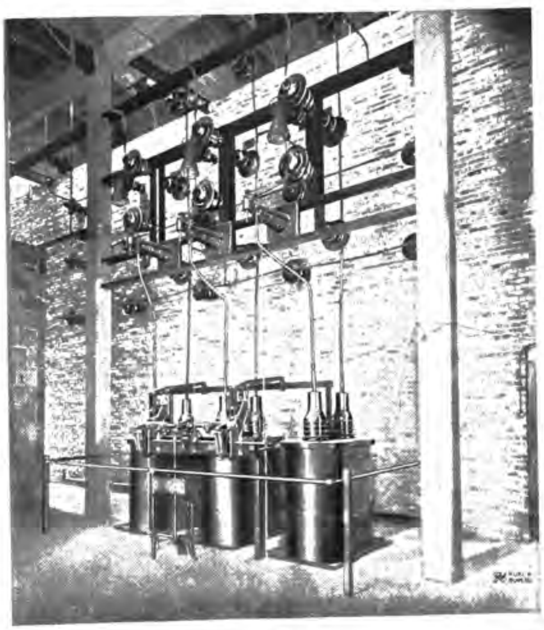

Fig. 12
OIL SWITCHES—WAUKESHA SUBSTATION

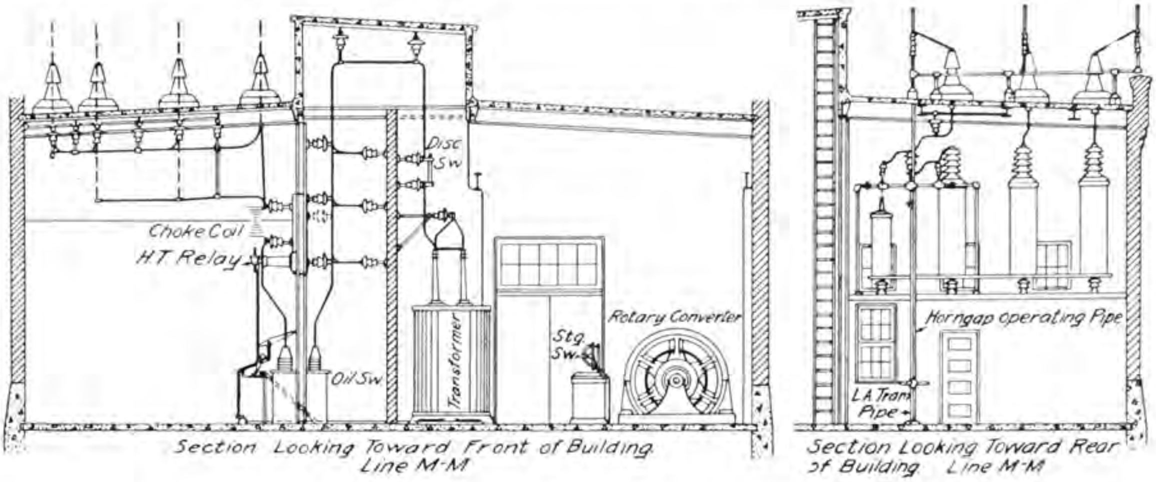

Fig. 13
SECTIONAL VIEW OF EAST TROY AND BURLINGTON SUBSTATION
(For Plan See Fig. 10

the advantages of a brick compartment in itself. The oil receptacles which constitute the body of the switch are made of steel boiler plate and support the switch leads and operating parts. The insulators are of the built-up type, having porcelain ends, and intermediate sections of a special insulating material with projecting washers to give a very large creepage surface. After these insulators have been assembled they are filled with compound and are clamped and supported separately on iron plates which are in turn bolted to the top of the oil tank. This construction permits the removal of parts without dismantling the switch. The stationary contacts are supported at the bottom of the insulator and consist of a double set of flared fingers which prevent pitting at the contact surfaces. A horizontal contact bar with wedge-shaped blades closes the circuit. This bar is connected to the operating mechanism by a series of treated wooden rods and in a set of three switches, forming a three-phase group; these bars are parallel to one another and are operated in a vertical direction to open or throw the switch. The drop of these contact bars interrupts the circuit, producing a double break or two breaks in series in each of the single pole elements.

LIGHTNING ARRESTERS AND SWITCHBOARD

The lightning arresters are of the electrolytic type, being aluminum cone-shaped plates housed in steel tanks. The tanks are of such a capacity as to hold an ample quantity of electrolyte and oil. Fig. 14 gives an illustration of these lightning arresters as installed in the Waukesha Beach substation. The three-phase legs are shown with the latest type of high tension outdoor bushings. The horn gaps are placed on the roof of the substation just above the ceiling bushings and are operated by a rod brought down into the substation.

The switchboards each consist of five panels, two low machine panels, two high machine panels and one 1200 volt feeder panel. There is also a swinging bracket. The most important items of equipment on the high machine panels are the circuit breakers, rheostat handwheel and power-factor meter. The circuit breakers are mounted on the back of the board and barriers are provided to eliminate all danger of flashovers; they are operated by handles mounted on the front. The equipment of the low machine panels is similar to that of the high machine panels, with the exception that a switch is substituted

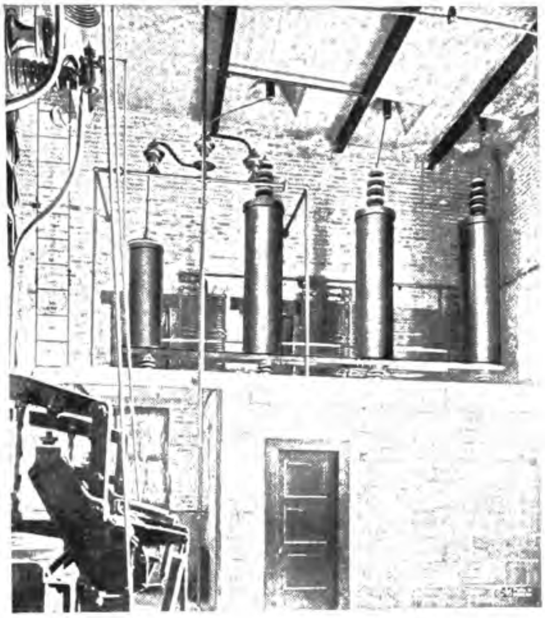

Fig. 14
ELECTROLYTIC LIGHTNING ARRESTERS
WAUKESHA SUBSTATION

Fig. 15
SWITCHBOARD—WAUKESHA SUBSTATION

Fig. 16
STANDARD HIGH TENSION TOWER USED ON
PRIVATE RIGHT-OF-WAY

Fig. 17
HIGH TENSION TRANSMISSION TOWER USED
IN CITIES AND TOWNS

for the circuit breaker and an ammeter is provided.

The 1200 volt feeder panel is equipped with both a circuit breaker and a switch with the circuit breaker tripping device brought to the front of the board. The swinging bracket is furnished with two voltmeters and subbases are provided for the wattmeters. Fig. 15 shows a view of one of these switchboards and it will be noted that in this instance the rheostats are mounted above the board. This is because there was no room on the ground at the back of this particular board for their reception, where there is sufficient room they are installed on the ground. All of the switchboard equipment, including instruments, was manufactured and supplied by the General Electric Company, but the panels were made and equipped in the shops of the Milwaukee Electric Railway and Light Company.

TRANSMISSION LINE

The transmission line from Kilbourn to Watertown is owned by the Southern Wisconsin Power Company and was constructed to feed the railway system of the Milwaukee Electric Railway and Light Company from the hydro-electric development on the Wisconsin River.

The distance between Kilbourn and Watertown is approximately 70 miles. At present the potential is 38,100 volts with the transformers connected in delta, but eventually connections giving 66,000 volts will be used. The transmission line is in duplicate for the entire 113 miles from Kilbourn to West Allis and is carried on steel towers between Kilbourn and Waukesha Beach, the remainder being carried on wooden poles. The steel tower line will extend to West Allis in the near future and then the voltage will be raised as explained. Stranded copper wire of No. 0 gauge is employed between Kilbourn and Watertown, while stranded aluminum is used between Watertown and West Allis, the aluminum conductors having a current carrying capacity equivalent to No. 0 copper wire. Between West Allis and St. Martins the transmission line is also in duplicate and consists of No. 2 copper wires carried on wooden poles. From St. Martins to East Troy and from St. Martins to Burlington the transmission line is single (three wires); it is carried on wooden poles and consists of No. 2 copper wires. A ground wire if desirable will eventually be strung throughout from West Allis to Watertown, and between Watertown and Kilbourn it is possible that two ground wires will be employed.

Fig. 18
VIEW OF TRANSMISSION, TROLLEY AND FEEDER LINE, SHOWING BRACKET CONSTRUCTION

The transmission line throughout is a most excellent piece of construction work consisting of galvanized steel towers bolted together on the ground. Figs. 16, 17 and 18 are representative of the transmission line. The insulators are of the suspension type and each consists of three units. Fig. 20 gives a close view of the high tension roof bushings. Fig. 19 shows very clearly the way the transmission line is carried on the roof of substations and the

Fig. 19
TAPPING TRANSMISSION LINE ON SUBSTATION ROOF

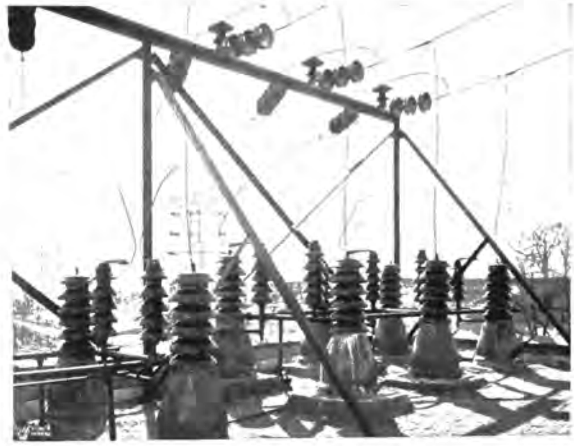

Fig. 20
HIGH TENSION ROOF BUSHINGS

manner of tapping. The horn gaps for the lightning arresters are in the background.

OVERHEAD CONSTRUCTION AND TRACK

The overhead construction on the interurban roads is the same as when single-phase equipments were is use. It is of the catenary suspended type on all 1200 volt sections. The accompanying table will give the more important detail covering the trolley, track and feeders. For convenience the distances between the substations is also given in this table.

The feeders are carried on the same poles as the trolley. Fig. 16 gives a good general idea of the construction. The pole lines are a splendid example of interurban railroading; the poles are all painted, are perfectly straight and are kept in perfect alignment. The track is well ballasted throughout the entire system; 80 lb. rails are used for the major portion of the distance.

SERVICE

The density of traffic varies with the season of the year. During the winter months the trains running on two hourly headway in each direction take care of the business, but in summer trains are run on one hour headway regularly and often several sections of two, three and four car trains are necessary to take care of the traffic. The holiday traffic is abnormally heavy. On holidays it is a common practice to haul as many as three trailers with one car and during the busy hours every day one or two trailers are usually hauled. The weight of each trailer is about 35,000 lbs. The 1200 volt cars run right into the city of Milwaukee to the terminal station in the Public Service Building.

	Watertown to Waukesha Beach	Waukesha Beach to West Allis	West Allis to East Troy	West Allis to Burlington
Feeder material	Aluminum	Copper	Aluminum	Aluminum
Feeder size	795,000 circ. mil.	500,000 circ. mil.	795,000 circ. mil.	795,000 circ.mil.
Trolley type	Single bracket catenary	Double span	Single bracket catenary	Single bracket catenary
Trolley size	No. 00	No. 000	No. 00	No.0000
Track	Single	Double	Single	Single
Distance	27.42 miles	16.04 miles	28 miles	27.07 miles

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General Electric Company
Schenectady, N.Y.

LIGHTING DEPARTMENT

November, 1910 *Bulletin No. 4796*

ALTERNATING CURRENT GENERATORS FOR DIRECT CONNECTION TO RECIPROCATING ENGINES

The use of alternating current permits a large amount of energy to be economically distributed over a wide area from a single generating station. The General Electric Company builds alternating current generators ranging in capacity from a fraction of a kilowatt to 20,000 kilowatts. It has now in process of construction several machines, each of 20,000 kilowatts capacity, and its total production of alternators in all sizes has in ten years amounted to over four millions of kilowatts.

Alternators are designated by their frequency, voltage, phase, speed capacity, and method of drive.

The frequencies in most general use today are sixty and twenty-five cycles. Sixty cycle apparatus is generally lower in price, and, since it has become the accepted standard, should always be chosen for general lighting and power service. The use of twenty-five cycle apparatus is practically confined to railway systems using rotary converter substations, to steel mills, and to the extension

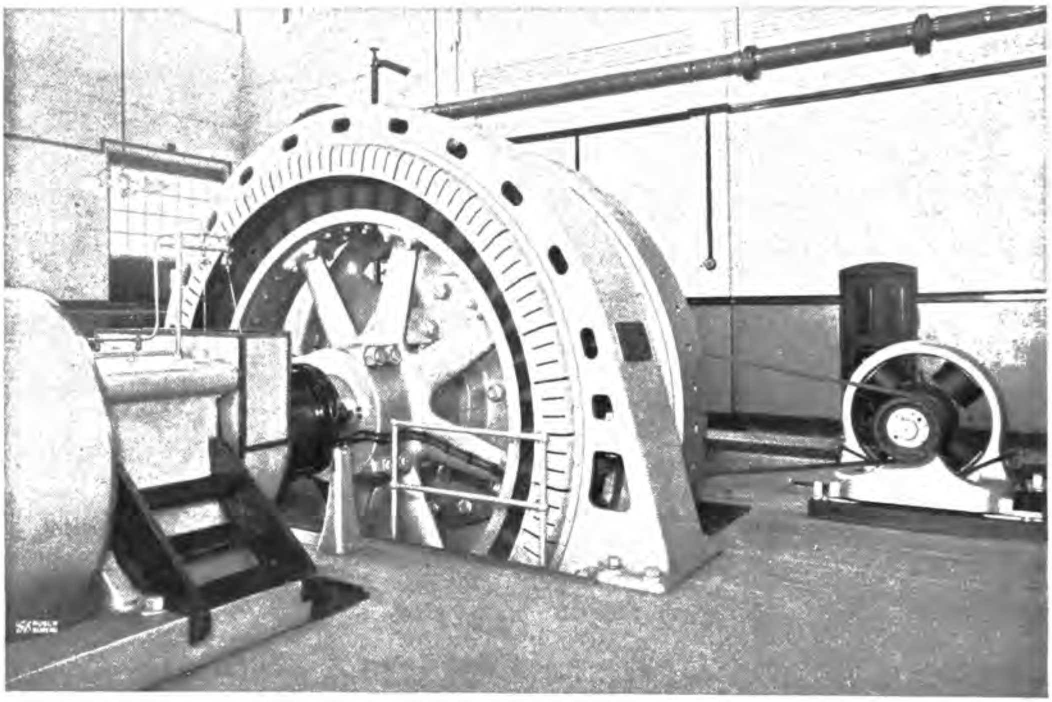


Fig. 1. 1000 KW. 550 VOLT 3-PHASE GENERATOR ENGINE-DRIVEN WITH BELT CONNECTED EXCITER

of existing plants already operating at this frequency.

The proper voltage for generating apparatus would, if there were no limiting conditions, probably be determined by the amount of power and distance to which it was to be transmitted, but in practice it is found desirable to select the voltage that is already in use in adjacent or similar plants, particularly k.v.a. generator should deliver its full energy output of 100 kilowatts at unity power factor; but if the power factor should be .8, the energy output of the machine would be reduced to 80 kilowatts, although the current, and consequently the heating of the armature, would be approximately the same as if it were delivering 100 kilowatts at unity power factor. It will be seen from the above that

Fig. 2. BOX FRAME TYPE ARMATURE

if this voltage is standard. The generator voltages listed in this bulletin correspond to those recommended by the American Institute of Electrical Engineers.

Three-phase apparatus is suitable for either lighting or power service, and, as energy can be most economically distributed with this system, it is strongly recommended in preference to either single- or two-phase.

Alternating current generators are rated in kilovolt ampere output, that is, a 100 the actual energy output in kilowatts is equal to the apparent power or kilovolt amperes multiplied by the power factor of the load.

The purpose of this bulletin is to illustrate and describe some of the recent improvements in the alternators built by the General Electric Company for direct connection to steam, oil or gas engines.

Stationary armature or revolving field alternators, since their design avoids the use of collector rings and brushes for collecting the armature current and permits the high voltage windings to be carried by the stationary portion of the machine, have become the recognized standard.

Stationary Armature

The stationary armature consists of a circular cast iron frame, supporting a laminated iron core in which the armature windings are embedded. The frame is either of the box type, (Figs. 1 and 2) or of the skeleton type, (Fig. 3). For manufacturing reasons the skeleton type is preferred for certain sizes of machines, as its construction readily permits of changes being made in the stacking of the core laminations without a change in the patterns.

The core is composed of punchings made from the best grade of carefully selected sheet iron, treated before assembling in order to reduce the core loss. The punchings are stacked together and held rigidly in place by heavy steel clamping fingers, ducts being provided in the stacking at frequent intervals to allow for the free circulation of air. The outer circumference of the laminations is dovetailed for fastening to the frame and the inner circumference is slotted to receive the windings.

Armature Windings

The armature windings consist of carefully insulated form wound coils held in slots by suitable wedges. Particular attention is called to the open slot construction of the armatures, which permits the use of form wound coils that can be easily removed and replaced in case of damage. The coils and windings are clearly shown in Fig. 4.

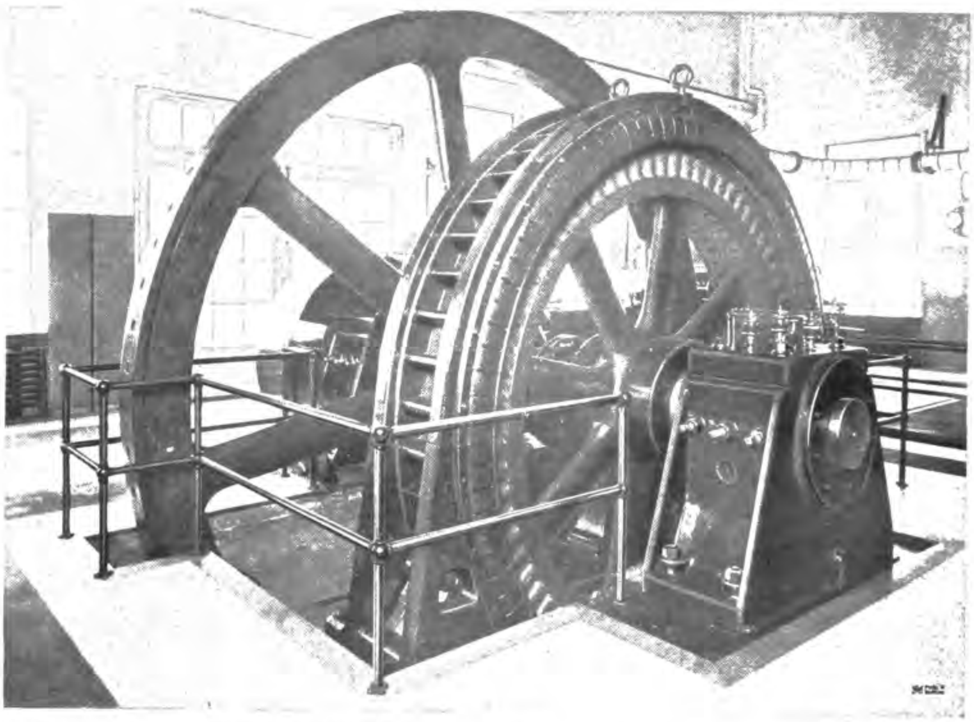


Fig. 3. 450 KW. 3-PHASE 60 CYCLE ENGINE-DRIVEN GENERATOR—SKELETON TYPE FRAME

Revolving Field Structure

The revolving field structure consists of laminated pole pieces bolted to a cast steel or iron ring, which is connected to the hub by arms of ample section. The pole pieces are built of sheet iron, spreading at the pole face so as to secure not only a wide polar

Fig. 4. SECTION OF ARMATURE SHOWING METHOD OF ASSEMBLING COILS

arc for the proper distribution of the magnetic flux, but also to hold the field windings in place.

Field Coils

Two methods are used for winding the field coils of these machines. In the smaller machines the wire is wound on spools which are slipped over the pole piece and held in place by the large pole tips previously mentioned. The field coils on the larger machines consist of a single strip of flat copper, wound on edge so that a surface of every turn is exposed to the air for cooling. The flat sides of the copper strip rest against each other and the entire coil forms a structure of great solidity that can be easily removed for inspection and repair.

Collector Rings

The collector rings for the low potential field current are provided with duplicate carbon brushes and require practically no attention in operation. The brush-holders are supported by a cast iron standard or yoke from which they are insulated by suitable bushings.

Method of Connection to Prime Movers

The capping of the foundation for direct connected generators may be arranged in any one of the following methods, depending upon the available room and the type of prime mover.

Rails and Carriers

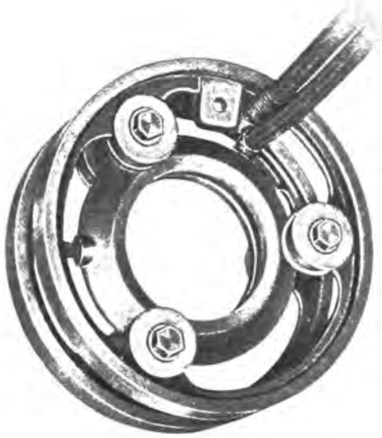
The foundation caps may be extended in the form of rails, so that the foot of the generator frame can be slid away from the engine along these rails in the direction of the

Fig. 5. REVOLVING FIELD—WITH WIRE WOUND COILS

length of the shaft, thereby exposing both the stator and rotor for inspection and repair. Cast iron carriers are sometimes attached to the bottom of the generator feet. These carriers slide easily along the rails and are, therefore, used with the larger and heavier machines.

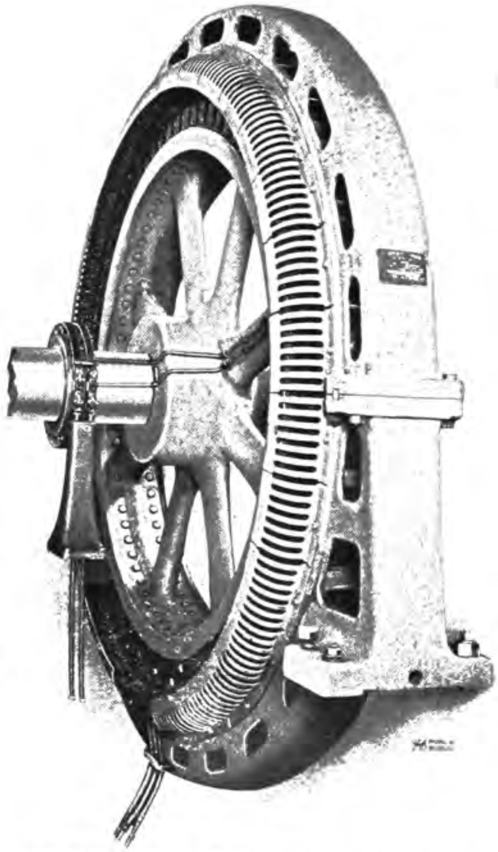
WIRE WOUND FIELD COIL

STRIP WOUND FIELD COIL



COLLECTOR RINGS

TERMINAL BOARD



ASSEMBLED GENERATOR SHOWING COLLECTOR RINGS, BRUSH-HOLDERS AND STANDARD

Sole Plates

If there is sufficient space for movement in the direction of the shaft, the foundation cap is a sole plate which is but slightly larger than the foot of the generator frame and permits no movement. Carriers are then unnecessary.

Common Base

The engine is sometimes furnished with an type of generators." An "engine type generator" is one whose base, shaft and bearings are not furnished by the generator builder.

Simple engines usually have a common base for the engine and generator. Cross compound engines have no extended base and the generator should, therefore, be supplied with sole plates, rails, or rails and carriers.

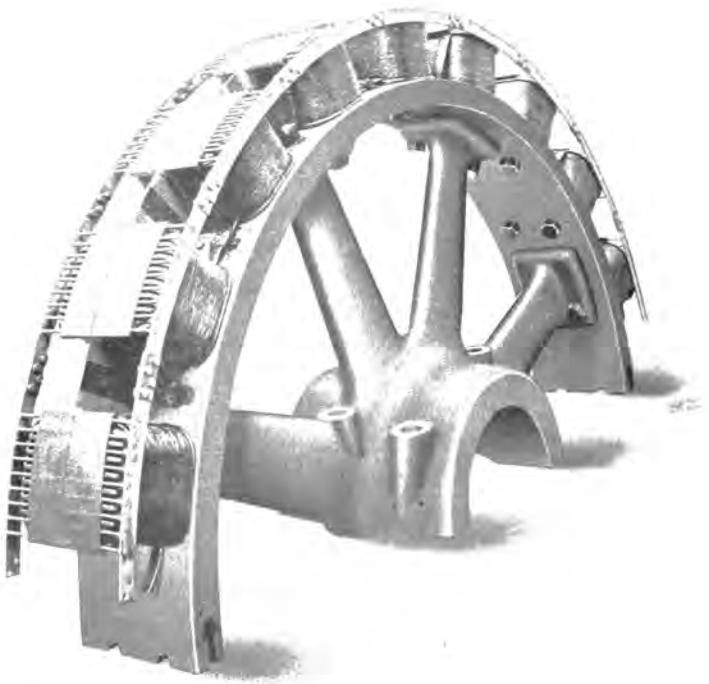


Fig. 6. SPLIT FIELD SPIDER WITH SQUIRREL CAGE WINDING

extended subbase. This extension may be arranged to permit the sliding of the generator frame or serve as a sole plate and permit no movement.

Generators for coupling to gas engines are frequently furnished with bearings, separate base and separate shaft; that is, the generator is self-contained. The shaft projects beyond the bearing and is arranged for coupling. In this respect they resemble the "waterwheel

The hub of the revolving field of a direct connected alternator is carefully bored out by the generator manufacturer to a certain gauge, and the shaft is turned by the engine builder to a similar gauge several thousandths of an inch larger to secure a press fit. This "pressing in" may be done at the ultimate destination or by the General Electric Company at their factory. An extra charge is made for doing this work.

Parallel Operation

The design of these machines, like that of all standard alternators, is such that they may be run successfully in parallel with each other if driven by engines of reasonable regulation whose reciprocating parts will not create or sustain a periodic movement between machines.

The builders of gas engines prefer to have the generators which they drive equipped with a short circuited "squirrel cage" or amortisseur winding over the revolving field. A tendency to pulsation or "hunting" between the engines, that is, accompanied by a sudden change in the angular velocity of the field, generates current in this short circuited winding which resists the forces causing the pulsation. The appearance of this short circuited winding is shown in Fig. 6.

Heating and Overloads

These generators will, with proper ventilation, operate continuously at rated k.v.a. load and power factor with a temperature rise not exceeding 40 degrees C. and for two hours thereafter at 25 per cent overload with a rise not exceeding 55 degrees C.

POLE PIECE AND FIELD COIL

The temperatures are measured by thermometer and are based upon a room temperature of 25 degrees C. and barometric pressure of 30 inches, in accordance with the Standardization Rules of the A.I.E.E.

Single-Phase Rating

Single-phase windings have not been standardized for these machines as it is intended to use two phases of the standard three-phase winding when single-phase units are desired.

REVOLVING FIELD WITH STRIP WOUND COILS

The generators listed in the following tables will deliver 70 per cent of their three-phase output when operated single-phase.

Excitation

Alternating current generators require for their fields a separate source of direct current excitation, which should preferably be automatically controlled. The excitation of an alternator at its rated overload and .8 power factor would not, if controlled by hand, exceed 125 volts, although, in order to make its armature voltage respond quickly to changes in the load and speed, the excitation of its fields may at times be momentarily varied by an automatic regulator between the limits of 70 and 140 volts. The exciter should, in turn, respond instantly to this demand upon its armature, and experience has shown that to do this its shunt fields must have sufficient margin at full load to deliver momentarily a range of from 25 to 160 volts at its armature terminals.

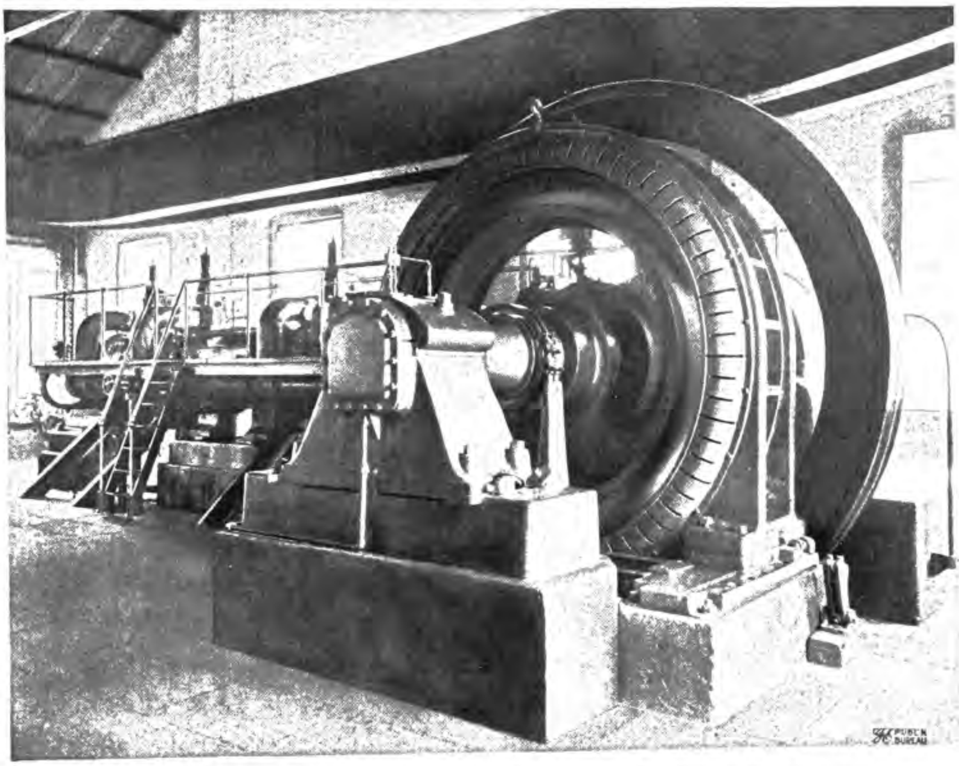
It is obvious from the above that an exciter suitable for use with an automatic TA regulator must commutate successfully over a wide range in voltage, and, if properly designed, have liberal margins in its shunt fields and magnetic circuits.

The General Electric Company designs all of its exciters to meet the foregoing specifications, regardless of whether they are belted, steam turbine-driven, induction motor-driven or direct connected.

Alternator fields designed for and operated at unity power factor have often proved unsatisfactory when the machines were called upon to deliver their rated k.v.a. at .8 power factor or lower. This was due to the increased field current required at the latter condition and resulted, first, in the overheating of the fields and, second, in the necessity of raising the direct current exciting voltage above 125 volts, which often required the purchase of new exciters.

The field windings of General Electric alternators have been increased in weight and cross section so that the heating is moderate and the excitation voltage required at the rated overload output and .8 power factor should not exceed 125 volts.

The direct connected exciters listed in the following tables are suitable for use with an automatic TA regulator and have sufficient capacity to excite their generators at rated overload and .8 power factor.



400 KW. 370 VOLT SKELETON FRAME TYPE ENGINE-DRIVEN ALTERNATOR

60 CYCLE TWO- AND THREE-PHASE GENERATORS, ENGINE-DRIVEN

CLASSIFICATION			KW. CAPACITY		Full Load Voltage	Provide 125 Volt Exciter Rated Kw.	Bore of Revolving Field Hub for Engine Shaft Inches
Poles	K.V.A.	R.P.M.	1.0 P.F.	0.8 P.F.			
ATB24	50	300	50	40	240	5	4 to 6.5
					480	5	4 to 6.5
					600	5	4 to 6.5
					2300	5	4 to 6.5
*ATB24	75	300	75	60	600	7	5½ to 7½
					2300	7	5½ to 7½
*ATB26	75	276	75	60	240	7	5½ to 7½
					480	7	5½ to 7½
					600	7	5½ to 7½
					2300	7	5½ to 7½
*ATB44	110	164	110	88	240	7.5	8 to 10
					480	7.5	8 to 10
					600	7.5	8 to 10
					2300	7.5	8 to 10
*ATB26	125	276	125	100	600	9	6 to 8½
					2300	9	6 to 8½
*ATB28	125	257	125	100	240	8.5	6 to 8½
					480	8.5	6 to 8½
					600	8.5	6 to 8½
					2300	8.5	6 to 8½
*ATB36	125	200	125	100	240	7.5	7 to 9
					480	7.5	7 to 9
					600	7.5	7 to 9
					2300	7.5	7 to 9
*ATB60	125	120	125	100	240	8	10 to 12
					480	8	10 to 12
					600	8	10 to 12
					2300	8	10 to 12
*ATB28	185	257	185	150	600	10	7 to 10
					2300	10	7 to 10
*ATB32	185	225	185	150	240	10	7 to 10
					480	10	7 to 10
					600	10	7 to 10
					2300	10	7 to 10
ATB44	187	164	187	150	240	9	10 to 12
					480	9	10 to 12
					600	9	10 to 12
					2300	9	10 to 12
*ATB60	187	120	187	150	2300	13.5	9 to 12
*ATB32	250	225	250	200	2300	13	9 to 12
*ATB36	250	200	250	200	240	10	9 to 12
					480	10	9 to 12
					600	10	9 to 12
					2300	10	9 to 12
*ATB48	250	150	250	200	2300	14	10 to 14
*ATB60	250	120	250	200	600	15	10 to 13
					2300	15	10 to 13
ATB36	312	200	312	250	2300	13	10 to 14
ATB60	312	120	312	250	600	16	12 to 15
					2300	16	12 to 15

Generator field rheostat included.

The same data as given above for three-phase generators (ATB) also applies to quarter-phase generators (AQB). Base, shaft or bearings are not included.

* Rails, carriers, brush-holder stands and supports not included on machines marked *.

4796–10 *Alternating Current Generators for Direct Connection to Reciprocating Engines*

60 CYCLE TWO- AND THREE-PHASE GENERATORS, ENGINE-DRIVEN

CLASSIFICATION			KW. CAPACITY		Full Load Voltage	Provide 125 Volt Exciter Rated Kw.	Bore of Revolving Field Hub for Engine Shaft Inches
Poles	K.V.A.	R.P.M.	1.0 P.F.	0.8 P.F.			
ATB72	312	100	312	250	480	15	16
					600	15	16
					2300	15	16
ATB48	375	150	375	300	240	15	11 to 15
					480	15	11 to 15
					600	15	11 to 15
					2300	15	11 to 15
ATB60	400	120	400	320	600	18	12 to 15
					2300	18	12 to 15
ATB48	500	150	500	400	2300	21	12 to 16
ATB60	500	120	500	400	240	20	12 to 15
					480	20	12 to 15
					600	20	12 to 15
					2300	20	12 to 15
ATB72	500	100	500	400	600	20	13 to 18
					2300	20	13 to 18
ATB60	600	120	600	480	600	22	13 to 17
					2300	22	13 to 17
					4000	22	13 to 17
ATB72	600	100	600	480	600	23	18 to 22
					2300	23	18 to 22
ATB48	625	150	625	500	240	14	12 to 16
					480	14	12 to 16
					2300	14	12 to 16
ATB48	750	150	750	600	600	17	13 to 17
					2300	17	13 to 17
					4000	17	13 to 17
ATB60	750	120	750	600	480	19	16 to 20
					11000	20	20 to 25
ATB72	900	100	900	720	600	26	22 to 24
					2300	26	22 to 24
					4000	26	22 to 24
ATB60	1200	120	1200	960	6600	28	20 to 25
ATB72	1200	100	1200	960	11000	30	26
ATB60	1250	120	1250	1000	2300	22	20 to 25
ATB72	1250	100	1250	1000	480	34	22 to 25
					2300	34	22 to 25
ATB72	1500	100	1500	1200	2300	34	24 to 27
					4000	34	24 to 27
ATB72	2000	100	2000	1600	2300	40	26
					4000	40	26

Generator field rheostat included.
The same data as given above for three-phase generators (ATB) also applies to quarter-phase generators (AQB). Base, shaft or bearings are not included.

(With Direct Connected Exciters)

CLASSIFICATION			KW. CAPACITY		Full Load Voltage	Max. Excitation Required at Rated Overload and P.F.	Bore of Revolving Field Hub for Engine Shaft Inches	Direct Connected Exciter Rating 125 Volts	SHIPPING WEIGHT	
Poles	K.V.A.	R.P.M	1.0 P.F.	0.8 P.F.					Generator	Exciter
ATB24	50	300	50	40	240	5	4 to 6.5	MP6-5-300	2940	900
					480					
					600					
					2300					
ATB26	75	276	75	60	240	7	5.5 to 7.5	MP6-7-276	4050	1250
					480					
					600					
					2300					

Table continued on page 11.

60 CYCLE TWO- AND THREE-PHASE GENERATORS, ENGINE-DRIVEN
(With Direct Connected Exciters)—Concluded

CLASSIFICATION			KW. CAPACITY		Full Load Voltage	Max. Excitation Required at Rated Overload and P.F.	Bore of Revolving Field Hub for Engine Shaft Inches	Direct Connected Exciter Rating 125 Volts	SHIPPING WEIGHT	
Poles	K.V.A.	R.P.M.	1.0 P.F.	0.8 P.F.					Generator	Exciter
ATB28	125	257	125	100	240	8.5	6 to 8.5	MP6-8.5-257	5850	1250
					480					
					600					
					2300					
ATB32	185	225	185	150	240	10	7 to 10	MP8-10-225	8400	1600
					480					
					600					
					2300					
ATB36	250	200	250	200	240	10	9 to 12	MP8-10-200	11900	1600
					480					
					600					
					2300					

The same data as given above for three-phase generators (ATB) also applies to quarter-phase generators (AQB). Base, shaft or bearings are not included. Direct connected exciter, exciter field rheostat and generator field rheostat are included.

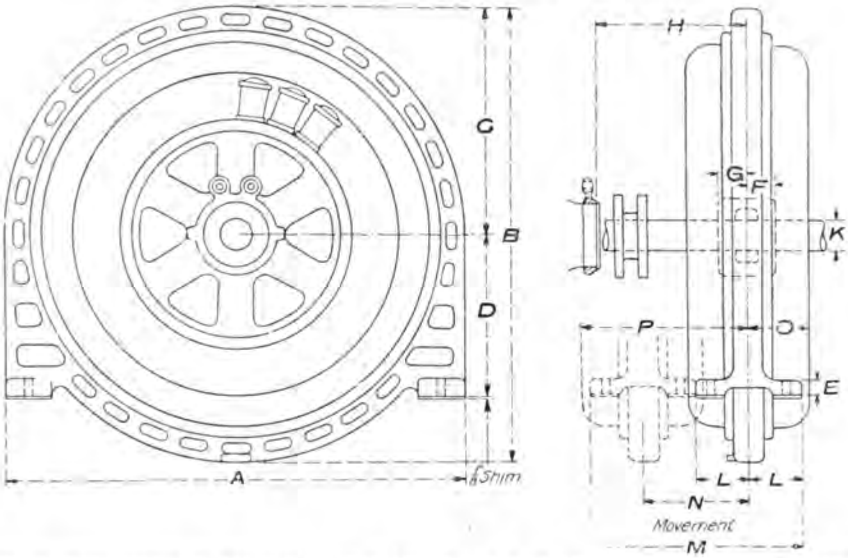
25 CYCLE TWO- AND THREE-PHASE GENERATORS, ENGINE-DRIVEN

CLASSIFICATION			KW. CAPACITY		Full Load Voltage	Provide 125 Volt Exciter Rated Kw.	Bore of Revolving Field Hub for Engine Shaft Inches
Poles	K.V.A.	R.P.M.	1.0 P.F.	0.8 P.F.			
*ATB14	180	214	180	144	480	6.5	10
					2200	6.5	10
*ATB18	240	167	240	192	480	9	—
					2200	9	—
ATB20	300	150	300	240	480	10	—
ATB20	360	150	360	288	370	10	18
ATB28	360	107	360	288	240	12	15
					480	12	15
					2200	12	15
ATB16	400	187½	400	320	480	10	14¼
					2200	10	14¼
ATB20	400	150	400	320	480	10	15 to 18
					2200	10	15 to 18
					13200	12	14
ATB28	400	107	400	320	13200	12	16
ATB18	450	167	450	360	480	12	15
ATB20	450	150	450	360	6600	12	14 to 15
ATB28	500	107	500	400	2200	13	16
ATB20	540	150	540	432	2200	15	14
ATB20	600	150	600	480	600	15	15
ATB28	600	107	600	480	240	18	15 to 20
					480	18	15 to 20
					13200	15	18
*ATB20	625	150	625	500	2200	15	14
*ATB24	625	125	625	500	480	14	16 to 18
					600	14	16 to 18
ATB28	800	107	800	640	600	18	—
*ATB24	1000	125	1000	800	2200	22	20
*ATB28	1000	107	1000	800	370	24	20 to 24
					600	24	20 to 24
*ATB32	1000	94	1000	800	600	25	23
ATB30	1600	100	1600	1280	2200	36	—
*ATB32	1800	94	1800	1440	6600	35	33
					13200	35	27
*ATB28	2000	107	2000	1600	13200	40	30

Generator field rheostat included.
The same data as given above for three-phase generators (ATB) also applies to quarter-phase generators (AQB). Base, shaft or bearings are not included.
* Machines marked * have split field spiders, see Fig. 6.

DIMENSIONS OF TYPE ATB ALTERNATING CURRENT GENERATORS
ENGINE-DRIVEN, DDO, THREE-PHASE, 60 CYCLES

(With or Without Direct Connected Exciters)



THIS ILLUSTRATION IS DIAGRAMMATIC AND DOES NOT SHOW EXACT CONSTRUCTION

Poles	KW. Capacity		Speed	Dimensions in Inches												
	1.0 P.F.	0.8 P.F.		A	B	C	D	E	F	G	H	Add to "H" for Direct Connected Exciter	K	L	M	Movement
ATB24	50	40	300	60	60	30	21	2	3½	3½	19	5	4 to 6½	7	30	14
ATB26	75	60	276	66	66	33	24	2	3½	3½	22	3	5½ to 7½	8	33	15
ATB28	125	100	257	74	74	37	27	2½	4½	4½	23	3	6 to 8½	9	35	16
ATB32	185	150	225	90	90	45	30	2½	5	5	23	4	7 to 10	9½	37	17
ATB36	250	200	200	100	100	50	36	3	5½	5½	25	4	9 to 12	11	40	18

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CHICAGO, ILL., Monadnock Building.
DETROIT, MICH., Majestic Bldg. (Office of Soliciting Agt.)
ST. LOUIS, MO., Wainwright Building.
KANSAS CITY, MO., Dwight Building.
BUTTE, MONTANA, Phœnix Building.
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DENVER, COLO., First National Bank Building.
SALT LAKE CITY, UTAH, Newhouse Building.
SAN FRANCISCO, CAL., Union Trust Building.
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LONDON OFFICE, 83 Cannon St., London, E. C., England.

For all CANADIAN Business,
Canadian General Electric Company, Ltd.,
Toronto, Ontario.

General Electric Company
Schenectady, N.Y.
RAILWAY DEPARTMENT

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GENERAL ELECTRIC STRAIGHT AIR BRAKE EQUIPMENTS

The rapid extension of electric railway lines and the increased speed necessary to maintain fast schedules has created a demand for a form of brake which will provide a reliable, positive and convenient means for controlling the speed of the modern electric car.

The almost universal use of the air brake in this country and in all important installations in foreign countries is testimony to the efficiency and safety of this type of power brake.

For single car operation the straight air brake system is recommended because it permits of the brakes being applied and released quickly. It is easy to manipulate, is compact, and is composed of a minimum number of moving parts, thus reducing the cost of maintenance, cost of installation and first cost of equipment.

MOTORMAN'S VALVE TYPE S, FORM F-4

The simplicity of this type of brake and the flexibility possible in locating the apparatus makes it applicable to the small single truck car as well as to the larger double truck cars operated on interurban lines.

The wide experience in the manufacture of high class electric railway apparatus is a guarantee that the air brake equipments placed on the market by the General Electric Company will embody all the best features of design, thus insuring safety, reliability and efficiency.

The straight air brake equipment consists essentially of the following apparatus:

A dust and waterproof motor-driven air compressor for furnishing a source of compressed air.

A suspension cradle for the compressor so designed that it can be easily removed from the car and any part of the compressor readily inspected.

An intake strainer placed inside of the car or on the roof to provide a supply of air free from dust and moisture for the compressor.

An air compressor governor for automatically opening and closing the compressor circuit at a predetermined maximum and minimum air pressure.

A combined switch and fuse for protecting the compressor circuit.

One or more reservoirs to provide air storage capacity for operating the brakes.

A brake cylinder complete with push rod for providing the necessary braking power.

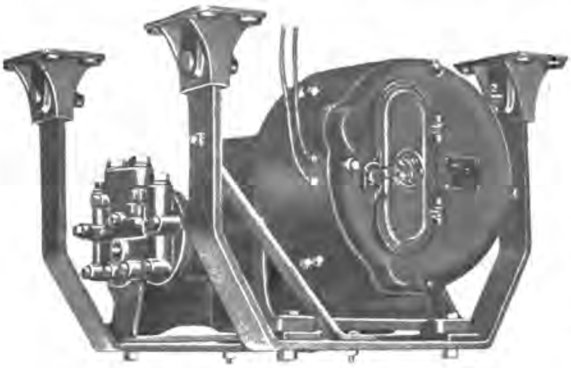
Motorman's valves and handle under the direct control of the motorman for regulating the supply and exhaust of brake cylinder air.

*Supersedes No. 4437.

A safety valve to prevent the possibility of excessively high pressure in the reservoir.

Pressure gauges for indicating the pressure of air in the reservoir

A detailed description of these parts is contained in the following pages:



CP-27 AIR COMPRESSOR AND SUSPENSION

AIR COMPRESSOR

The compressor is of the enclosed type and all parts are thoroughly protected from dust and water, and, therefore, no external enclosing box or other covering is needed. It has duplex horizontal cylinders and herring-bone gear drive, and is designed to be supported from the car body in a suspension cradle.

In every mechanical and electrical detail, the compressor is designed strictly in accordance with the General Electric Company's standard railway motor practice.

All bearings and working parts are automatically lubricated from one source—a well formed in the compressor frame immediately below the gear. This oil well is supplied through the oil filler, consisting of a projecting elbow fitted with a handle plug so designed that any dirt collected around it is lifted off when it is unscrewed, thus preventing dirt from entering the oil hole. This oil filler is immediately accessible from the side of the car, and of such a height as to insure the proper oil level in the crank case. The driving gear picks up oil from the well and throws it in a steady stream into an oil pan on the underside of the crank chamber cover. Oil distribution to bearings is effected through large channels formed in the oil pan, from which the oil flows to the various bearings.

No oil waste or oil rings are used, and there are no pipes or small holes to clog with sediment or thick oil.

The oiling system is positive in action and continuously delivers oil to the bearings, which flows back into the well after doing its work. So long as oil remains in the well, all parts of the compressor are perfectly lubricated.

These compressors which are the latest design, have been developed after long experience in the building of air compressors. They are generally considered as surpassing all competing makes in accessibility, simplicity and the general balanced design.

Compressors of this type are manufactured in several sizes to meet the requirements of all classes of railway service. Although primarily designed for installation on electrically operated cars, these compressors are perfectly adapted for any class of work requiring the use of compressed air.

INTAKE STRAINER

The supply of air is drawn into the cylinders, through an intake pipe which has a strainer containing curled hair on the end furthest from the air compressor. This strainer when practicable should be placed inside the car or on the roof.

These strainers, in effectually preventing the entrance of dust and dirt into the cylinders increase the life of the compressor and reduce the cost of maintenance of the entire brake equipment.

The cradle shown in the illustration on page 2 is designed to permit the removal of the compressor from the car body with the minimum amount of labor. It is provided with four malleable iron brackets which are bolted permanently to the car frame. These brackets are provided with pockets which receive the ends of the suspension cradle, the cradle being attached to the brackets by means of pins.

For a more detailed description see Bulletin on Air Compressors.

EXTERIOR SECTION
MC FORM B AIR COMPRESSOR GOVERNOR

AIR COMPRESSOR GOVERNOR

The MC Form B air compressor governor for use in connection with this compressor is of the mechanically operated type and has fully demonstrated its claim of superiority, efficiency and reliability. It can be depended upon to hold the pressure constant and to operate as frequently as necessary without adjustment or other attention. It is recommended that this governor be placed inside the car in an upright position.

It is provided with a metal cover which protects all the working parts from mechanical injury. For a more detailed description of this governor see Bulletin No. 4427.

COMBINED SWITCH AND FUSE

The combined switch and fuse is of fireproof construction and is so designed that it is capable of positively opening the circuit under all conditions.

All the current carrying parts are enclosed in moulded insulation, and a powerful magnetic blowout is provided for extinguishing the arc. The fuse being of the well known enclosed type is placed in a separate compartment which is isolated from the switch by barriers of insulation. Both the switch and fuse are readily accessible by opening the cover, which is held closed by a simple latch. This combined switch and fuse is shown in the accompanying illustration.

MOTORMAN'S VALVE

The Type S Form F-4 motorman's valve supplied with all straight air brake equipments is shown in the illustrations on pages 1 and 4.

MS-43-E COMBINED SWITCH AND FUSE

The Type S Form F-4 motorman's valve is of the slide-valve type and is simple in construction. The principal parts are the valve body, bonnet, valve stem, slide valve and driving block. The slide valve operates on a raised seat which is formed on the upper surface of the valve body. The ports which are located in this seat are rectangular in shape and are machined accurately to size and position. The port leading to the train line is located at an angle in order to give a greater degree of refinement in applying and releasing the brakes. The valve seat raised above the body presents a clear surface which facilitates regrinding the valve. The slide valve is rectangular in form and is provided on the wearing surface with a cavity for connecting the train line and exhaust ports together. Provision is made on the upper part of the slide valve to receive the steel driving block, this block in turn being operated by a crank pin formed on the end of the valve stem. The slide valve is held in alignment by guides cast integral with the bonnet. The guide on one side is provided with a slot which engages with a tongue on the slide valve. The object of this construction is to prevent the slide valve being assembled in the wrong position and also to keep it from dropping out of the bonnet when the valve is taken apart. In order to remove the slide valve from the bonnet it is necessary to turn the valve handle to the release position until the tongue above referred to registers with the slot in the guide. The valve can then be withdrawn from the bonnet. The stem is provided with a ball seat at the base which prevents air leaking between the stem and bonnet. This construction allows the stem to wear without any leakage taking place. The material of the stem is a hard gun metal which reduces to a minimum the lost motion between the stem and handle. Thorough lubrication of the valve seat and stem is provided by two oil holes in the bonnet.

PARTS OF TYPE S, FORM F-4, MOTORMAN'S VALVE

The following are the positions and functions of the valve in moving the handle from the extreme left to the extreme right positions.

Release Position

Direct connection is made between the train line and atmosphere through a large port.

Service Release and Running Position

The train line is connected to atmosphere through a restricted opening in order to give a graduated release of the brakes. When running the valve handle should be left in the release position to prevent the brakes creeping on if there is any leak in the valve seat.

Lap Position

In this position all ports are blanked. This is the only position in which the handle can be removed.

Service Position

In this position a connection is made between the main reservoir and the train line.

Emergency Position

In this position the valve handle is at the extreme right. A large port is opened from the main reservoir to the train line in order to give a quick application of the brakes in case of emergency.

In the design of this valve particular attention has been paid to the following points:

Very liberal surface is provided to prevent leakage between the valve and seat. The valve stem is provided with a ball seat which absolutely prevents any leakage at this place. The valve body is provided with union couplings of generous proportions, thus permitting the train and reservoir lines to be easily connected.

BRAKE CYLINDER

The brake cylinders furnished with these equipments are designed with a view of incorporating such features as have been found to be most satisfactory in the past, and which therefore have become almost universally standard. The castings of the brake cylinders together with the packing leathers are treated by a special process which renders

BRAKE CYLINDER

them absolutely air-tight. The pressure head of the cylinder is provided with a boss to which malleable iron brackets are attached for receiving the dead cylinder lever. When required a slack adjuster of approved type can be furnished with these cylinders and can be attached to the boss in place of the brackets.

The cylinders are fitted with tubular piston rods which surround the push rods for attaching to the live cylinder lever. This construction permits the brakes being applied by hand without disturbing the brake cylinder piston.

RESERVOIR

Reservoirs are made of a special grade of steel and are so constructed as to give maximum strength with minimum weight. A one-half inch drain cock of substantial construction with a large opening is furnished with each reservoir. The reservoirs are tapped at one end for the pipe connection to the compressor, and at the other end for the pipe connection to the main reservoir line leading to the motorman's valve. Provision is also made for separate connection to the air compressor governor. Reservoir hangers are supplied for attaching to the bottom of the car.

SAFETY VALVE

The safety valves are similar in construction to the pop safety valve used in steam practice and can be readily adjusted by

SAFETY VALVE

removing the cap on the upper part of the valve and turning the adjusting screw. All standard safety valves are adjusted to open at 100 lbs. per square inch.

AIR WHISTLE

PRESSURE GAUGE

The pressure gauges supplied are especially adapted for this class of service. These gauges are constructed in such a manner that they will retain their calibration indefinitely. With straight air brake equipments single hand gauges are furnished for connection to the main reservoir line. When required these gauges can be provided with an illuminating attachment which contains a small ¾ c.p. lamp; this lamp to be located on the ground side of one of the car lighting circuits. If necessary duplex gauges can be furnished of the same general type as described above, which indicate the brake cylinder and main reservoir pressures.

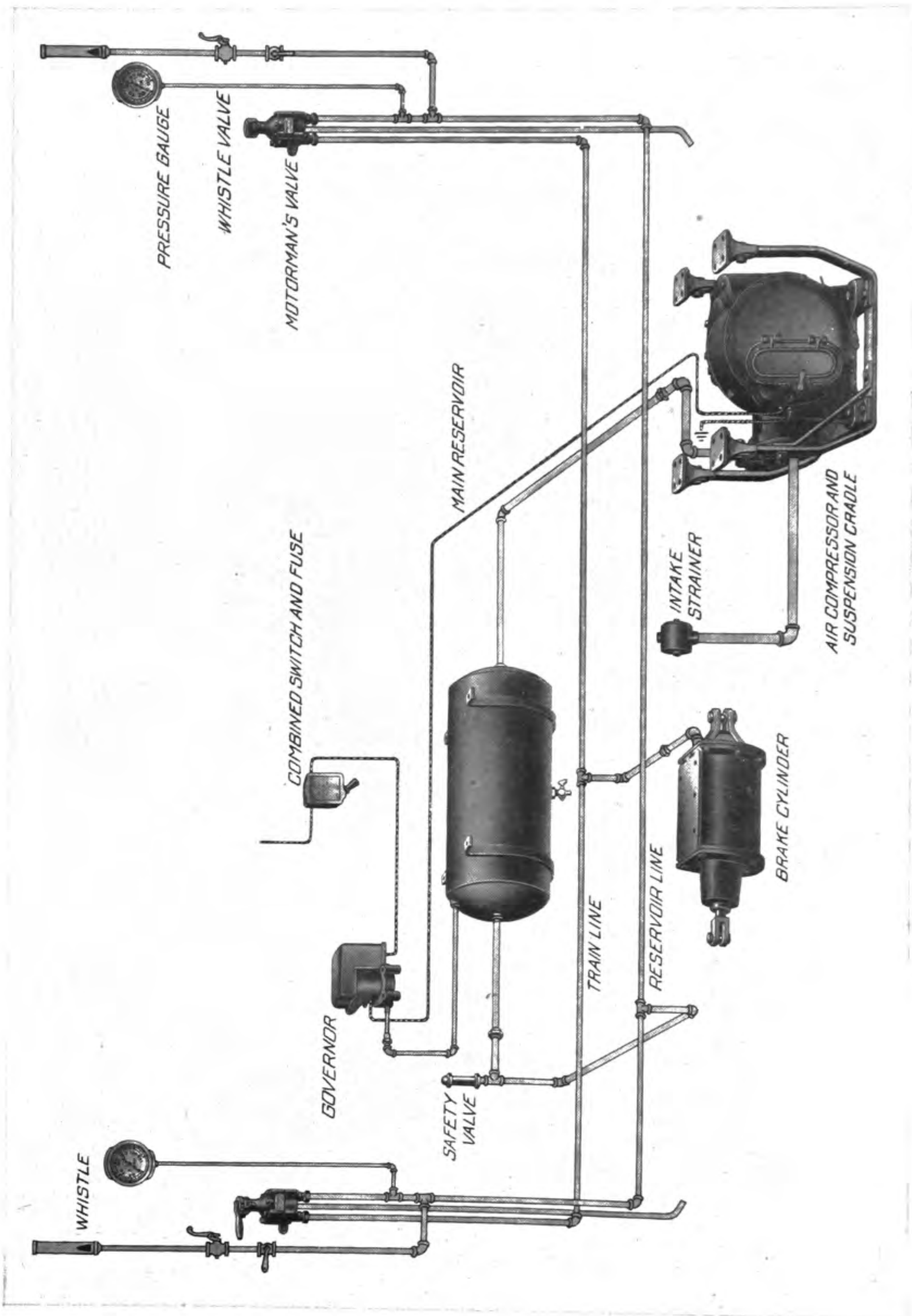
EXTRA MATERIAL NOT INCLUDED IN STANDARD EQUIPMENTS—WHISTLE

The General Electric Company have made exhaustive tests on whistles to be operated by air pressure for use in connection with air brake equipments. The result has been the development of a deep tone organ whistle of agreeable note which possesses great carrying power. These whistles are operated by means of an independent whistle valve placed in the motorman's cab or vestibule.

The design of this whistle valve is such as to eliminate the escape of air around the stem, which is a common source of annoyance and lowers the efficiency of the whistle.

MATERIAL AND WORKMANSHIP

Special attention is given to the workmanship and material of all air brake equipment parts. Each piece of apparatus is subjected to a rigid inspection and thorough test during the process of manufacture and after it is completed.



STRAIGHT AIR BRAKE EQUIPMENT FOR MOTOR CAR—(Schedule S.M.-1)

(Pipe, pipe fittings, wire and whistle sets do not form a part of *Standard* equipment unless specified as extras)

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Kansas City, Mo.	Dwight Building
Butte, Montana	Phœnix Building
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London Office, 83 Cannon St., London, E. C., England

General Electric Company
Schenectady, N.Y.

February, 1911

Bulletin No. 4799

WATERWHEEL-DRIVEN ALTERNATORS

In order to meet most successfully the requirements of the modern hydro-electric plant, the generators must combine those characteristics which result in high electrical efficiency with a mechanical strength of the moving elements which will insure uninterrupted service, and an ample factor of safety when operating at the relatively high speeds often used with this type of machine.

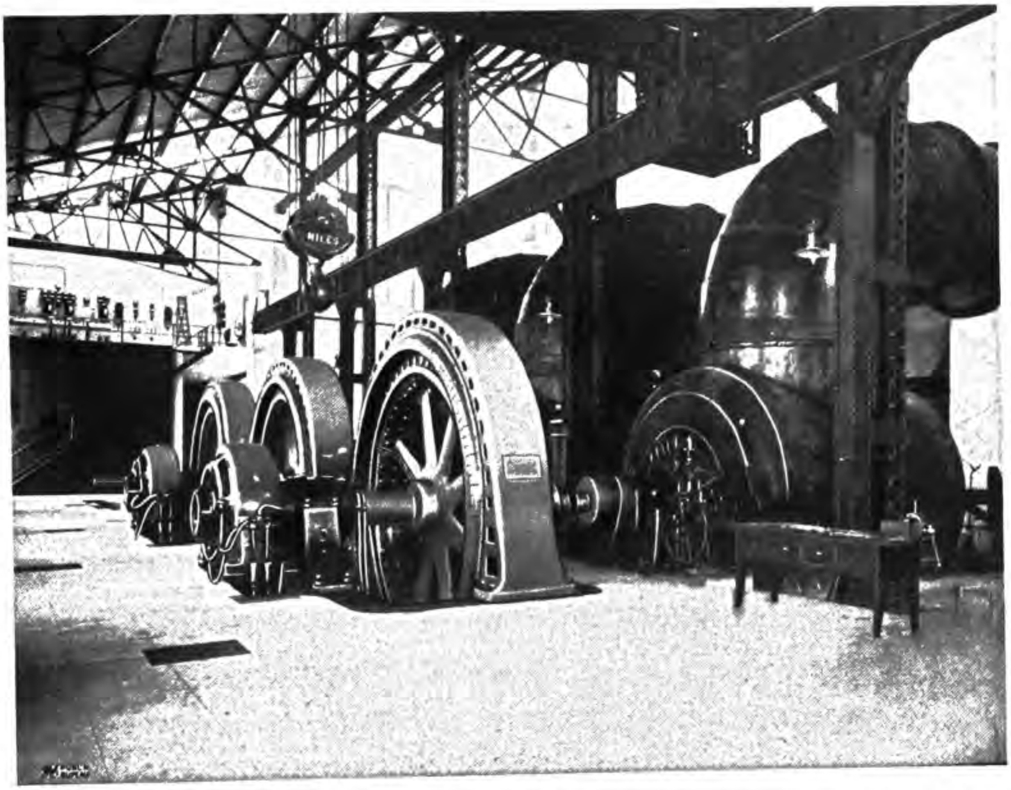
When selecting an alternator for waterwheel operation, a careful analysis of the details of construction should be made in order to properly compare different makes, and to determine the relative values which have been assigned by the designers to the properties of the various materials used: This will permit the selection of a type of machine best adapted to the intended service and which embodies to the greatest possible extent the required characteristics of safety,

FOUR ATB 2250 KW., 13,200 VOLT, 210 R.P.M. WATERWHEEL-DRIVEN ALTERNATORS
ST. ANTHONY FALLS (MINN.) POWER COMPANY

durability and efficiency. The care thus exercised will frequently avoid and will always minimize replacement and repair work which is, as a rule, both troublesome and costly in hydro-electric plants.

The General Electric Company manufactures a complete line of polyphase waterwheel-driven alternators for all commercial frequencies, and for potentials up to 13,200 volts. Both horizontal and vertical shaft types are the various types illustrated and described herein.

All the manufacturing processes are carried on in the shops of the General Electric Company, the possibility of the defects in the component parts being thereby minimized, while accurate construction work is facilitated by an unequaled factory equipment. The alternators thus produced are, in every case, subjected to exhaustive tests, under the



2250 KW., 60 CYCLE, 3-PHASE, 2300 VOLT, 138 R.P.M. WATERWHEEL-DRIVEN ALTERNATORS
WASHINGTON WATER POWER CO., SPOKANE, WASH.

included in sizes up to 20,000 kw. capacity.

These machines embody in their design and structural details the experience gained by the engineers of the General Electric Company for the past twenty years in the construction of waterwheel-driven alternators, during which time all those features which have proven successful in actual service have been embodied in their most improved form in closest possible approximation to service conditions, before being shipped.

The following pages illustrate and briefly describe the various forms of General Electric waterwheel-driven alternators, and show some typical installations of horizontal and vertical shaft machines of different capacities and voltages in both high and low head hydro-electric power stations.

STATOR

The alternator frames are made in two general styles, known as the box type and skeleton type. The former consists of a single casting for the smaller sizes but for large capacity alternators the frame castings are usually divided into upper and lower sections. The skeleton type consists of two side castings between which substantial spacing rods are set at regular intervals. On

Fig. 1
SECTION OF ALTERNATOR SHOWING METHOD OF DOVETAILING CORE LAMINATIONS TO STATOR FRAME

both types the contact surfaces are carefully machined to secure proper alignment when the frame is assembled.

The core consists of sheet iron laminations made of the special metal which has been adopted by the General Electric Company as a standard for this work. These laminations are carefully tested, and are slotted and assembled so as to minimize both hysteresis and eddy current losses; they are mounted on the inner periphery of the frame, making lap joints, and each section is dovetailed to the stator frame; Fig. 1 shows the usual construction.

Heavy clamping rings or end plates are mounted on both sides of the core by means of bolts, and supporting fingers extend along the slot projections. (See Figs. 2 and 4). The design is such that an ample circulation of air is available to insure rapid heat radiation, and the entire core provides a mechanically strong and compact magnetic circuit of low reluctance.

The air circulation is provided for by means of ducts formed by suitable spacing blocks inserted at intervals between the laminations, the air ducts thus formed being clearly indicated in the illustrations of the armature sections. (Figs. 2 and 3.)

The armature coils are form wound and can be replaced readily in case of injury.

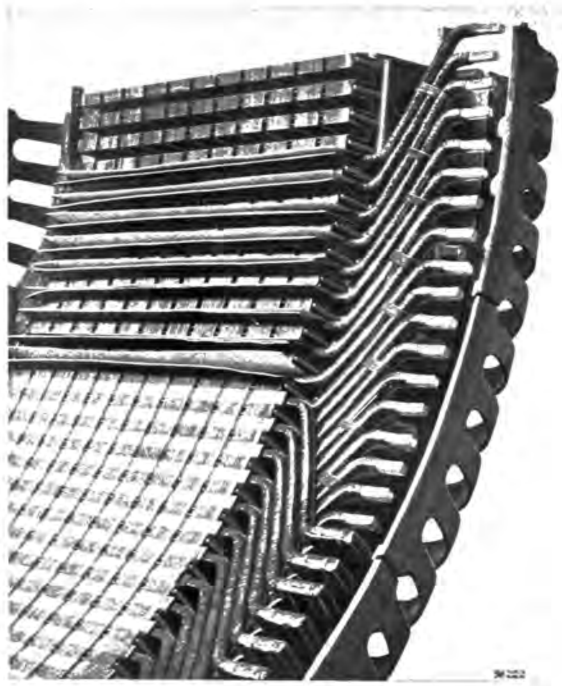


Fig. 2
SECTION OF STATOR SHOWING AIR DUCTS AND SUPPORTING FINGERS EXTENDING ALONG THE SLOT PROJECTIONS

They are taped and treated with an impregnating compound, the materials used being carefully selected to avoid deterioration or diminution of the dielectric strength through aging.

After being tested the coils are inserted in the armature slots in an armor of horn fiber and retaining wedges of wood are dovetailed into the slot walls.

Where heavy windings project beyond the laminations, an additional support is provided by means of an insulated metal ring, to which the outer ends of the coils are fastened; the coils are thereby protected from mechanical displacement, or distortion due to the magnetic disturbances caused by violent fluctuations of the load or short circuits.

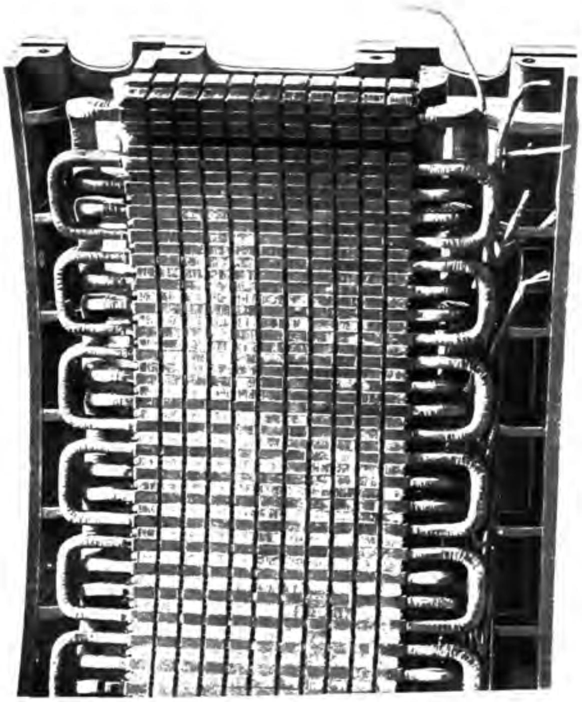


Fig. 3
SECTION OF STATOR SHOWING VENTILATING DUCTS

Fig. 4 shows a section of a supporting ring of this type and indicates the method of connecting the coils to it. In order to admit of the prompt replacement of damaged coils, sufficient space is usually provided between the alternator bearings to allow ample movement of the stator to permit of ready access to both stator and rotor coils. Where space economy necessitates the use of a short shaft, access to the windings may be had by disconnecting some of the coils and lifting the upper half of the stator.

ROTOR

The field or rotor consists of pole pieces mounted on a cast iron or steel ring connected to the hub by arms of ample section; in some cases a solid steel casting such as that shown in Fig. 6 is used, and for some of the larger sizes the rotor is split, due to the conditions governing the practical size of castings and to facilitate shipment.

When it is necessary to split the rotor, the halves are securely held together by heavy bolts through the hub and by link keys set into the rim.

Fig. 4
SECTION OF STATOR SHOWING SUPPORTING RING AND METHOD OF ASSEMBLING COILS

The field spools are built up of copper strip wound edgewise and properly insulated. For some of the smaller sized alternators the spools are wire wound.

As an additional protection the pole pieces are provided with an insulation of fiber before the windings are mounted.

As will be noted by the accompanying illustration, the field spools are so spaced and interconnected as to insure ample ventilation, this open spacing between the field coils being a characteristic of General Electric alternator design.

Fig. 5
POLE PIECE

The pole pieces (Fig. 5) are built up of laminated iron sheets either riveted or bolted together and reinforced by two stiff end plates. They are solidly mounted on the spider by means of dovetail slots in the rim as shown in Fig. 7, the steel wedges being guarded by two bolted end rings.

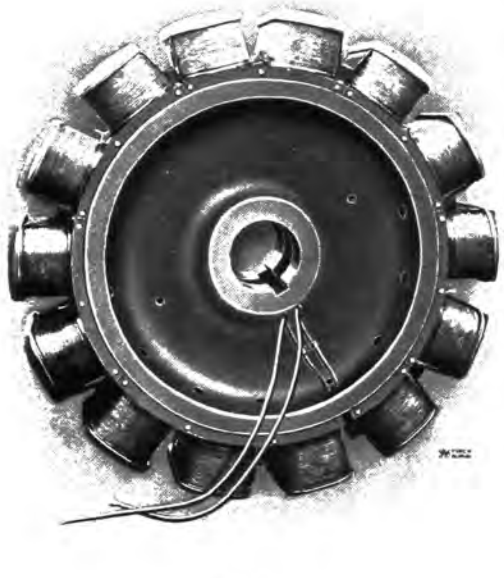


Fig. 6
ROTOR COMPLETE

Fig. 7
ROTOR SPIDER

For machines of moderate speed the poles are bolted to the field spider.

After assembly the rotor is thoroughly tested and carefully balanced to insure freedom from vibration when in operation.

Collector rings for the field are made of cast iron and are so designed that all surfaces of the rings have easy access to the air, thus insuring good ventilation. (See Fig. 8.)

A yoke carrying brush-holder stud and holders is ordinarily mounted on the pillow block.

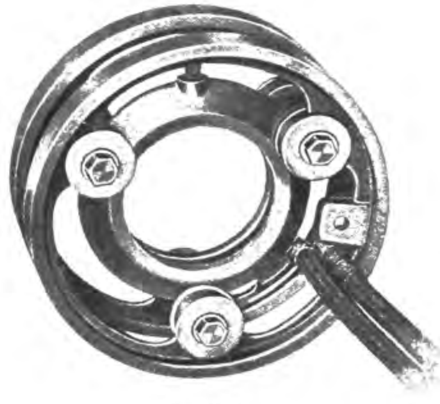


Fig. 8
COLLECTOR RINGS

Every effort has been made to render these rotors compact homogeneous units of great strength, capable of withstanding the stresses imposed by high peripheral velocity and of such exceptional speeds as may be the result of runway waterwheels.

FOUNDATIONS

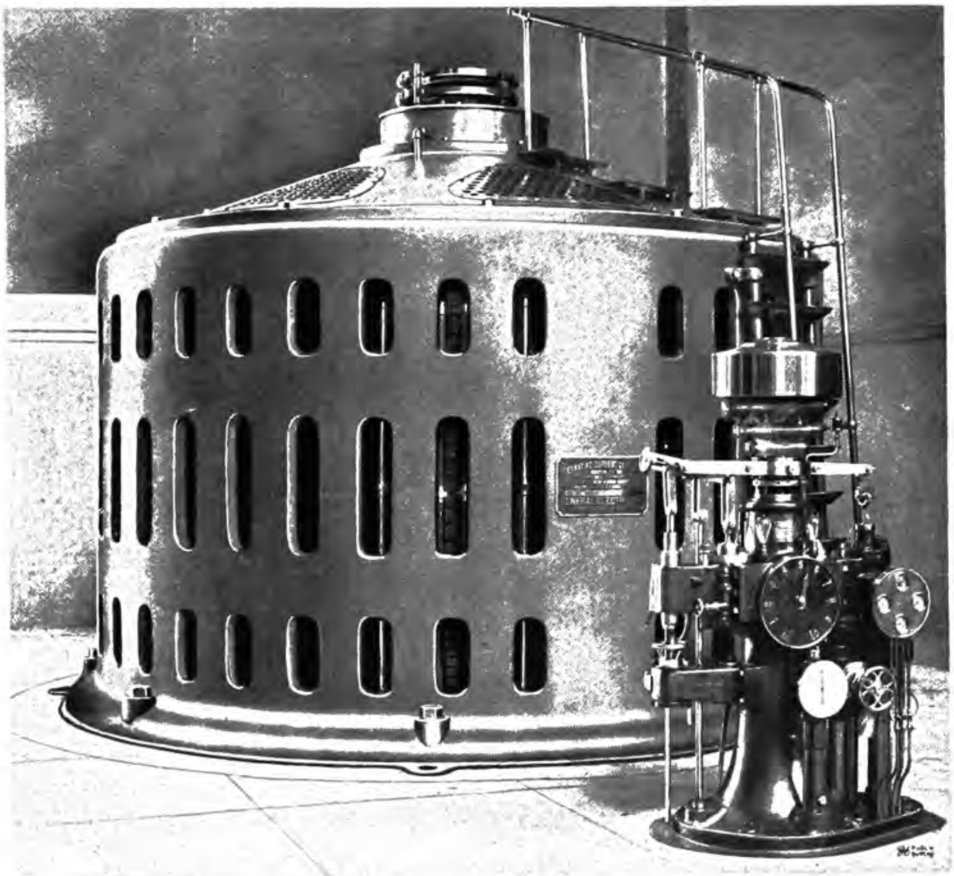
The form of foundation used with the different types varies with the service for which they are intended. For the horizontal shaft machines cast iron or channel iron bases are used, and in some cases simple bases are used, and in some cases simple foundation plates are provided for the stator with separate sole plates for the bearing standards.

For vertical shaft alternators the base is constructed either for mounting directly on the turbine casing or on separate foundations above the wheel pit.

SHAFT AND BEARINGS

The shafts are keyed to the rotor and are arranged for coupling to the waterwheel shaft. They are of ample cross section to insure rigidity.

Some of the smaller sized alternators are equipped with end shield bearings, but the standard form for the horizontal shaft type of machine is a pedestal bearing arranged for oil ring lubrication. Large alternators may be provided with water-cooled bearings as shown in Fig. 9. This auxiliary consists of a number of short tubes extending horizontally through the oil well below the bearing; water is circulated through the



10,000 KW., 60 CYCLE, 3-PHASE, 11,000 VOLT, 400 R.P.M. WATERWHEEL-DRIVEN ALTERNATOR
GREAT WESTERN POWER CO., BIG BEND, CAL.

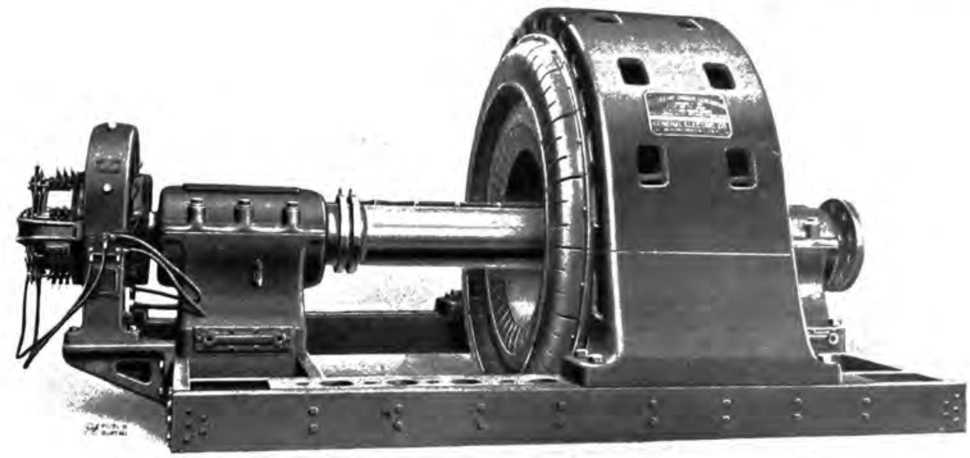


Fig. 9

3000 KW., 2300 VOLT, 514 R.P.M. WATERWHEEL TYPE ALTERNATOR WITH SELF-CONTAINED EXCITER AND WATER-COOLED BEARINGS

tubes which thereby disseminate the heat of the oil.

The bearings are self-oiling and have ample surface to insure cool running and minimize the rate of wear. The oil reservoirs will hold a liberal supply of oil and are provided with convenient gauges for indicating the height of the oil, and with outlets for drawing it off.

Vertical shaft alternators are arranged for direct connection to the waterwheel shaft and are ordinarily provided with one or two guide bearings. Where the electrical manufacturer is required to supply step or suspension bearings, the General Electric Company has designed bearings arranged for forced oil circulation and so constructed that there is no throwing of oil while in operation.

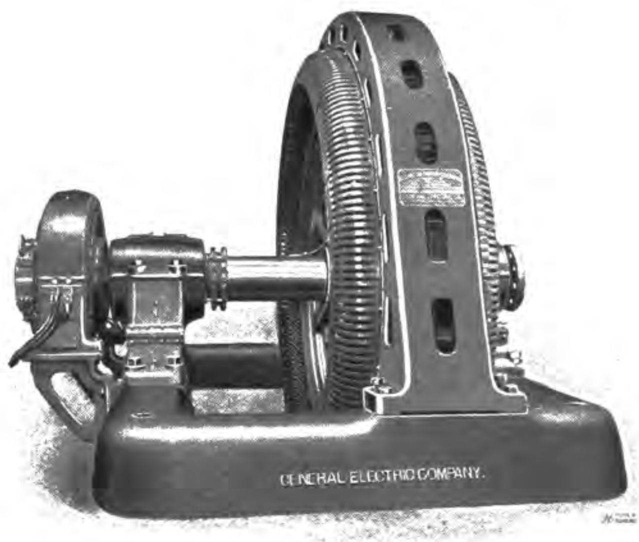


Fig. 10

3000 KW., 2300 VOLT, WATERWHEEL TYPE ALTERNATOR WITH WATER-COOLED BEARINGS

RATING

General Electric waterwheel-driven alternators are conservatively rated on the basis of energy output at .08 power-factor, and are, therefore, especially adapted for carrying either a mixed lighting and power load, or an induction motor load alone.

All sizes will deliver the rated kilovolt-amperes at any power-factor between 1.0 and .08 at a temperature rise not exceeding 40 degrees C. under continuous operation, and will carry 25 per cent overload for two hours with a temperature rise of not more than 55 degrees C. The temperature ratings are in accordance with the standards of the A.I.E.E.

The full load single-phase rating at unity power factor is approximately 70 per cent of the full load three-phase rating: Three-phase windings being used on all standard types of waterwheel-driven alternators.

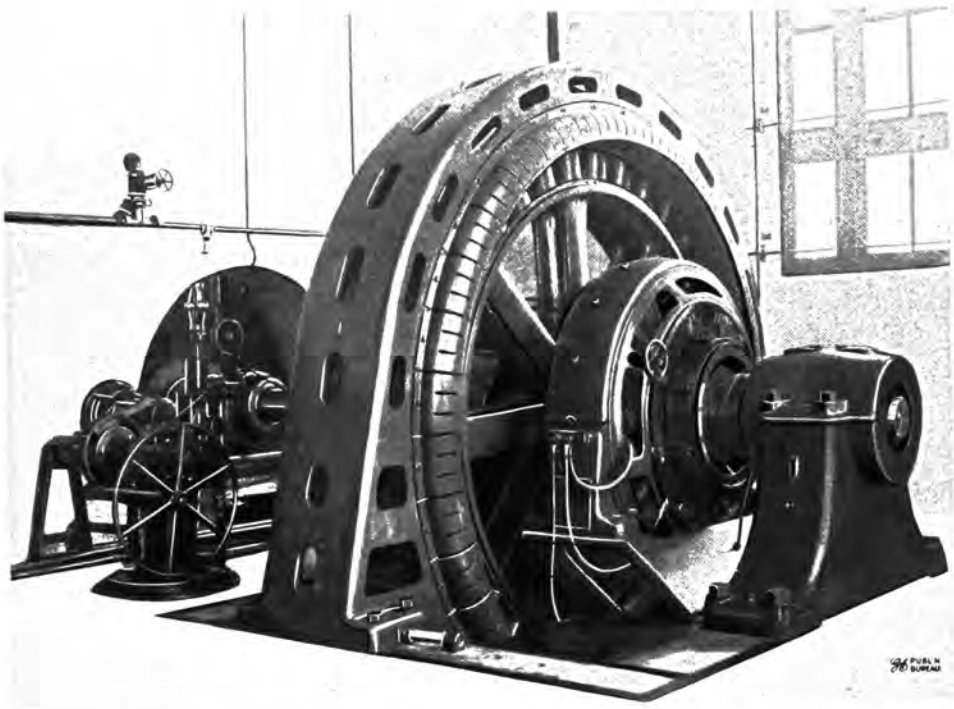
PARALLEL OPERATION

By properly designing the pole pieces the wave form has been made to closely follow the sine curve. This is of advantage not only in improved efficiency and superior regulation but it results in parallel operation more nearly perfect for all conditions of changing load and power-factor.

In the parallel operation of waterwheel-driven alternators it is not usually necessary to supply a flywheel, as due to the characteristics of the modern water turbine, ample flywheel effect is supplied by the rotating elements of the prime mover and the alternator.

This is especially true in the larger developments operating with a long distance transmission system, having several hydro-electric stations and steam turbine units, or their equivalent, floating on the system.

The flywheel consideration depends on so many factors, not electrical, that each case



1800 KW., 40 CYCLE, 3-PHASE, 4400 VOLT, 150 R.P.M. WATERWHEEL-DRIVEN ALTERNATOR
SCHENECTADY POWER CO., JOHNSONVILLE, N. Y.

must be considered with regard to its special conditions.

For successful parallel operation it is necessary to avoid fluctuations in the speed of the prime mover, such as might result from poor governing, but the efficiency of the average waterwheel governor is such that the alternators in most of the modern hydro-electric plants can be safely arranged for parallel operation and in many instances alternators in power plants widely separated are being successfully operated in parallel.

PHASES AND VOLTAGES

The standard designs are adapted to three-phase or two-phase windings without change except in the coils and armature punchings.

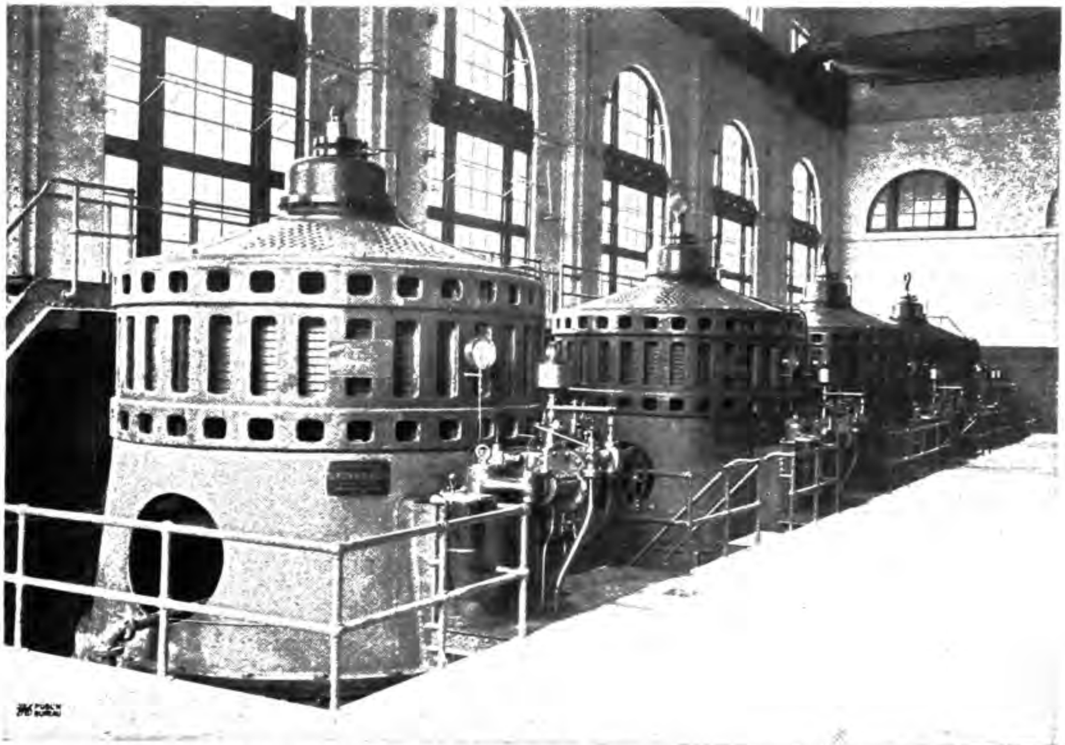
Where single-phase is required the three-phase windings can be used at reduced rating.

Where transformers are used to step-up voltage for transmission, it is generally advisable to install machines wound for 2300 or 6600 volts, but where current is to be transmitted at the generator voltage, windings for 60 cycles, 11,000 volts. or 25 cycles, 13,200 volts have been adopted as a standard.

EXCITATION

These alternators may be furnished either with or without direct connected exciters. When arranged for direct connection the armature of the exciter is carried on the generator shaft. In the smaller sizes the magnet frame is bolted to the bearing bracket, but in the larger sizes special construction is used depending upon the conditions to be met. Some typical methods of mounting the exciter are shown in the accompanying illustrations.

These exciters are very liberally designed and capable of furnishing the required excitation for low power-factors. The use of a type TA generator voltage regulator is strongly recommended, by means of which the terminal voltage may be kept practically constant through wide changes in the character of the



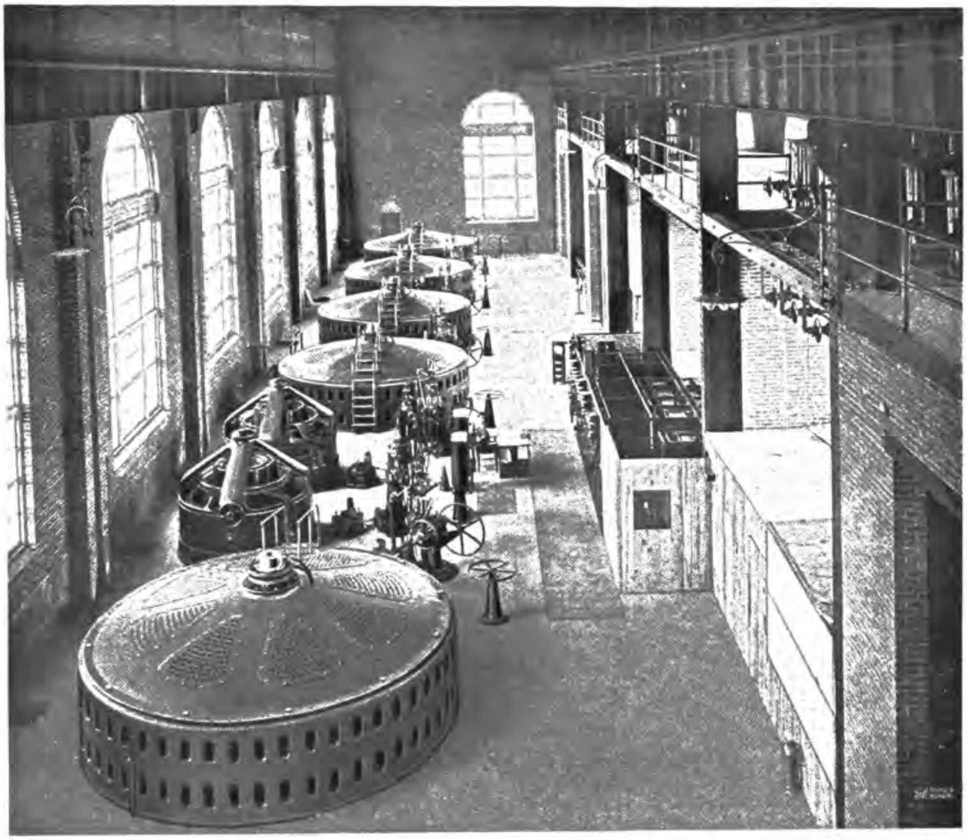
3000 KW., 40 CYCLE, 3-PHASE, 4400 VOLT, 300 R.P.M. WATERWHEEL-DRIVEN ALTERNATORS
SCHENECTADY POWER CO., SCHAGHTICOKE, N. Y.

load and with varying conditions of speed. On all alternators of standard design the field is built for 125 volts excitation, however, in special cases, 250 volt fields can be supplied.

If the alternators are not equipped with direct connected or independently driven exciters, the shaft is extended for mounting a pulley for belted exciters.

at its guaranteed overload. Since the exciters have an overload capacity they will carry the alternator demand even under extreme variations of temperature and power-factor.

The extreme variations in the conditions affecting hydro-electric development in different territories and the special construction thereby involved in the generating equipment,



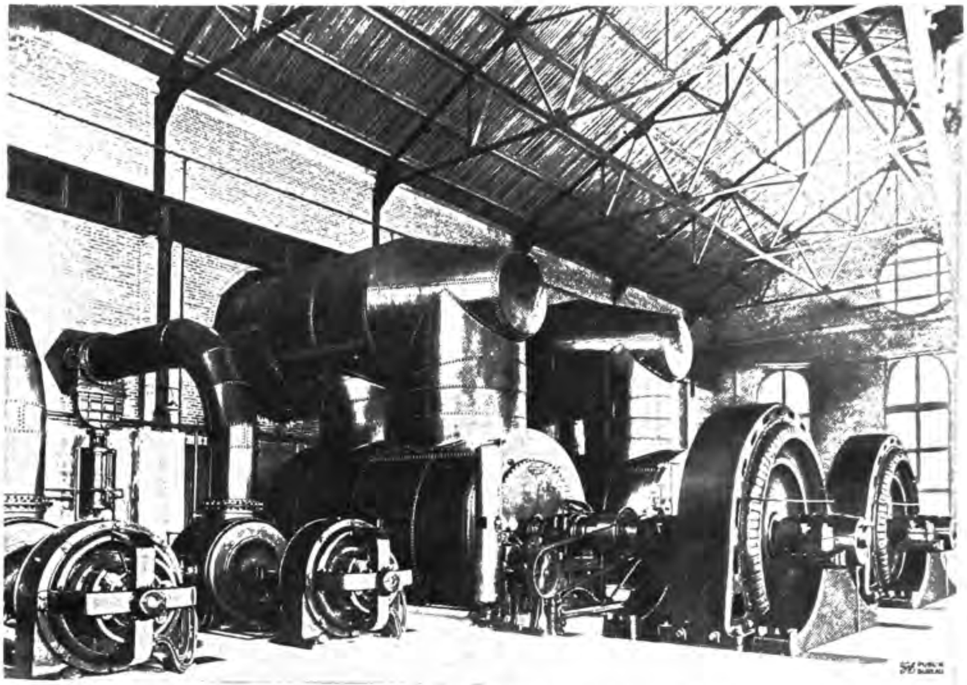
2500 KW., 60 CYCLE, 3-PHASE, 2300 VOLT, 133 R.P.M. WATERWHEEL-DRIVEN ALTERNATORS AND EXCITERS
CONNECTICUT RIVER POWER CO., VERNON, VT.

has resulted in the building by the General Electric Company of numerous alternators differing in detail from their standard types. These machines have proved the value of the specialization to which the question of the necessary characteristics for a successful waterwheel-driven alternator has been subjected by the engineers of the company. Their success has been clearly indicated by the test and operating records of actual installations,

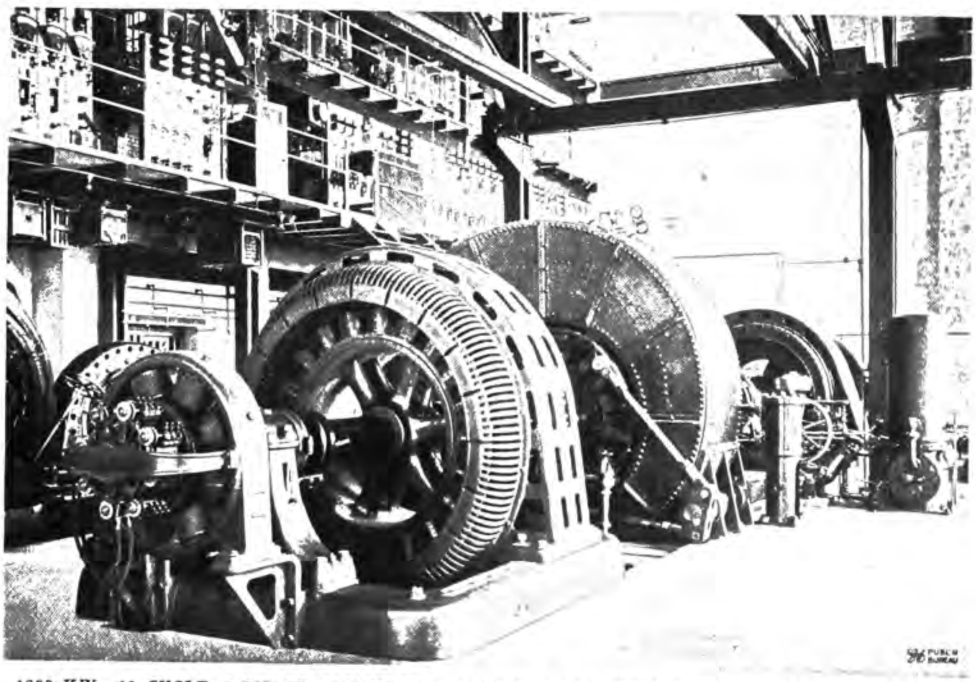
REGULATION

On account of their liberal design these machines will meet the requirements of good regulation even with loads of low power-factor. This feature may be accomplished automatically by the use of a generator voltage regulator.

It is the practice of the General Electric Company when furnishing exciters to make the capacity of the exciter at normal rated load sufficient for excitation of the alternator and the co-operation of the company's engineers can always be obtained by the customer in determining the most suitable equipment for any given conditions.



2600 KW., 60 CYCLE, 3-PHASE, 2300 VOLT, 300 R.P.M. WATERWHEEL-DRIVEN ALTERNATORS AND EXCITERS. LA CROSSE WATER POWER CO., BLACK RIVER FALLS, WIS.



1200 KW., 60 CYCLE, 3-PHASE, 4150 VOLT, 360 R.P.M. WATERWHEEL-DRIVEN ALTERNATORS ROCHESTER (N.Y.) RAILWAY AND LIGHT CO., STATION 5

GENERAL ELECTRIC COMPANY

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FOREIGN DEPARTMENT,
Schenectady, N. Y., and 30 Church St., New York, N. Y.
London Office, 83 Cannon St., London, E. C., England

General Electric Company
Schenectady, N.Y.

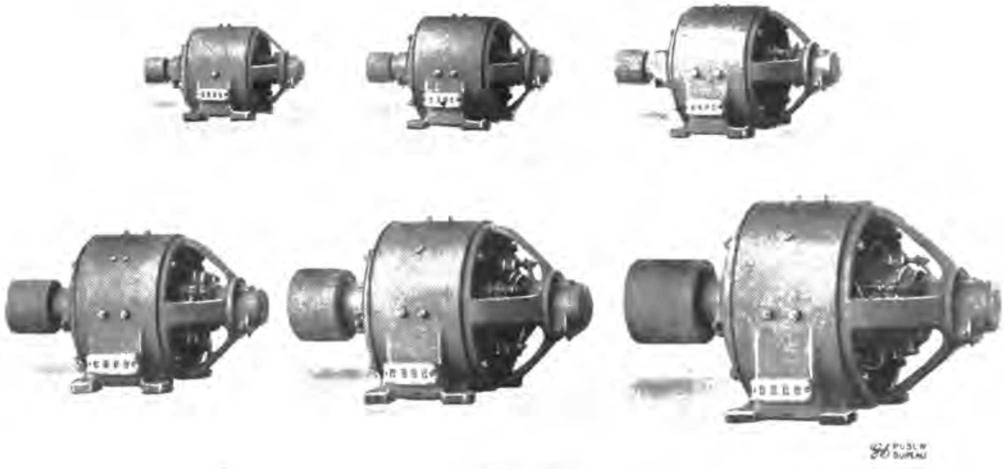
SMALL MOTOR DEPARTMENT

January, 1911 *Bulletin No. 4800*

DIRECT CURRENT MOTORS, TYPE CVC

COMMUTATING POLE DESIGN

The use of commutating poles, while not a strictly new development in the design of direct current motors, provides, nevertheless, such marked improvement in operating characteristics over the non-commutating pole design that it may be pertinent to briefly consider herewith a few fundamental reasons justifying the use of motors with auxiliary poles.



CVC MOTORS

As a better understanding has been attained regarding the complex phenomena surrounding the action and reaction of a rotating armature in a magnetic field; as winding methods, active material and general design have been improved in step with increased theoretical knowledge and the practical experience gained by years of commercial operation, motors have steadily improved electrically and mechanically until the ability of the best designers and most experienced manufacturers has been taxed to further improve efficiency or add to the niceties of mechanical refinements.

In the recognition, however, that each increment of loss—electrical, magnetic or frictional—decreases efficiency, the most careful tests and investigations have been conducted for the purpose of segregating such losses so that by research and experiment each source of waste might be reduced to the greatest degree commercially practicable. Thus mechanical friction has been reduced by more adequate lubrication, better quality of shaft steel, the use of anti-friction metal, ball or roller bearings, etc. Foucault, or eddy currents (i.e., currents generated within

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the mass of a moving iron or steel core in a magnetic field) have been greatly reduced by dividing or laminating the poles or pole tips; hysteresis losses (the energy wasted in magnetizing and demagnetizing core bodies), have been cut down by the reduced iron densities of commutating pole design and by the use of special iron reducing the "lag" between inductive and magnetic forces. Even brush friction, ordinarily but an inconsiderable percentage of the total loss, has been lessened by the adoption of high grade specially treated carbon brushes having a low coefficient of friction. These and other methods have resulted in markedly bettering the life, reliability and operating characteristics of the electric motor, increasing as well the maximum output per unit weight of active material. Motor output permissible by heating may be increased to a point where commutation becomes the limiting factor; it is, therefore, an indispensable condition that armature currents be unified in the direction of current flow in such a manner as to minimize all disturbing magnetic influences having a tendency to cause brush sparking.

By permanently inserting between the main poles of a direct current motor an auxiliary set of coils, connected in series with the armature but so arranged as to magnetize in the opposite direction, the effect of armature and field magnetization may be automatically balanced at the point of commutation and brush disturbances effectually eliminated. The commutating poles are somewhat stronger magnetically than the poles produced in the armature and set up a flux (the "commutating flux") inducing in the coil under the brush an electromotive force tending to neutralize the self-induction of each coil at the moment of current reversal; sparking is thus entirely obviated.

CVC 3 H.P. MOTOR

The commutating pole motor in addition to its superior overload and operation characteristics is also preferable to the non-commutating pole type in that a wider speed range by field control is obtainable and brush adjustments once made require no change for load fluctuations. Again freedom from sparking adds to the life of both commutator and brushes and renders negligible the attention and repairs required by those parts. In general, commutating pole motors render the highest degree of all day service efficiency, especially where the fluctuation in voltage or the power demands are severe.

DESIGN AND CONSTRUCTION

The design of the line of CVC motors is the result of long experience, backed by the best technical ability in motor manufacture. All raw or partly finished materials used are purchased under the most rigid specifications, and subjected to exacting tests to insure maintenance of excellence. The tool equipment and factory facilities of the General Electric Company are recognized as second to none among manufacturers of electrical apparatus. The most skillful workmen are employed on machining, winding and testing. Each integral part, however small, is interchangeable, and made to gauge, tested and inspected repeatedly before final assembly into the finished machine, which is also subjected to rigid examination and test before shipment.

In brief then, the success of the CVC motors is justly due to a combination of correct design, excellence of material, superior shop facilities, conscientious workmanship, and, finally, most painstaking care in inspection and test.

FIELD FRAMES

The field frames of CVC motors are cast from soft steel of high magnetic permeability,

CVC FRAME

free from blow holes, porous spots or other defects of material or workmanship. As the frame yoke is cylindrical in shape without joints and of ample cross section, an unbroken magnetic section is permanently assured and the windings are adequately protected. The general design of the frame when assembled with bearing heads is compact, symmetrical and pleasing. Feet of generous bearing surface, added to a particularly low center of gravity, insure freedom from vibratory effects and obviate the necessity for heavy foundations.

BEARING HEADS

The bearing heads of CVC motors have been at once designed to protect and render

BEARING HEAD—COMMUTATOR END

accessible the windings, commutator and brush rigging, in addition to rigidly supporting the bearing linings and armature.

The flanges of the bearing heads are carefully machined to fit the field frame, and accurately jig-drilled with four equally spaced holes to allow for side wall or ceiling suspension. The bearing housings for both commutator and pulley end heads are identical.

The bearing heads being interchangeable, the relation of the commutator and pulley end heads, with respect to the terminal block, may be changed by removing the heads and turning the armature end for end and replacing the heads to correspond. This feature is of great advantage in that it is possible to have the terminal block accessible under all conditions of installation.

Commutator End Bearing Head

The commutator end bearing heads have four sturdy radial "T" section arms cast integrally to a rigid supporting flange. For the CVC type of motor it has been demonstrated that the four bearing arm construction of "T" section has especial advantages both in the safeguarding of internal parts and by allowing freer circulation of air to reduce the operating temperatures of windings and commutator.

Pulley End Bearing Head

The pulley end bearing head, as will be seen in the accompanying illustration, differs from the commutator end head in having smaller openings, shorter arms and wider flanges. The four openings lead to a funnel-

BEARING-HEAD—PULLEY END

shaped inner extension of the bearing head and are cast as an integral part of it. This duct, or funnel, provides ingress to the cool air required for internal ventilation.

BEARING LININGS

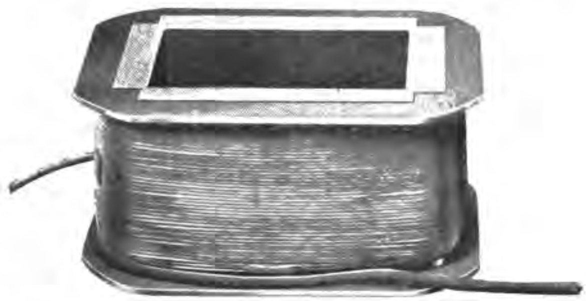
The bearing linings of CVC motors are renewable, and consist of a unit sleeve of special composition having ample bearing surfaces and a low coefficient of friction to minimize wear and heating. Constant and copious lubrication between shaft and bearing is obtained by large and sturdy oil rings of non-magnetic material which revolve with the shaft and dip into oil wells of ample size. Drains are provided at the lowest point of the oil wells. Oil well covers are carefully fitted and provided with a lip at the hinge insuring gravity return to the closed position. A combination oil filler and gauge, also with

BEARING LININGS

return cover, is attached to each bearing housing. A screw plug in the bearing at the opposite oil level allows interchangeability of the oil filler to permit ready accessibility for lubrication, independent of belt arrangement. The use of oil deflectors, separate grooves for the distribution of the lubricant and to prevent creeping, prove the care and detail employed in the design of all component parts to insure freedom from bearing wear, expense and annoyance.

MAIN AND COMMUTATING FIELDS

The main pole pieces of CVC motors are of sheet laminated steel, rigidly secured to



FIELD COIL FOR MAIN POLES

raised pads in the field frame. Eddy currents are minimized by the use of laminated poles in 115 and 230 volt windings, and laminated pole faces for 550 volt windings. In all cases pole tips are properly flared for the purpose of holding the field spools in place. The main field coils are wound on strong horn fiber spools, amply insulated with press board, mica, varnished cambric, etc. Stamped tags attached to the leads indicate the start and finish of each coil. Abrasions and breakages inherent to loose connections are obviated by soldering the field coil leads to terminals in the main connection block on the outside of the magnet frame. The windings are rendered impervious to ordinary moisture by thorough impregnation with a special insulating compound.

Before final assembly, the coils are armor wound with a single layer of enamelled copper wire, serving the double purpose of protecting the active windings from mechanical injury, and assisting to a better degree of heat radiation than would be possible with the old style taped or cord protected coil.

FIELD COIL FOR COMMUTATING POLES

The commutating poles of CVC motors are wound with rectangular cotton covered wire, and, like the main poles, the coils are assembled on horn fiber spools of snug pole piece fit and having collars of sufficient width to afford ample leakage distance between the active windings and the frame parts. Armored binding either for the mechanical protection afforded or its increased radiating properties is not employed on the commutating field spools, since the turns are made up of wire having greater cross section as well as less radial depth than the main field windings.

COMMUTATOR AND ARMATURE

The design, materials and construction of the commutator are important factors in securing cool and sparkless operation of direct current motors. The commutators of CVC motors represent the specialized knowledge and accumulated experience of many years in the perfection of these parts. The segments are liberal in wearing surface and

COMMUTATOR SHOWING COMPONENT PARTS

depth, of the best grade, hard drawn, high conductivity copper, with the grain running at right angles to the brush friction; all assuring that glass-like surface so desirable in a smooth running motor. The commutator bars are insulated from each other and from the commutator shell by selected sheet mica, micrometer gauged to a uniform thickness, and of proper hardness to wear down evenly with the copper. The segments embody a number of refinements, making for satisfactory service; for example, the outer corners are rounded to prevent the chipping of mica and the inner edges notched out to avoid possible short-circuiting between bars. Serrations or small grooves on both flat sides of each bar serve, when the commutator is hydraulically pressed in its assembly ring, to firmly anchor the mica insulating strips, effectually avoiding high mica and making the finished commutator extremely rigid and durable.

Armature

The armature core is built up of selected annealed sheet steel laminations, in which the coil slots are punched before assembly on the shaft. After japanning, to reduce eddy currents, the laminæ are forced directly on the shaft under heavy hydraulic pressure. Punchings of extra thickness at core extensions prevent flaring and vibration of the thinner inner disks with possible injury to the coil insulation. All laminations are keyed directly to the shaft and held in place by retaining rings and heavy cast iron core heads. In the larger sized frames, air ducts are provided through the core to introduce ventilating effect. By the use of proper dies, accurately fitting keys and general excellence of workmanship the coil slots are free from irregularities or sharp points which might injure the coil insulation.

CVC ARMATURE CORE ASSEMBLED ON SHAFT

Armature Coils

All armature coils are form wound, carefully insulated, and are interchangeable on armatures of the same rating and voltage. The coils are placed in the core slots which provide mechanical protection and are held in position by proper binding bands, recessed flush with the armature surface. Especial care is used in coil slot insulation to prevent grounding at points where the coils are shaped to or leave the slots. The ends of the

CVC ARMATURE COMPLETE

coils constituting the leads are brought out and soldered directly into the commutator segment slots. All coils are tested as assembled on the core, and the completed armature is also tested to avoid any possibility of short circuits or grounds. Treatment with a special compound, renders the armature at once moisture-proof and materially improves the entire insulation of the rotating member.

Armature Shafts

All CVC armature shafts are of special, high grade machinery steel of great strength and elasticity, accurately finished and of ample cross section to resist all rotative strains enabling the armature to carry its full h.p.

BRUSH-HOLDER RIGGING

without vibration. Fillets of liberal radius are provided at all diameter changings. Keyways are cut deeply and accurately; grooves to obviate oil creeping are machined outside of the pulley end bearing lining and inside of the bearing housing. No feature has been omitted which could add to the mechanical excellence of these parts.

BRUSH RIGGING

The salient features of the standard CVC yokes, studs, brush-holders, brushes, etc., may be briefly enumerated as follows:

Yoke

Cast iron of split ring type, carefully fitted to machined surfaces on the inside of the commutator end bearing bracket.

An adjusting screw binding the split ring of the yoke allows setting or simultaneous shift of all brushes by rotating the rocker.

Studs

Brush studs are made up of steel studs assembled in a steel mica-insulated sleeve.

BRUSH-HOLDER COMPLETE

The studs are readily attached or detached, being held in place by a simple "hex" nut and lock washer. As the yoke ends of the studs are carefully insulated before being embedded in the rocker arm, the yoke may be handled or the brushes thereby shifted without fear of shock.

BRUSH-HOLDERS

The CVC brush-holder represents an improved pattern of the well-known clock spring type. The metal brush-slides or boxes are accurately broached to gauge, and carefully finished; the brushes, while allowed free movement, are thereby prevented from chat-

BRUSHES

tering. Brush-holders may be readily adjusted or removed without taking off the commutator end bearing head or disturbing the connections; the loosening of a single screw performs the entire function. This feature is important in case reversal of the armature rotation is desired.

BRUSHES

The brushes for CVC motors are made from especially treated carbon, having a low coefficient of friction, and in all cases ample current carrying capacity. Each brush is held firmly and uniformly against the commutator through a lever arm actuated by a spiral spring embracing the stud upon which the lever arm is pivoted. In addition to the spiral spring, an auxiliary phosphor bronze spring of proper flexibility is attached to the underside of the lever arm; this spring having

SLIDING BASE SHOWING FASTENING AND ADJUSTING BOLTS

small inertia serves to prevent jumping of the brushes when slight irregularities are encountered in the commutator surface. The various refinements briefly enumerated above have aided materially in reducing sparking with attendant heating of brush parts and commutator.

SLIDING BASE

The unified bases used with CVC motors are suitable for floor, wall or ceiling suspension. Backward or forward belt shift is obtained by loosening the holding down bolts of the motor and then turning a single set screw bolt projecting through the end of the subbase. Carefully machined grooves with suitable bolts and square washers between the movable and stationary members of the base assure permanently correct belt or chain alignment between the driving and driven units.

PAPER PULLEYS

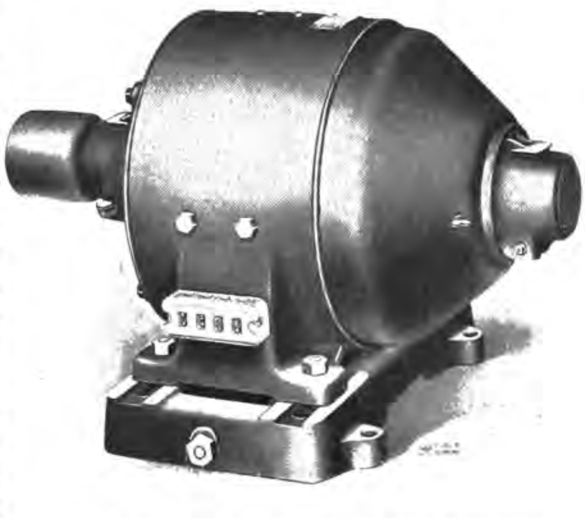
All belted CVC motors are furnished with paper pulleys having a high coefficient of

TYPE OF PAPER PULLEY USED ON CVC MOTORS

friction and capable of transmitting power with great uniformity. Wherever a high belt efficiency is necessary to the successful operation of the driven machinery, paper pulleys have superior qualifications in lightness, correct balance and mechanical accuracy. The high adhesive or tractive power possessed by this type of pulley allows reduced belt tension and lowers the first cost and maintenance expense of both belting and the mechanical transmission.

ENCLOSING COVERS

Where service requirements demand that internal parts be wholly or partially protected from possible injury due to water, moisture,



CVC 3 H.P. TOTALLY ENCLOSED TYPE MOTOR

dust, metal particles, etc., CVC motors may be provided with perforated or solid hand hole covers of simple and sturdy design. The cover used for the commutator end is of light but strong sheet iron spun into the form of a truncated cone and entirely surrounding the end head. Machined surfaces on the heads of all CVC standard motors provide a perfect seating for the covers which are rigidly held in place by strong wing bolts. Motors in service, originally shipped without enclosing covers, may be so supplied at any time, as all covers are strictly interchangeable on frames of a given size.

ROTATION

All standard CVC motors are arranged for counter-clockwise rotation when facing the commutator end. If it is desirable to arrange for clockwise rotation, the brush-holders

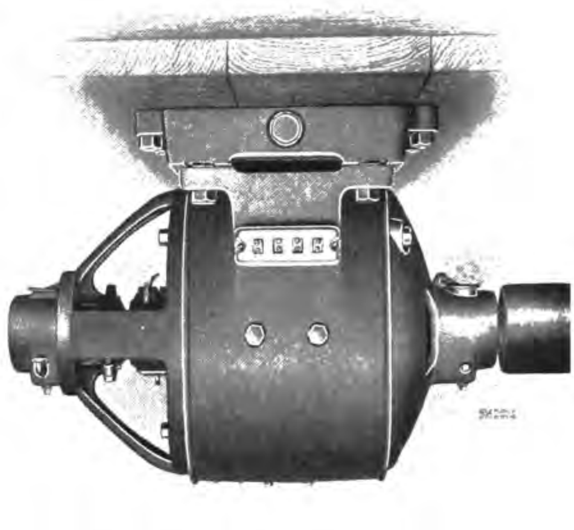
CVC MOTOR, SEMI-ENCLOSED TYPE

should be removed from the studs and reassembled, so that they project to the right of the stud when facing the commutator. The brush yoke is then shifted so that the brushes are returned to their original position with reference to the pole pieces. (For lead reversal directions, see Instruction Book.)

INSTALLATION

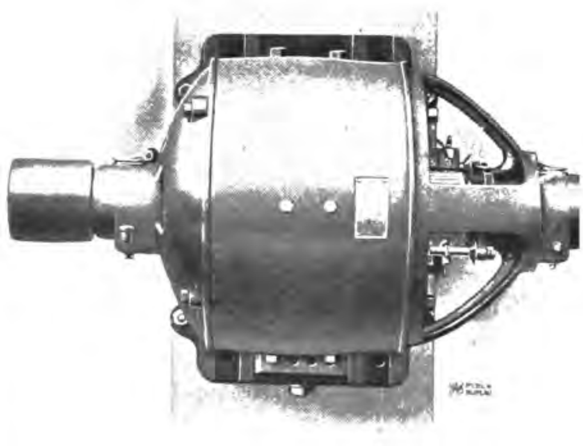
Floor, Side Wall or Ceiling

Unless otherwise ordered, all CVC motors are shipped for floor installation. However, as bearing brackets and frame are drilled and tapped symmetrically, motors may be readily arranged for side wall or ceiling suspension by



CVC MOTOR INSTALLED ON CEILING

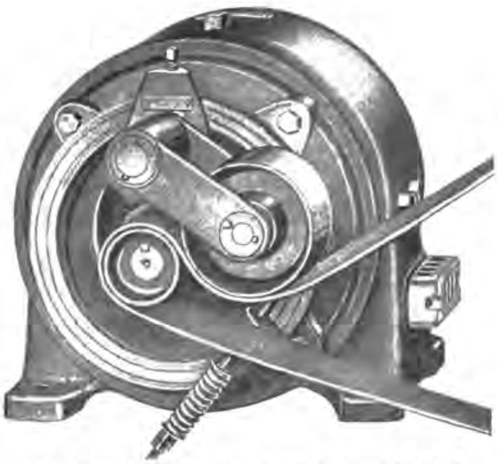
turning the bearing heads in relation to the frame, 90° or 180° respectively.



CVC MOTOR MOUNTED ON WALL

BELT TIGHTENER ATTACHMENTS

All standard CVC motors may be furnished with belt tightener attachments. These devices may be readily applied to standard motors by substituting longer bearing head screws to hold in place both the belt tightener attachment and the standard bearing head. These long screws are furnished with the attachment. The equipment consists primarily of a cast iron ring with an adjustable spring arm carrying an idler tension or binder pulley. The arm with its pulley may be rotated to the position necessary to provide the required arc of contact on the driving pulley.



CVC MOTOR WITH BELT TIGHTENER HEAD

The equipment includes a driving pulley of smaller diameter than the standard pulley ordinarily supplied with motors not fitted with this attachment. Two styles are used, admitting the same range of adjustment and differing only in mechanical detail. The adjustment of the belt tension on the smaller tightener is accomplished by moving a lever held by a cap screw; on the larger machines the same function is performed by simply tightening or loosening a nut on the extremity of a tension rod.

LUBRICATION OF TENSION PULLEYS

The tension pulley bushings for CVC 111 and 112 frames are made from a special patented composition requiring no lubrication. Frames above the 112 size are fitted with compression grease cups of sufficient size to obviate the necessity of frequent attention.

ADVANTAGES OF BELT TIGHTENER HEADS

Automatic tightening devices afford several important advantages for belt drives.

Belt Tighteners:
- Permit short distances between shaft centers.
- Allow the use of small driving pulleys or wide reduction of speed if desired.
- Afford greater arc of belt contact on both driving and driven pulleys.
- Decrease belt slip for a given tension.
- Eliminate necessity of a sliding base, the device itself acting as an automatic belt tightener.

A full line of CVC belt tightener attachments are carried in stock for immediate shipment. (See page 22 for detailed dimensions of these devices.)

VENTILATING OUTFITS

Standard motors may be readily designed to meet the speeds of disk fans, and, since the fans are mounted directly on the armature

VENTILATING FAN DRIVEN BY CVC MOTOR

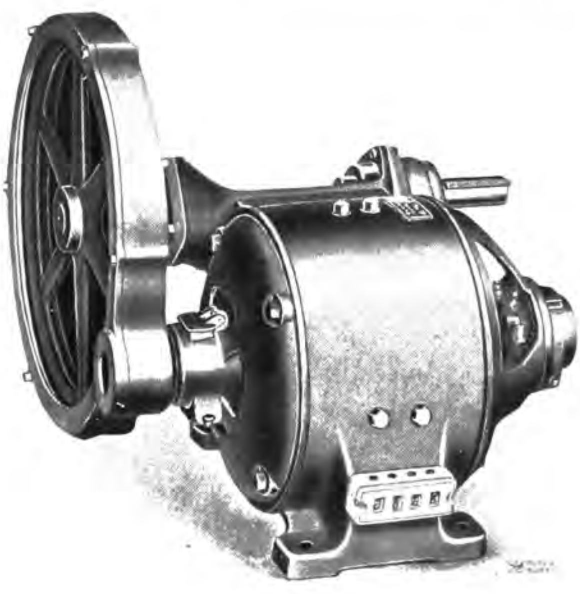
shaft, these outfits are particularly compact, rigid and efficient. CVC ventilating outfits consisting of fan, motor and supporting tripod and speed regulating rheostats, are furnished in six sizes (i.e., 18 in., 24 in., 30 in., 36 in., 42 in. and 48 in.)

VENTILATING FAN DRIVEN BY A.C. MOTOR

Outfits similar to those shown, and designed for connection to single- or polyphase motors, are also available.

BACK-GEARED MOTORS

Where weight, size or cost prohibit the use of special direct connected motors to driven



CVC BACK-GEARED MOTOR

machines requiring slow speed, back-geared motors are widely used. Back-geared CVC motors have a countershaft supported by machined pads on the magnet frame, thus insuring permanent maintenance of proper alignment and spacing between the armature and the back-geared shaft. The back-geared shaft is of large diameter, having a stub extension amply long to take the hub of the larger pulley needed to transmit the full rated power of the motor at the lower belt speed.

A protecting guard surrounding the gear and pinion avoids accidental injury to operatives and prevents obstructions falling between the tooth meshing. Where it is desirable to reduce the noise to a minimum, rawhide or cloth pinions may be furnished in place of the cut steel pinion ordinarily supplied.

CVC MOTOR GENERATOR SET

Two ratios of gear reduction have been adopted as standard, i.e., 4 to 1 and 8 to 1.

Speeds and Gear Ratios

Consideration of the speeds and gear ratios tabulated on pages 20 and 21 will show that the majority of requirements may be met by using motors with standard armature speeds.

When selecting a back-geared motor, the diameter and face of the driving pulley should be carefully considered in its relation to the diameter, face and speed of the driven pulley.

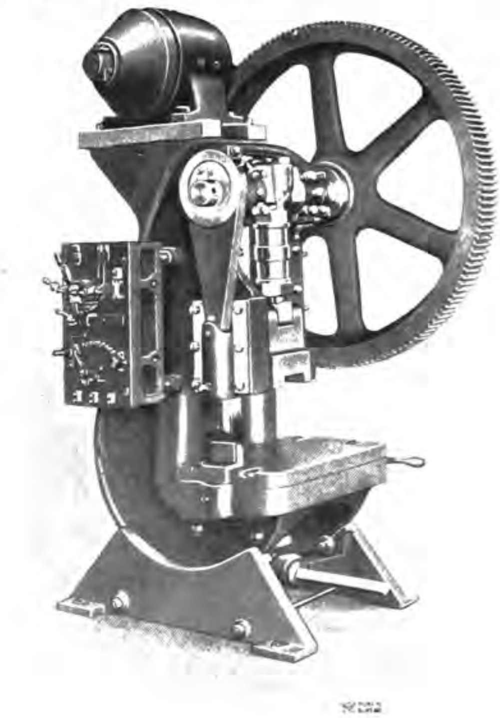
MOTOR-GENERATOR SETS

Motor-generator sets are used in the operation of telegraph instruments, electric automobiles and launches, for securing direct current from alternating current mains, to change direct current from a higher to a lower voltage, or vice versa; as balance sets, etc.

The illustration on page 11 shows two standard CVC frames bolted rigidly and compactly together. This design avoids the necessity for a subbase and in general simplifies construction, decreases weight per kw. output and economizes space.

Both motor and generator armatures are mounted on a single shaft, thus eliminating the alignment and lubrication difficulties attendant upon the use of separate shafts joined by a coupling.

As standard frames are employed, special combinations of voltages can readily be arranged at a moderate cost.

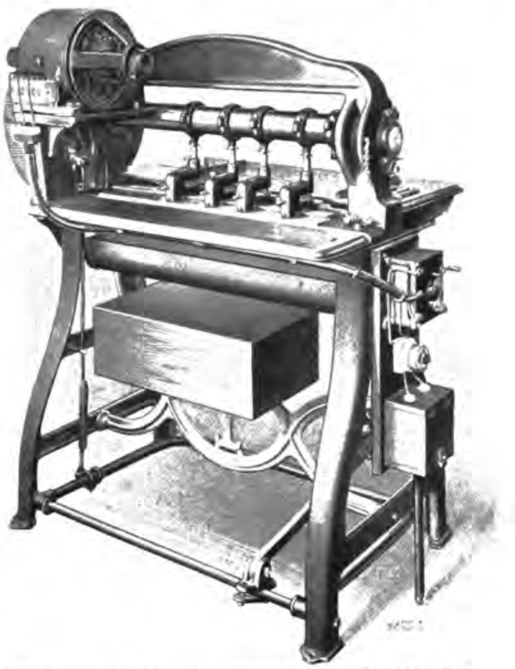


PUNCH PRESS DRIVEN BY A CVC MOTOR

HEATING

Open Motors

Standard CVC open motors will deliver their rated h.p. continually with a temperature rise by thermometer not to exceed 40° C.



PUNCHING MACHINE DRIVEN BY CV. MOTOR

on the windings, or 45° C. on the commutator. An overload of 25 per cent may be maintained for two hours with a temperature rise not to exceed 55° C. on the windings and 60° C. on the commutator.

Semi- or Totally-Enclosed Motors

Due to the fact that the radiating surface of motors, generators, transformers, etc., increases as the square of the dimensions and the output as the cube of linear measurements, the ratings of CVC motors, if totally enclosed, are necessarily reduced to keep the heating within the limits established by safety. For semi-enclosed motors, the same temperature rise is maintained as for open motors, the input, however, being reduced to compensate for the increased temperature rise due to decreased radiating surface.

VOLTAGES AND SPEEDS

Standard and Special Voltages

Standard motors are wound for 115, 230 or 550 volts; standard generators for 125 volts. Other voltages on special order.

Permissible Range of Voltage

Standard guarantees for heating and satisfactory operation of CVC motors will be maintained at the three commercial voltages. If the voltage range does not exceed the following limits, satisfactory operation, without excessive heating will be guaranteed over the entire range.

115 volts, range 110 to 125 volts.
230 volts, range 220 to 250 volts.
550 volts, range 500 to 600 volts.

Speed Variation (Inherent)

While the speed of CVC motors will vary approximately in proportion to change in voltage, it should be remembered that in

OPEN, SEMI-ENCLOSED AND TOTALLY-ENCLOSED RATINGS FOR TYPE CVC STANDARD SHUNT OR COMPOUND WOUND MOTORS

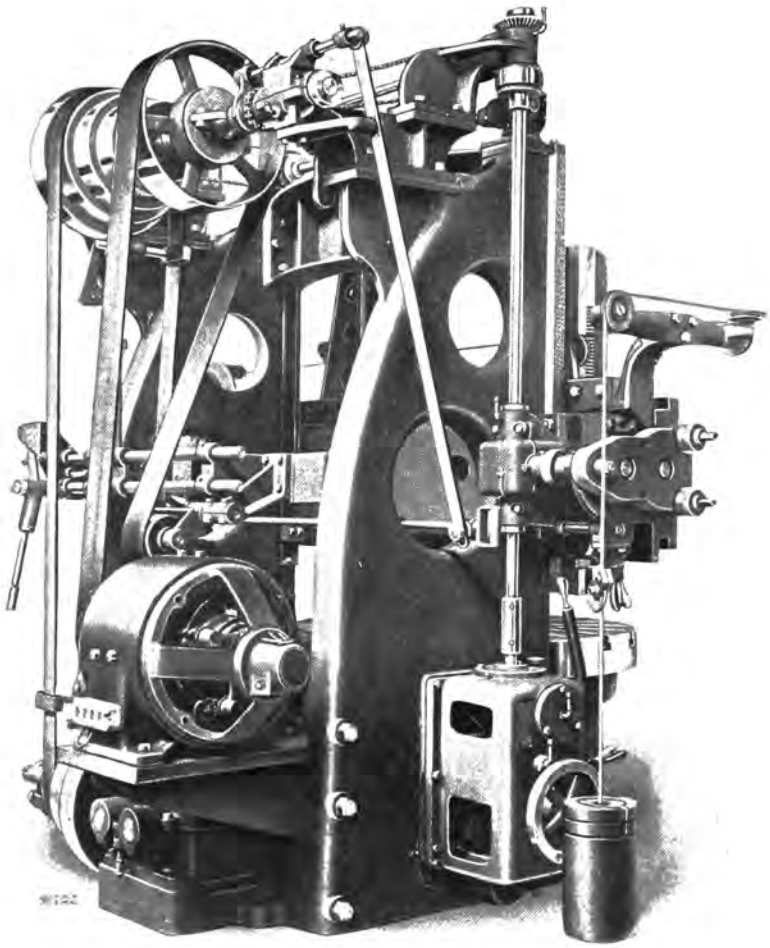
Frame	Volts	Speed	*40° RISE OPEN		*40° RISE SEMI-ENCLOSED		*55° RISE ENCLOSED		
			H.P.	Amps.	H.P.	Amps.	Speed	H.P.	Amps.
CVC 111	115	1100	2	16.0	1¾	14.0	1200	1¾	14.0
	230	1100	S.S.	8.0	S.S.	7.2	1200	S.S.	7.1
	550	1350		3.4		3.0	1475		3.0
CVC 111	115	1650	3	23.9	2.5	20.0	1825	2.5	20.0
	230	1650	M.S.	11.9	M.S.	10.0	1825	M.S.	10.0
	550	2000		5.0		4.2	2100		4.2
CVC 112	115	1100	3	23.4	2.5	19.5	1200	2.5	19.5
	230	1100	S.S.	11.7	S.S.	9.8	1200	S.S.	9.8
	550	1350		4.9		4.1	1475		4.1
CVC 112	115	1650	5	38.8	4	31.0	1825	3.5	27.5
	230	1650	M.S.	19.0	M.S.	15.4	1825	M.S.	13.5
	550	2000		8.0		6.5	2100		5.7
CVC 113	115	1100	5	38.0	4	31.0	1200	3.5	27.5
	230	1100	S.S.	19.0	S.S.	15.4	1200	S.S.	13.5
	550	1350		8.0		6.5	1475		5.7
CVC 113	115	1525	7.5	57.9	6	46.0	1675	5.5	40.0
	230	1525	M.S.	28.8	M.S.	23.0	1675	M.S.	22.0
	550	1850		12.0		9.9	2025		8.7
CVC 114	115	825	7.5	56.8	6	46.0	900	5.5	42.0
	230	825	S.S.	28.4	S.S.	22.5	900	S.S.	22.0
	550	1125		11.9		9.8	1225		8.7
CVC 114	115	1250	10	75.5	8	61.0	1375	5¾	45.5
	230	1250	M.S.	37.7	M.S.	30.0	1375	M.S.	23.0
	550	1500		15.7		12.6	1650		9.6
CVC 115	115	700	10	74.5	8	61.0	775	5¾	45.5
	230	700	S.S.	37.2	S.S.	30.0	775	S.S.	23.0
	550	900		15.6		12.6	1000		9.6
CVC 115	115	925	15	112.0	10	75.0	1025	6¾	53.0
	230	925	M.S.	55.8	M.S.	38.0	1025	M.S.	26.0
	550	1350		23.4		15.7	1475		11.0
CVC 116	115	700	15	112.0	10	77.0	775	7¼	57.5
	230	700	S.S.	55.8	S.S.	38.0	775	S.S.	28.0
	550	825		23.4		15.7	900		12.0
CVC 116	115	925	20	149.0	15	114.0	1025	9½	76.5
	230	925	M.S.	74.5	M.S.	57.0	1025	M.S.	39.0
	550	1250		31.2		23.3	1375		15.5

NOTE.—Motors may be operated at full output when semi-enclosed with a temperature rise not exceeding *50° C.

The speed variation of Standard CVC shunt wound motors from full load to no load will not exceed 9 per cent for sizes up to CVC 113 7½ h.p. moderate speed, and will not exceed 6 per cent for sizes CVC 114 7½ h.p. slow speed to CVC 116 20 h.p. moderate speed inclusive.

*Commutator 5° higher

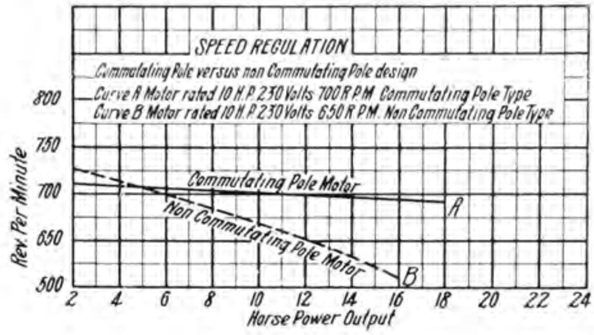
general the speed of all direct current motors depends as well upon a number of other qualifying factors, e.g., the temperature of the room in which the motor is being operated; changing temperature of field and armature due to increased or decreased heating with load; the difficulty in securing iron and steel of absolutely uniform magnetic properties, etc. The belt speed is of really more importance than the number of armature revolutions, and, where it is necessary to secure a certain belt speed, this can be provided for by the use of a special pulley entailing less expense and delay than by winding the motor to meet exact load and speed conditions. Due consideration of the foregoing should be of value where the factor of speed of the driven unit is especially important.



54 IN. VERTICAL BORING AND TURNING MILL DRIVEN BY A 10 H.P. CVC MOTOR

Speed Adjustment (By Field)

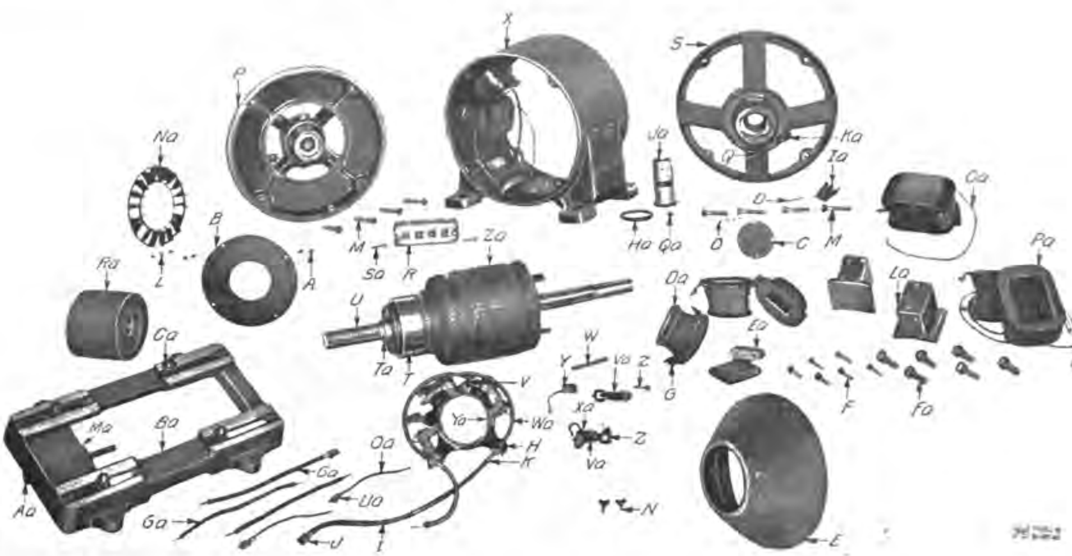
For machines requiring a limited speed adjustment, which shall remain unaffected by change in load, all standard CVC motors may have speeds increased by field weakening 15 per cent above normal rating.



Speed Regulation

For all service where the speed of the driven machine must be automatically maintained at a constant value independent of load conditions, motors of commutating pole design are greatly superior to the non-commutating pole types. The accompanying curve graphically illustrates for both designs the variation of speed obtaining within the limits shown.

CVC MOTOR REPAIR PARTS



A Round head screw for pulley end bearing head hand hole cover
B Hand hole cover for pulley end bearing head
C End cover for commutator end oil well
D Cotter pin to hold oil well cover in place
E Hand hole cover for commutator end bearing head
F Cap screw for commutating pole piece
G Terminal for commutating field spool
H Leakage bushing for brush-holder
I Armature lead
J Armature lead terminal, external
K Armature lead terminal, internal
L Flat head screw for fan
M Cap screw for bearing head
N Thumb screw for commutator end hand hole cover
O Round head screw for commutator end oil well
P Pulley end bearing head
Q Oil drain plug
R Terminal block
S Commutator end bearing head
T Commutator
U Armature shaft
V Brush-holder yoke cap screw
W Key for armature shaft
X Magnet frame
Y Carbon brush with pigtail
Z Brush-holder clamping screw
Aa Adjusting screw for base
Ba Sliding base
Ca Float bolts
Da Commutating field coil
Ea Commutating pole piece
Fa Cap screw for main pole piece
Ga Commutating field lead
Ha Oil ring
Ia Oil well cover
Ja Bearing lining
Ka Overflow plug
La Main pole piece
Ma Sliding base yoke
Na Fan
Oa Main field lead
Pa Main field spool
Qa Plug for bearing lining
Ra Pulley
Sa Terminal block screw
Ta Thrust collar
Ua Field lead terminal
Va Brush-holder body
Wa Brush-holder cable
Xa Brush-holder lever
Ya Brush-holder yoke
Za Armature, complete

In ordering give name of part and reference letter.

MOTOR STARTING DEVICES, RHEOSTATS AND PANELS

To secure efficient and reliable service from motor installations, it is indispensable that the starting or controlling devices be equally satisfactory and dependable. Weaknesses in rheostat design or construction must occasion interrupted service and general dissatisfaction with the power equipment. The partial line of G.E. rheostatic devices briefly described herewith have, under the most rigorous service conditions, proven to be entirely trustworthy. Bulletin No. 4559 should be referred to for more detailed information.

CR 107
Capacities, 1/8 to 35 h.p., 115 volts; 1/8 to 50 h.p., 230 and 550 volts

CR 107 motor starting rheostats are for use with shunt, series or compound wound motors, and have no-voltage release attachment.

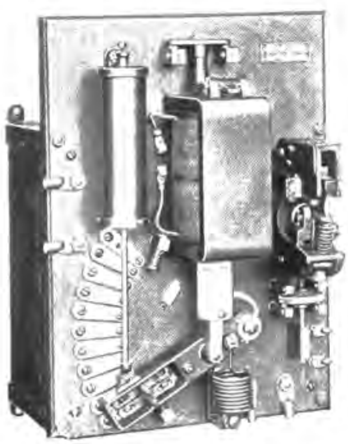
CR 111 is similar to CR 107 with the addition of an overload release coil in series with the motor armature.

Capacities { 1/8 to 35 h.p., 115 volts.
1/8 to 50 h.p., 230 and 550 volts.

CR 114
Capacities, 1/8 to 10 h.p., 115 volts; 1/8 to 20 h.p., 230 and 550 volts

CR 114 reversible motor starting rheostats for shunt, series or compound wound constant speed motors are so designed that only one no-voltage release magnet is required to protect the motor in either direction of rotation.

The CR 120 is a time limit self-starting rheostat designed for the remote control of direct current motors. Starting and stopping may be manually effected either by push buttons or automatically through variation of level or pressure in a tank or gauge. By means of a time limit device the starting or acceleration period when once adjusted remains fixed and independent of the operator's control.

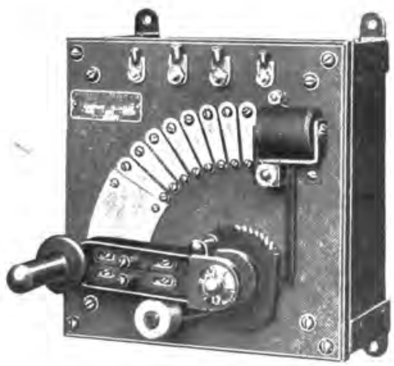


CR 120
Capacities, 1 to 10 h.p., 115 volts; 1 to 15 h.p., 230 and 550 volts

CR 121 self-starters have been designed for use with motor driven pumps or other machines where either automatic starting and stopping or manual control is involved. CR 121 starters are furnished in two (2) types.

CR 121
Capacities ½ to 3 h.p., 115 volts, 230 volts, 550 volts

In one type a manually controlled switch may be interposed at convenience in the motor circuit. In the second type a contacting device is used operated through a pilot circuit and pilot switch.



CR 151
Capacities, ¼ to 40 h.p., 115 volts; ¼ to 50 h.p., 230 and 550 volts

CR 151 rheostat, for shunt, series or compound wound motors, will reduce speed 50 per cent by armature resistance. Provided with no-voltage release attachments.

CR 133
Capacity ¼ to 20 h.p., 115 volts, 230 volts, 550 volts

CR 133 G.E. motor starting panels consist of standard CR 107 starting rheostats mounted upon a slate base with double-pole line switch and fuses.

CR 135
Capacities, 1 to 35 h.p., 115 volts, 1 to 50 h.p., 230 and 550 volts

CR 135 motor starting panels are similar to the CR 133 panel except that the switch and fuses are replaced by a double-pole circuit breaker.

Motor starting panels, on account of economy, reliability and general appearance, are recommended in preference to separate starting devices and switches or circuit breakers.

THE CHOICE OF MOTORS

The choice of the motor which should be used for a given purpose is influenced largely by the character of the work to be performed.

Shunt Winding

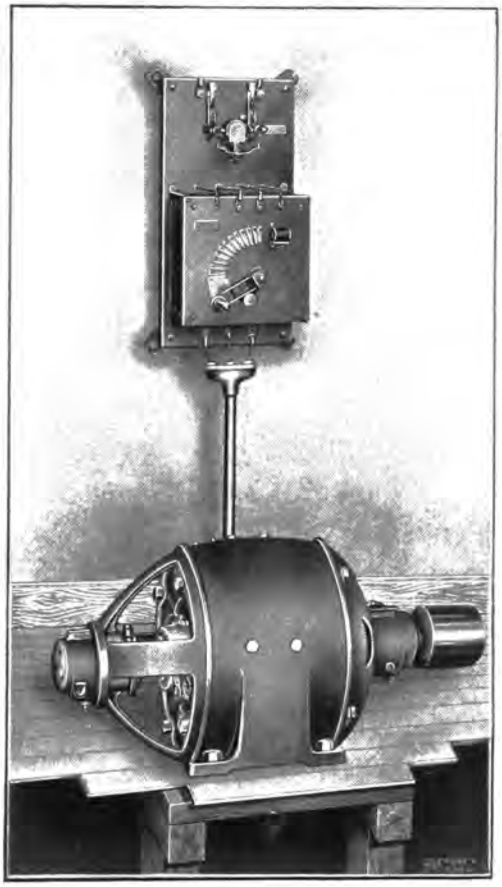
The shunt wound motor is applicable to all machines requiring close speed regulation, and where the load may be accelerated slowly, and has a reasonably uniform value, i.e., free from violent fluctuations.

Series Winding

The inherently heavy torque of the series wound motor guarantees ready acceleration on loads having great inertia or those subject to violent fluctuations. The CVC series wound motor will be found applicable to cranes, hoists, or, in general, for apparatus having either fixed load values or those subject to manual control.

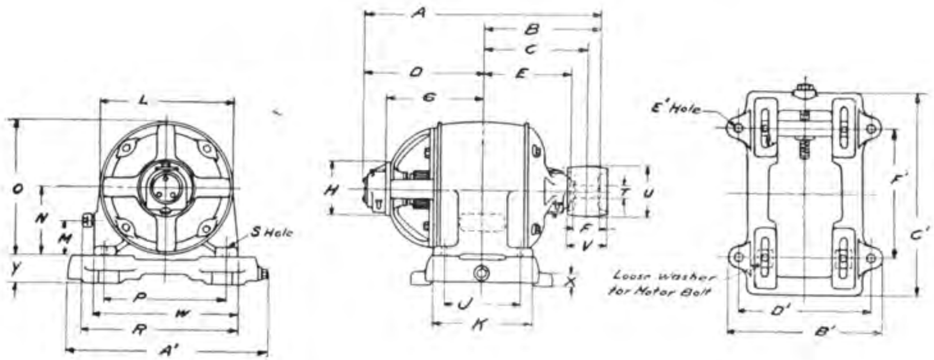
Compound Winding

The compound wound motor possesses the leading characteristics of both the shunt and series types. The CVC compound wound motor may be successfully applied to all loads demanding either heavy starting torque or those subject to violent fluctuations. The compound wound motor under operative conditions possesses sufficiently close regulation to avoid serious fluctuation in speed with change in load.



CR 135 STARTING PANEL AND 5 H.P. CVC MOTOR

DIMENSIONS OF CVC FORM A MOTORS



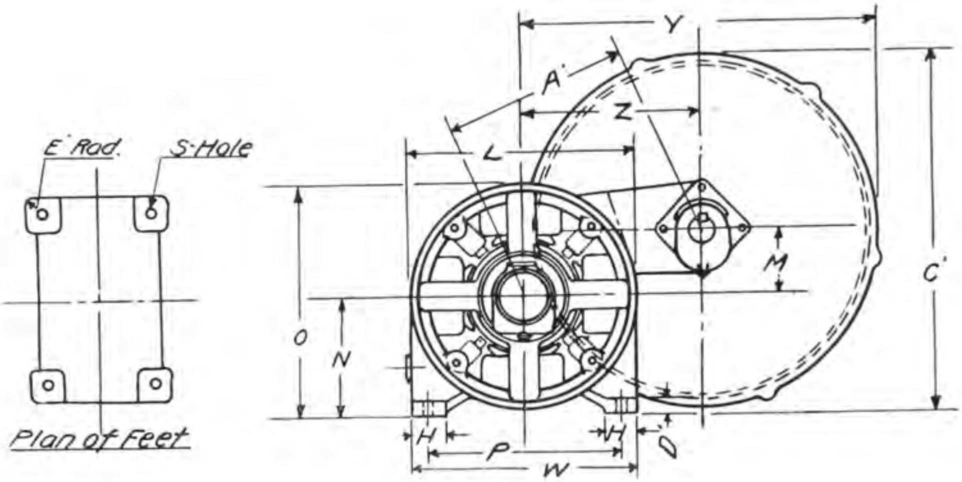
Type and Class	No. of Poles	H.P.	*Speed (Shunt and Comp. Wound Motors) 110v	115v	125v	220v	230v	250v	500v	550v	600v	Weight without Base	Weight with Base
CVC 111	2	2	1060	1100	1175	1060	1100	1175	1250	1350	1450	290	325
		3	1600	1650	1750	1600	1650	1750	1850	2000	2150		
CVC 112	2	3	1060	1100	1175	1060	1100	1175	1250	1350	1450	400	450
		5	1600	1650	1750	1600	1650	1750	1850	2000	2150		
CVC 113	2	5	1060	1100	1175	1060	1100	1175	1250	1350	1450	555	605
		7 1/2	1475	1525	1625	1475	1525	1625	1725	1850	1975		
CVC 114	4	7 1/2	800	825	875	800	825	875	1050	1125	1200	760	830
		10	1220	1250	1310	1220	1250	1310	1400	1500	1600		
CVC 115	4	10	670	700	760	670	700	760	835	900	965	970	1050
		15	885	925	1000	885	925	1000	1250	1350	1450		
CVC 116	4	15	670	700	760	670	700	760	750	825	900	1330	1410
		20	885	925	1000	885	925	1000	1150	1250	1350		

Type and Class	A	B	C	D	E	F	G	H	J	K	L	M	N	O	P	R	S	W
CVC 111	25	12 1/4	11 1/4	12 1/2	9 7/16	2 1/4	10 1/4	6 1/4	8 1/2	11	14 3/4	4	7 1/4	14 7/16	13	16 11/16	41/64	15 1/2
CVC 112	28 11/16	14 1/4	13 3/16	14 5/16	10 3/4	3 1/4	12 1/16	6 3/4	9 1/2	12 1/2	16 3/4	4 1/2	8 1/2	16 3/4	15	19 11/16	53/64	18
CVC 113	34	16 13/16	15 1/4	17 3/16	12 13/16	3 3/4	14	7 1/4	9 1/2	12 1/2	18 3/4	4 1/2	9 1/2	18 13/16	16	20 1/2	53/64	19
CVC 114	37	17 5/16	15 7/8	19 3/16	12 13/16	4 13/16	15 15/16	8 3/4	11	14 1/2	21 3/4	4	11	21 15/16	17 1/2	22 13/16	41/64	21
CVC 115	40 1/4	19 3/4	16 5/16	20 7/8	13 13/16	5 3/4	16 13/16	9 3/4	12	15 1/2	23 1/2	4	12	23 3/4	19 1/2	24 13/16	53/64	23
CVC 116	44 3/4	21 1/16	18 3/4	23 13/16	15	5 7/8	19 5/16	10 1/4	12 1/2	16 1/2	26 3/4	4 1/4	13 1/2	26 13/16	22	27 13/16	53/64	26

Type and Class	Base X	Y	A'	B'	C'	D'	E'	F'	Pulley T	U Dia.	V Face	Keyway
CVC 111	1 1/2	2 3/4	20 3/4	15 1/4	20	14 1/4	3/4	12 3/4	1 1/8	4 1/2	3 1/2	2 5/16 x 1/4 x 1/8
CVC 112	1 1/2	3 1/4	24 3/4	17 1/2	24	15 3/4	7/8	15 1/2	1 3/8	5	4	3 1/16 x 3/8 x 3/16
CVC 113	1 1/2	3 1/4	24 3/4	17 1/2	24	15 3/4	7/8	15 1/2	1 3/8	5 1/2	5	3 9/16 x 3/8 x 3/16
CVC 114	1 1/2	3 1/4	27 3/4	19	27	17 1/4	7/8	16 3/4	1 5/8	8	6 1/4	4 3/16 x 3/8 x 3/16
CVC 115	1 3/4	3 3/4	33 1/2	21 1/4	32 3/4	19 1/2	1	20 3/4	2	10	7 3/4	5 1/16 x 1/2 x 1/4
CVC 116	1 3/4	3 3/4	33 1/2	21 1/4	32 3/4	19 1/2	1	26 3/4	2 1/4	11	9 3/4	5 9/16 x 1/2 x 1/4

* Speed at full load is subject to a maximum variation of 4 per cent above or below standard.

DIMENSIONS CVC BACK GEARED



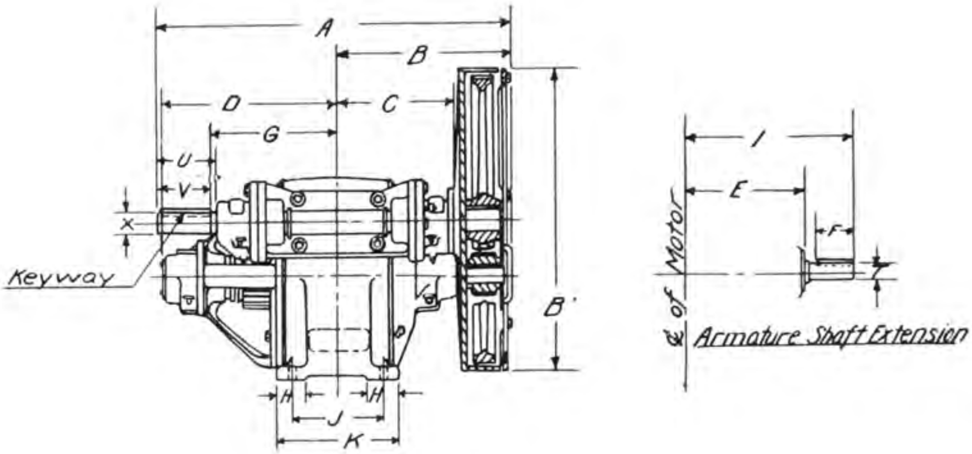
Type and Class	No. of Poles	H.P.	Weight Ratio 4:1	Weight Ratio 8:1	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
CVC 111	2	2	425	450	26¾	12¾	9⅝	12½	9 9/16	2⅞	9 13/16	2½	12½	8½	11	14¾	3½	7¼	14 7/16	13
CVC 112	2	3	545	595	30⅞	14½	10 7/16	14 9/16	10¾	3⅛	11 3/16	3	14¼	9½	12½	16¼	4	8¼	16⅞	15
CVC 113	2	5	790	865	35⅝	17 3/16	12 9/16	17 3/16	12 13/16	3¾	13⅛	3	16 13/16	9¼	12½	18¼	4½	9½	18 13/16	16
CVC 114	4	7½	1060	1160	37 13/16	18¼	12⅞	19 3/16	12 13/16	4 11/16	13⅞	3½	17 13/16	11	14½	21⅜	5⅛	11	21 11/16	17½
CVC 115	4	10	1370	1495	41¼	19⅝	13½	20⅞	13 11/16	5 3/16	14 1/16	3½	19¼	12	15½	23¼	6 5/16	12	23⅞	19½
CVC 116	4	15	1855	2005	44 7/16	21 9/16	14 7/16	23 11/16	15	5 11/16	15 1/16	4	21 1/16	12½	16½	26¾	6 5/16	13½	26 11/16	22

SPEED

Type and Class	H.P.	110 & 220 Volts Ratio 4:1	110 & 220 Volts Ratio 8:1	115 & 230 Volts Ratio 4:1	115 & 230 Volts Ratio 8:1	125 & 250 Volts Ratio 4:1	125 & 250 Volts Ratio 8:1	500 Volt Ratio 4:1	500 Volt Ratio 8:1	550 Volts Ratio 4:1	550 Volts Ratio 8:1	600 Volts Ratio 4:1	600 Volts Ratio 8:1
CVC 111	2	265	132	275	137	294	147	312	156	337	169	362	181
	3	400	200	412	206	437	219	462	231	500	250	537	269
CVC 112	3	265	132	275	137	294	147	312	156	337	169	362	181
	5	400	200	412	206	437	219	462	231	500	250	537	269
CVC 113	5	265	132	275	137	294	147	312	156	337	169	362	181
	7½	369	184	381	191	406	203	431	216	462	231	494	247

Speed at full load is subiect to a maximum variation of 4 per cent above or below standard. D+B is over all for CVC 116.

MOTORS—SHUNT AND COMPOUND WOUND

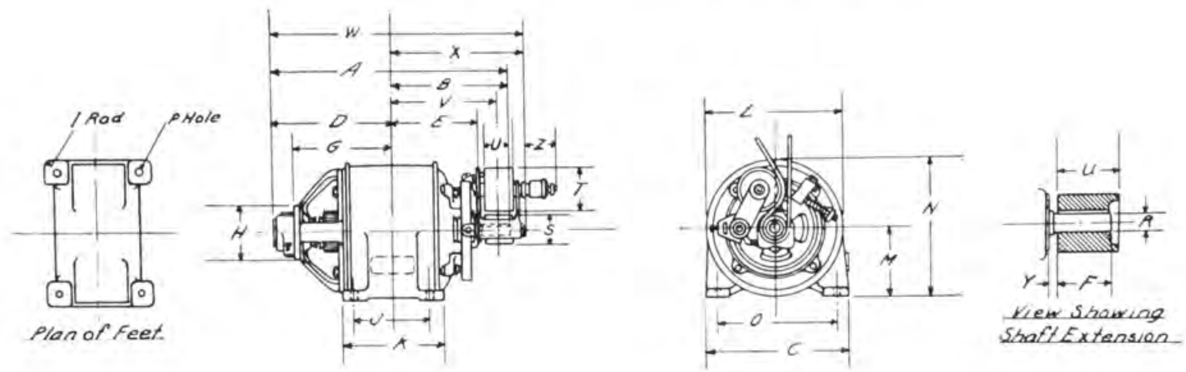


Type and Class	S	T	U	V	W	X	Reduction 4:1 Y	Z	A′	B′	C′	Reduction 8:1 Y	Z	A′	B′	C′	D′	E′	Back Gear Shaft Extension Keyway
CVC111	41/64	1¼	4¾	4 1/16	15½	1 11/16	18⅛	9.368	10.000	17½	19½	21	10.353	10.929	21⅛	21 5/16	1	¼	4 1/16x⅜x3/16
CVC112	43/64	1⅜	5	4 11/16	18	1 13/16	19¾	10.180	10.937	19⅝	22 1/16	24 5/16	12.106	12.750	24⅜	24 13/16	1⅛	⅜	4 13/16x⅜x3/16
CVC113	43/64	1½	5⅝	5 5/16	19	2 3/16	22¼	11.661	12.500	21½	24¾	27 5/16	13.679	14.400	27⅝	27 11/16	1⅛	⅜	5 5/16x½x¼
CVC114	43/64	1¾	6¼	6 1/16	21	2 7/16	25 11/32	13.158	14.167	24⅜	28 5/16	31 31/32	16.037	16.875	31⅞	32 3/16	1¼	⅜	6 1/16x⅜x3/16
CVC115	45/64	2	7½	7 3/16	23	2 11/16	27 11/32	14.042	15.500	26¾	31⅞	36¼	18.135	19.286	36¼	36 11/16	1⅜	¼	7 3/16x¾x⅜
CVC116	57/64	2¼	8¼	7 13/16	26	3 3/16	31 5/32	16.222	17.500	29⅞	35	39⅜	19.972	21.000	39⅜	39¾	1½	¼	7 13/16x¾x⅜

SPEED

Type and Class	H.P.	110 & 220 volts Ratio 4:1	110 & 220 volts Ratio 8:1	115 & 230 volts Ratio 4:1	115 & 230 volts Ratio 8:1	125 & 250 volts Ratio 4:1	125 & 250 volts Ratio 8:1	500 volts Ratio 4:1	500 volts Ratio 8:1	550 volts Ratio 4:1	550 volts Ratio 8:1	600 volts Ratio 4:1	600 volts Ratio 8:1
CVC114	7½	200	100	206	103	218	109	262	131	281	141	300	150
	10	305	153	312	156	328	164	350	175	375	187	400	200
CVC115	10	168	84	175	88	190	95	208	104	225	113	241	121
	15	221	111	231	116	250	125	312	156	337	169	362	181
CVC116	15	168	84	175	88	190	95	187	94	206	103	225	113
	20	221	111	231	116	250	125	287	144	312	156	337	169

DIMENSIONS OF CVC BELT TIGHTENER MOTORS



Type and Class	No. of Poles	H.P.	*Speed (Shunt and Comp. Wound Motors) 110v	115v	125v	220v	230v	250v	500v	550v	600v	Weight without Attachment	Weight with Attachment	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Pulleys R	S Dia.	T Dia.	U Face	V	W	X	Y	Z	Keyway
CVC111	2	2	1060	1100	1175	1060	1100	1175	1250	1350	1450	290	315	25	12 1/2	15 1/2	12 1/4	9 5/16	2 3/8	10 1/2	6 1/4	3/4	8 1/2	11	14 3/4	7 1/4	14 1/16	13	41/64	1 1/4	2 1/4	4 1/2	3 1/2	11 3/4	27	14 1/4	5/16	..	2 5/16x1/4x1/4
		3	1600	1650	1750	1600	1650	1750	1850	2000	2150																												
CVC112	2	3	1060	1100	1175	1060	1100	1175	1250	1350	1450	400	435	28 13/16	14 1/4	18	14 9/16	10 1/8	3 1/8	12 5/16	6 3/4	3/4	9 1/2	12 1/2	16 3/4	8 1/2	16 7/8	15	49/64	1 1/4	3 1/4	5 1/2	4	13 1/4	30 13/16	16 1/4	1/4	...	3 1/16x3/8x3/16
		5	1600	1650	1750	1600	1650	1750	1850	2000	2150																												
CVC113	2	5	1060	1100	1175	1060	1100	1175	1250	1350	1450	555	600	34	16 13/16	19	17 3/16	12 13/16	3 3/8	14	7 1/8	3/4	9 1/2	12 1/2	18 3/4	9 1/2	18 13/16	16	49/64	1 3/8	4	7	5	15 11/16	36 13/16	19 1/4	1/4	5 3/16	3 7/16x3/8x3/16
		7 1/2	1475	1525	1625	1475	1525	1625	1725	1850	1975																												
CVC114	4	7 1/2	800	825	875	800	825	875	1050	1125	1200	760	810	37	17 13/16	21	19 3/16	12 13/16	4 13/16	15 11/16	8 3/8	1/4	11	14 1/2	21 3/8	11	21 13/16	17 1/2	49/64	1 7/8	5	8	6 1/4	16 1/2	40 1/2	21 5/16	3/16	4 13/16	4 5/16x3/8x3/16
		10	1220	1250	1310	1220	1250	1310	1400	1500	1600																												
CVC115	4	10	670	700	760	670	700	760	835	900	965	970	1030	40 1/4	19 1/4	23	20 5/8	13 13/16	5 3/16	16 13/16	9 3/8	1/4	12	15 1/2	23 1/2	12	23 3/4	19 1/2	49/64	2	6	9	7 3/4	18 1/16	44 15/32	23 31/32	1/4	4 3/8	5 1/16x1/2x1/4
		15	885	925	1000	885	925	1000	1250	1350	1450																												
CVC116	4	15	670	700	760	670	700	760	750	825	900	1330	1405	44 1/4	21 1/16	26	23 11/16	15	5 11/16	19 3/16	10 1/4	1/4	12 1/2	16 1/4	26 1/4	13 1/2	26 13/16	22	41/64	2 1/8	7	9 1/2	9 1/4	20 1/4	50 1/4	26 13/16	1/4	4 1/4	5 7/8x1/2x1/4
		20	885	925	1000	885	925	1000	1150	1250	1350																												

* Speed at full load is subject to a maximum variation of 4 per cent above or below standard.

GENERAL ELECTRIC COMPANY

PRINCIPAL OFFICES, SCHENECTADY, N. Y.

SALES OFFICES

(Address nearest office)

BOSTON, MASS.	84 State Street
NEW YORK, N. Y.	30 Church Street
Syracuse, N. Y.	Post-Standard Building
Buffalo, N. Y.	Ellicott Square Building
New Haven, Conn.	Malley Building
PHILADELPHIA, PA.	Witherspoon Building
Baltimore, Md.	Electrical Building
Charlotte, N. C.	Trust Building
Charleston, W. Va.	Charleston National Bank Building
Erie, Pa.	632 State Street
Pittsburg, Pa.	Park Building
Richmond, Va.	Mutual Building
ATLANTA, GA.	Empire Building
Birmingham, Ala.	Brown-Marx Building
Macon, Ga.	Grand Building
New Orleans, La.	Maison-Blanche Building
CINCINNATI, OHIO	Provident Bank Building
Columbus, Ohio	Columbus Savings & Trust Building
Cleveland, Ohio	Citizens Building
Chattanooga, Tenn.	James Building
Memphis, Tenn.	Randolph Building
Nashville, Tenn.	Stahlman Building
Indianapolis, Ind.	Traction Terminal Building
CHICAGO, ILL.	Monadnock Building
Detroit, Mich.	Majestic Building (Office of Soliciting Agent)
St. Louis, Mo.	Wainwright Building
Kansas City, Mo.	Dwight Building
Butte, Montana	Electric Building
Minneapolis, Minn.	410-412 Third Ave., North
DENVER, COLO.	First National Bank Building
Salt Lake City, Utah	Newhouse Building
SAN FRANCISCO, CAL.	Nevada Bank Building
Los Angeles, Cal.	124 West Fourth Street
Portland, Ore.	Electric Building
Seattle, Wash.	Colman Building
Spokane, Wash.	Paulsen Building

For TEXAS and OKLAHOMA Business refer to
General Electric Company of Texas,

Dallas, Tex.	Praetorian Building
El Paso, Tex.	Chamber of Commerce Building
Oklahoma City, Okla.	Insurance Building

FOREIGN

FOREIGN DEPARTMENT,
Schenectady, N. Y., and 30 Church St., New York, N. Y.
London Office, 83 Cannon St., London, E. C., England

General Electric Company

Schenectady, N.Y.

LIGHTING DEPARTMENT

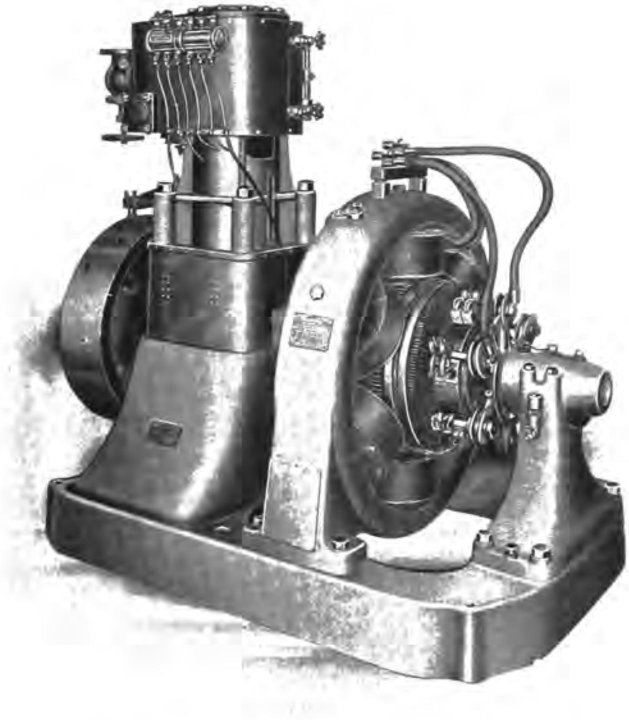
December, 1910 **Bulletin No. 4804*

DIRECT CONNECTED GENERATING SETS

The General Electric Company manufactures a line of small direct connected generating sets, of the highest grade electrically and mechanically, in sizes ranging from 2½ to 75 kw. Designed originally to meet the severe conditions of marine work, which demand light, compact and durable sets of close regulation and quiet operation, they are also well adapted, and have been used extensively, for both power and lighting in isolated plants, and as exciters for alternating current generators in central station work.

In addition to their many specific points of superiority, these sets have the great advantage of being manufactured complete at one factory, which insures perfect fit, uniformity of finish and thorough test of the combined unit before shipment is made. These facts obviously promise more for successful operation than would be the case if the engine and generator were built by different manufacturers.

In material and workmanship these sets are similar to those built for the U. S. Navy, of which a very large proportion have been



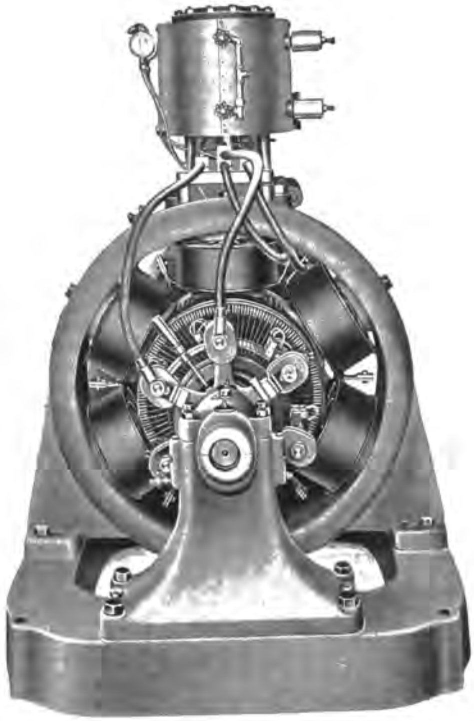
MP 6-20-360, 125 VOLT GENERATOR WITH SINGLE CYLINDER ENGINE

NOTE.—The data in this publication are for the convenience of customers, and every effort is made to avoid error, but this Company does not guarantee their correctness, nor does it hold itself responsible for any errors or omissions in this publication. Subject to change without notice.

**Supersedes No. 4617.*

4804–2 Direct Connected Generating Sets

furnished by this company. As commercial installations have been made in almost every section of the country, prospective purchasers can be referred to sets in regular service, and inspection at the factory is also invited. Similar parts of each size of machine are built to templets and gauges, and are interchangeable. All sets are subjected to rigid tests before being sent out, and the test report of each set is kept on file.



GENERATOR VIEW OF 20 KW. SET

DIRECT CONNECTED GENERATING SETS WITH SINGLE CYLINDER ENGINES HAVING GRAVITY SYSTEM OF LUBRICATION

Classification: Type Poles Kw. Speed	Volts Full Load	Amperes Full Load	Floor Space	Height	Weight Pounds	Diameter Steam Pipe	Diameter Exhaust Pipe	Diameter Cylinder	Stroke
*MP 4– 2½–700	110	23	40″ x 24″	32″	850	¾″	1 ″	3½″	3 ″
†MP 4– 4 –600	110	36	49″ x 28″	40″	1500	1 ″	1½″	4½″	4
MP 4– 7 –550	110	64	51″ x 29″	46″	2000	1¼″	1½″	5 ″	4½″
MP 6–10 –450	110	91	54″ x 30″	50″	2600	1½″	2 ″	6½″	5 ″
MP 6–15 –400	110	136	60″ x 35″	60″	3600	2 ″	2½″	8 ″	6 ″
MP 6–20 –360	125	160	64″ x 38″	64″	5600	2½″	3 ″	9 ″	7 ″
MP 6–30 –305	125	240	76″ x 48″	76″	7800	3 ″	3½″	11 ″	8 ″
‡MP 6–50 –280	125	400	97″ x 55″	99″	13100	3½″	4 ″	12 ″	11 ″

*Good for 3 kw. on 100 lbs. initial steam pressure.
†Good for 5 kw. on 100 lbs. initial steam pressure.
‡This engine is of the single cylinder forced lubrication type, designed for 100 lbs. steam pressure and at 80 lbs. initial steam pressure will carry 15 per cent overload. There is no corresponding engine of the gravity lubrication type.
Sets wound for 220 or 250 volts can be furnished on short notice.
Based on 80 lbs. steam pressure, non-condensing.

STABILITY

The bed-plate is carried out to the full width of the generator frame, making an ample base surface for foundation without increasing the floor space required.

SIMPLICITY AND COMPACTNESS

The accompanying illustrations show the simplicity of design and the freedom from complications.

On the single cylinder engines, only one valve is used, the motion being transmitted from the eccentric pin of the governor weight through the rocker arm by means of a valve rod.

By the adoption of a short stroke for the engines and a special armature winding

CONNECTING ROD

for the generators the height and length of the sets have been reduced without detracting from their efficiency or accessibility.

DURABILITY

The construction of all parts insures perfect alignment, balance and adjustment for wear. The materials used are of the kinds and qualities best adapted to the purpose, and are advantageously employed in the execution of carefully prepared designs.

PISTON, PISTON ROD AND CROSSHEAD

ENGINES

Single cylinder engines of the vertical marine type described in the following paragraphs are furnished in sizes from 2½ to 50 kw., inclusive, as listed on the opposite page.

Connecting Rod

The connecting rod is forged in one piece of best machine steel. The wrist-pin is made of steel, hardened, ground true and shrunk in the connecting rod. The crank-pin box is cast steel lined with babbitt metal. Removable liners provide for taking up wear, and the boxes may easily be rebabbitted when necessary.

Piston, Piston Rod and Crosshead

The piston rod and crosshead are forged in one piece from the best machine steel, the

DIRECT CONNECTED GENERATING SETS WITH SINGLE CYLINDER ENGINES HAVING GRAVITY SYSTEM OF LUBRICATION

NOT CARRIED IN STOCK BUT CAN BE FURNISHED ON SHORT NOTICE

CLASSIFICATION Type Poles Kw. Speed	Volts Full Load	Amperes Full Load	Floor Space	Height	Weight Pounds	Diameter Steam Pipe	Diameter Exhaust Pipe	Diameter Cylinder	Stroke
MP-6- 8.5-550	110	77.5	51" x 30"	45"	2225	1¼"	1½"	5 "	4½"
MP-6-12.5-450	110	114	56" x 35"	51"	3050	1½"	2 "	6½"	5 "
MP 6-17.5-400	110	160	66" x 37"	60"	3850	2 "	2½"	8 "	6 "
MP 6-25 -360	125	200	74" x 48"	68"	6475	2½"	3 "	9 "	7 "
MP 6-35 -305	125	280	76" x 48"	76"	8700	3 "	3½"	11 "	8 "
MP 6-40 -305	125	320	76" x 48"	76"	8800	3 "	3½"	11 "	8 "
*MP 6-60 -280	125	480	97" x 55"	99"	14400	3½"	4 "	12 "	11 "

Based on 100 lbs. steam pressure, non-condensing. All sets may be operated on any pressure up to 125 lbs. condensing or non-condensing, but cannot readily be adapted for lower pressures.

*Engine is of the forced lubrication type.

crosshead having phosphor bronze shoes attached. On account of the material used and the large wearing surface of these shoes, adjustment is rarely needed, but when required can be accurately obtained by placing a thin sheet of paper or metal between the crosshead and shoe. As the engine runs always in one direction, only one shoe needs adjustment. The piston is of solid cast iron with spring rings made of a special quality

CRANK SHAFT AND HALF COUPLING

of hard cast iron. The wrist-pin bearing is fitted with adjustable phosphor bronze boxes.

Crank Shaft and Coupling

The crank shafts and half couplings of single cylinder engines are made of best open hearth machine steel forged in one piece, the crank shaft being machined out, and all turnings are accurately fitted to gauge. Tandem compound sets are connected by flange couplings shrunk on the shafts. These forms of couplings have proved convenient and satisfactory.

MAIN BEARING BOX

Main Bearing Boxes

The main bearing boxes are separate from the bed-plate and are of cast iron lined with babbitt metal. They are securely held in place by two studs which also form the guides for the box. This construction simplifies and facilitates the aligning and rebabbitting of the bearings.

PISTON VALVE—4 KW. AND BELOW

Valve

The valve is of the well-known balanced piston type and is accurately ground to a fit in its steam chest. The use of piston

DIRECT CONNECTED GENERATING SETS WITH SINGLE CYLINDER ENGINES HAVING GRAVITY SYSTEM OF LUBRICATION WITH SPECIAL CYLINDERS FOR LOW STEAM PRESSURES

Classification: Type, Poles, Kw., Speed	Volts Full Load	Amperes Full Load	Floor Space	Height	Weight Pounds	Diameter Steam Pipe	Diameter Exhaust Pipe	Diameter Cylinder	Stroke	Steam Pressure
MP 4- 7-550	110	36	51″ x 29″	46″	2150	2 ″	2½″	9 ″	4½″	35
MP 4- 7-550	110	36	51″ x 29″	46″	2100	2 ″	2½″	7 ″	4½″	50
MP 6-10-450	110	91	54″ x 30″	50″	2750	2 ″	2½″	9 ″	5 ″	50
MP 6-10-450	110	91	54″ x 30″	50″	2675	2 ″	2½″	7½″	5 ″	60
MP 6-15-400	110	136	60″ x 35″	60″	3800	2½″	3 ″	12½″	6 ″	35
MP 6-15-400	110	136	60″ x 35″	60″	3700	2½″	3 ″	10 ″	6 ″	50
MP 6-20-360	125	160	64″ x 38″	64″	5850	3 ″	4 ″	13 ″	7 ″	35
MP 6-20-360	125	160	64″ x 38″	64″	5725	3 ″	3½″	11 ″	7 ″	50
MP 6-30-305	125	240	76″ x 48″	76″	8000	3 ″	4 ″	16 ″	8 ″	35
MP 6-35-305	125	280	76″ x 48″	76″	8900	3 ″	4 ″	16 ″	8 ″	45
MP 6-40-305	125	320	76″ x 48″	76″	9000	3 ″	4 ″	16 ″	8 ″	50
*MP 6-50-280	125	400	97″ x 55″	99″	13300	4½″	6 ″	17½″	11 ″	50
*MP 6-60-280	125	480	97″ x 55″	99″	14600	4½″	6 ″	17½″	11 ″	50

Based on steam pressures given above and atmospheric exhaust.
*Engine is of the forced lubrication type.
Sets wound for 220 or 250 volts can be furnished on short notice.

valves on these engines secures light mechanism, perfect regulation, and freedom from excessive friction.

PISTON VALVE ABOVE 4 KW.

Governor

The governor possesses features of simplicity not found in the various fly-wheel governors using shifting eccentrics. The construction of the governor and the operation of its only moving part will be understood by reference to the illustration. The fly-weight contains the eccentric pin and a spring opposes the centrifugal force of the weight. If the load be decreased, the fly-weight, by increased centrifugal force, moves out and draws the eccentric pin toward the center of the shaft. The consequent reduction in the throw of the valve changes the steam admission and compression to suit the load, and maintains the speed of the engine practically constant. The governor is capable of changing the cut-off from ¾ to 0, and the speed can be changed within certain limits by tightening or loosening the spring.

This governor requires the least amount of attention, as it has practically no parts that can give trouble or wear out.

The fly-weight bearing has ample surface so that no appreciable wear can be detected

GOVERNOR CONNECTING ROD

after long service. The bearing is lubricated by a conveniently located grease cup.

Cylinder

The cylinder, valve chest and crosshead guides are made in one casting. Both the guides and the cylinder are bored at one operation, and perfect alignment is thus obtained. The cylinder is mounted on four hollow cast iron columns, through which steel rods extend and bolt the cylinder casting firmly to the bed-plate. The cylinder is cased with Russia iron and the space between the casting and the casing is filled with the best non-conducting material.

Lubrication

All moving parts of the single cylinder engines, with the exception of the governor and rocker arm, are lubricated by a conveniently located oil tank with a number of

GOVERNOR

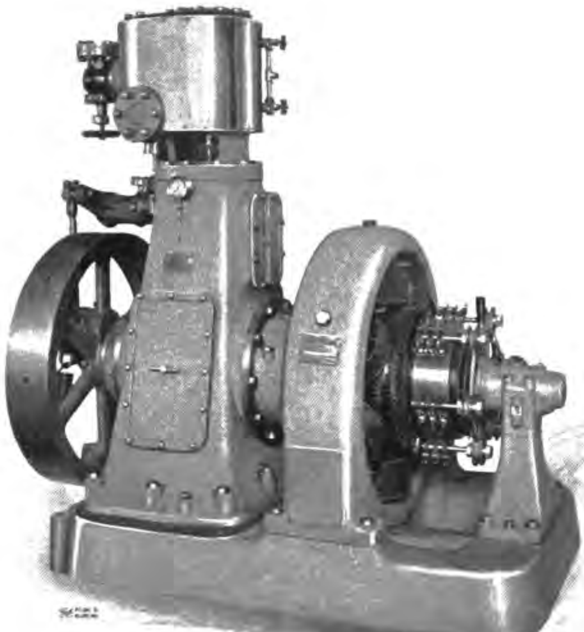
adjustable sight feed tubes, allowing different rates of feed to the various bearings. Pressure grease cups are used for lubricating the governor and rocker arm.

Steam Pressure

The ratings of the standard single cylinder engines are based on a steam pressure of 80 lbs. non-condensing, but they can be operated on pressures up to 125 lbs., either condensing or non-condensing. When the pressure is above 125 lbs. a reducing valve should be used. For steam pressures of less than 80 lbs. these sets can be supplied with special cylinders to operate at various pressures as given in the table on the opposite page and orders can be filled with reasonable promptness.

SINGLE CYLINDER ENGINES WITH FORCED SYSTEM OF LUBRICATION

In response to demands for a set using the forced system of lubrication for oiling the moving parts of the engine, the line of sets listed below has been developed. In these engines all the moving parts are automatically lubricated by oil under pressure, and the cylinder is separated from



GENERATING SET WITH FORCED LUBRICATION ENGINE

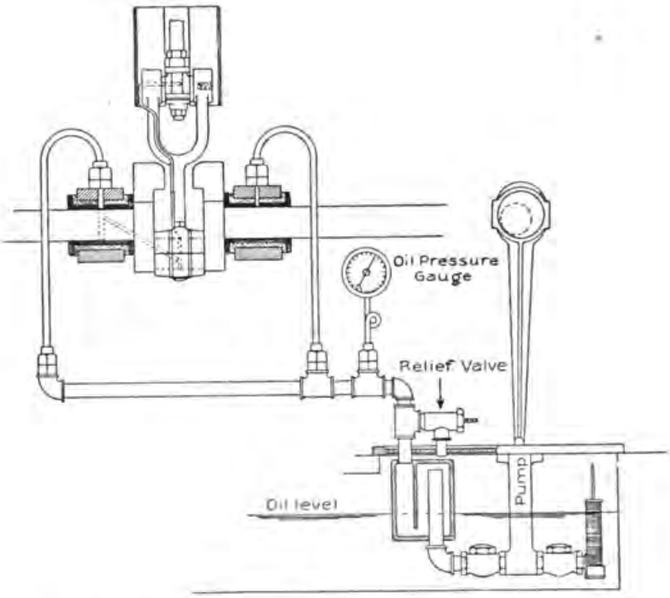
DIRECT CONNECTED GENERATING SETS WITH SINGLE CYLINDER ENGINES HAVING FORCED SYSTEM OF LUBRICATION

* CLASSIFICATION Type Poles Kw. Speed	Volts Full Load	Amperes Full Load	Floor Space	Height	Weight Pounds	Diameter Steam Pipe	Diameter Exhaust Pipe	Diameter Cylinder	Stroke
MP 6- 7-550	110	64	50″ x 30″	50″	2100	1¼″	1½″	5 ″	4½″
MP 6-10-450	110	91	54″ x 34″	57″	3075	1½″	2 ″	6½″	5 ″
MP 6-15-400	110	136	68″ x 38″	64″	4600	2 ″	2½″	8 ″	6 ″
MP 6-20-360	125	160	71″ x 46″	72″	6600	2½″	3 ″	9 ″	7 ″
MP 6-30-305	125	240	85″ x 50″	85″	9700	3 ″	3½″	11 ″	8 ″
MP 6-50-280	125	400	97″ x 55″	99″	13700	3½″	4 ″	12 ″	11 ″

* Based on 80 lbs. steam pressure, non-condensing, except MP 6-50-280 which is designed for 100 lbs. Sets may be operated on any pressure up to 125 lbs., condensing or non-condensing, but cannot readily be adapted for lower pressures than 80 lbs.
Sets wound for 220 or 250 volts can be furnished if required.

the column to give access to the stuffing boxes when the engine is in operation and to prevent water from mixing with the oil.

The general construction of these engines is in other respects similar to that of the standard single cylinder type, but the special features necessarily increase their cost and lengthen the time of delivery.



LUBRICATING MECHANISM FOR FORCED LUBRICATION AND TANDEM COMPOUND ENGINES

DIRECT CONNECTED GENERATING SETS WITH SINGLE CYLINDER ENGINES HAVING FORCED SYSTEM OF LUBRICATION

*Classification Type Poles Kw. Speed	Volts Full Load	Amperes Full Load	Floor Space	Height	Weight Pounds	Diameter Steam Pipe	Diameter Exhaust Pipe	Diameter Cylinder	Stroke
MP 6– 8.5 –550	110	77.5	50″ x 30″	50″	2150	1¼″	1½″	5 ″	4½″
MP 6–12.5 –450	110	114	54″ x 34″	57″	3150	1½″	2 ″	6½″	5 ″
MP 6–17.5 –400	110	160	68″ x 38″	64″	4650	2 ″	2½″	8 ″	6 ″
MP 6–25 –360	125	200	71″ x 46″	74″	6700	2½″	3 ″	9 ″	7 ″
MP 6–35 –305	125	280	85″ x 50″	85″	9800	3 ″	3½″	11 ″	11 ″
MP 6–40 –305	125	320	85″ x 50″	85″	9900	3 ″	3½″	11 ″	8 ″
MP 6–60 –280	125	480	97″ x 55″	99″	14400	3½″	4 ″	12 ″	11 ″

* Based on 100 lbs. steam pressure, non-condensing. All sets may be operated on any pressure up to 125 lbs., condensing or non-condensing, but cannot readily be adapted for lower pressures than 100 lbs.

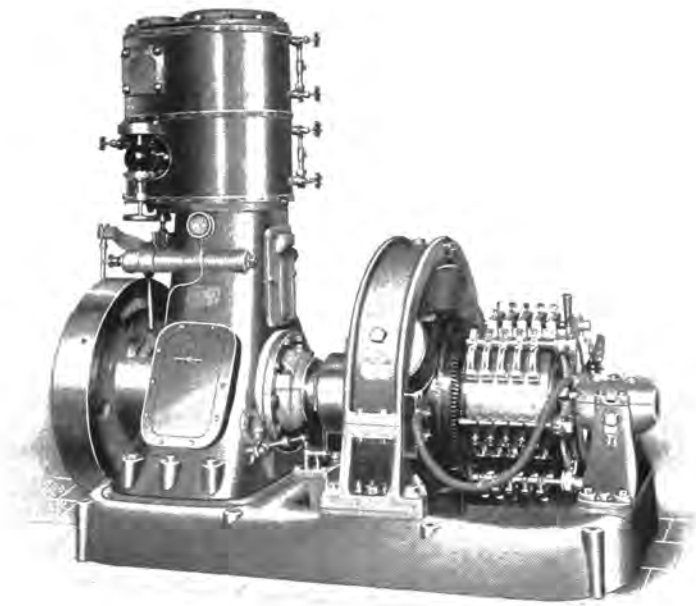
TANDEM COMPOUND ENGINES

Where high pressure steam is available and economy of operation is an essential consideration, the sets with tandem compound engines are recommended on account of their high efficiency. The general construction of these sets is the same as that of the single cylinder type and they present the same desirable features, viz., simplicity, compactness, stability and durability. All the bearings are oiled automatically under pressure, so that the labor is reduced to a minimum and perfect lubrication is insured at all times.

The ratings of the tandem compound sets are based on 125 lbs. steam pressure, condensing, or 140 lbs., non-condensing, but they may be operated on any pressure up to 160 lbs., condensing or non-condensing.

EXTRA PARTS

With each generating set the following accessories are supplied: one throttle valve, one nickel-plated cylinder lubricator, one set of case-hardened steel wrenches and eyebolts, and one set of soft packing, and where necessary one self-detachable starting bar.



TANDEM COMPOUND GENERATING SET

DIRECT CONNECTED GENERATING SETS WITH TANDEM COMPOUND ENGINES

Classification: Type Poles Kw. Speed	Volts Full Load	Amperes Full Load	Floor Space	Height	Weight Pounds	Diameter Steam Pipe	Diameter Exhaust Pipe	Diameter Cylinders	Stroke
MP 6–25–450	125	200	73″ x 46″	65″	6000	2 ″	3 ″	6½″–10½″	5″
MP 6–35–400	125	280	88″ x 51″	76″	8000	2 ″	3½″	7½″–12½″	6″
MP 6–50–400	125	400	89″ x 54″	85″	10300	2½″	4 ″	9½″–15 ″	6″
MP 6–75–310	125	600	102″ x 60″	95″	15500	3 ″	5 ″	10½″–18 ″	8″

GENERATOR

Frame

Generators for the single cylinder sets have magnet frames of good quality iron, cast in one piece, with the exception of the 50 kw. size, which is split horizontally.

Generator frames for the tandem compound sets are of cast steel and all sizes split horizontally. These generators are mounted on an extension of the engine base which is carefully machined to allow direct connection.

The pole pieces are of soft steel cast in one piece and securely bolted to the frame.

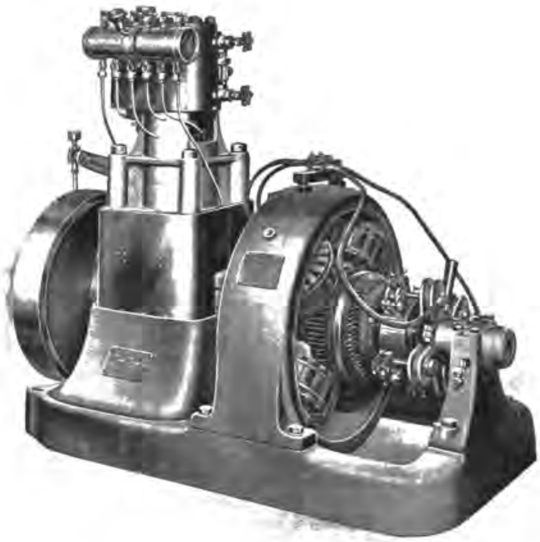
Armature

The armature is of standard construction, using an iron spider and a core built up of sheet iron laminations. Metal space blocks used in the assembly provide ventilating ducts, which carry away the heat generated in the armature body and coils.

The armature conductors are hard drawn copper of high conductivity, shaped on standard forms and carefully insulated before being placed in the armature slots. The insulating materials used are moisture proof, and are built to stand a severe high potential test.

Commutator

The commutator is assembled on an extension of the armature spider or is mounted directly on the shaft and is well ventilated to insure cool running. The copper and mica are of the same high grade and uniform quality used in all General Electric machines, securing the even wearing surface necessary for perfect commutation.



4 KILOWATT SET

Compounding

Armatures are wound for either 110 or 125 volts and series windings on the field spools will allow for any degree of compounding up to 10 per cent. This is effected by the use of a German silver shunt connected across the field terminals. An allowance of two per cent drop in speed in the engine is made to give correct compounding.

Field Coil

The field coils are of the round pattern wound on suitable forms and protected from the metal parts by insulating boards. Space blocks inserted in the coil winding provide sufficient ventilation to insure low running temperature.

FIELD COIL

Brush Rigging

Standard CS brush-holders are used, arranged for individual spring adjustment. The brushes can thus be easily removed for inspection and returned without altering the brush tension. The brush-holder yoke carrying the studs is supported from the bearing (except the 50 kw. which is supported from the magnet frame), and may be made fast in the proper position by a suitable set screw.

BRUSH-HOLDER

Outboard Bearing

In all sizes the outboard bearing, which is securely bolted to the engine bed-plate, is of the self-aligning, self-oiling type. A continual supply of oil is taken from the oil cellar by revolving rings and distributed by the action of the revolving shaft toward the

ARMATURE

center and ends of the bearing. It is there collected and returned to the cellar, where it has time to settle and cool.

Temperatures

These generators will operate continuously under full rated load with a temperature rise not exceeding 40° C. on any part of the machine except the commutator which will not exceed 45° C. On a one hour overload the

OUTBOARD BEARING

temperature rise will not exceed 55° C. An overload of 50 per cent will be carried momentarily without injurious heating.

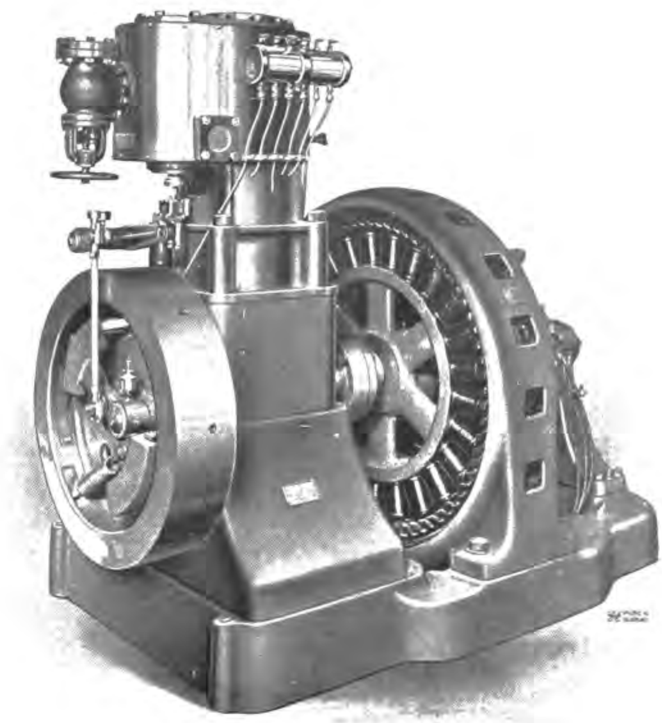
SINGLE CYLINDER ENGINE WITH ALTERNATING CURRENT GENERATORS

For isolated plants and central stations a small alternating current unit is often required to permit shutting down the main generating units during the hours of light load. This need is most satisfactorily met by a direct connected alternating current generating set of the type illustrated on this page. These sets are complete with exciter carried on the generator shaft and can be furnished on special order to meet the customer's requirements as to voltage and frequency and in capacities up to 60 kw.

The stationary armature of this generator is mounted on the extended engine base, an arrangement similar to the direct current sets.

The windings of both armature and field are especially suited to the character of work which this machine is likely to encounter, being moisture proof and well ventilated. The revolving field coils are of standard construction well suited to operation in engine rooms, and so wound that the greatest possible heat radiating surface is exposed.

Standard heating guarantees apply to these machines, the temperature rise with continuous full load being 40° C. With a 25 per cent overload for two hours the temperature rise will not exceed 55° C.



A.C. GENERATING SET

General Electric Company

Schenectady, N.Y.

LIGHTING DEPARTMENT

December, 1910 **Bulletin No. 4807*

SMALL PLANT ALTERNATING CURRENT SWITCHBOARD PANELS

76 inches high—For controlling *one* generator, *one* exciter and *one* or *two* feeders.

90 inches high—For controlling *one* generator, *one* exciter, *one* or *two* feeders and *one* constant current transformer.

Front View

Rear View

Three-Phase Panel, 76 Inches High, for Controlling One Feeder Circuit

GENERAL INFORMATION

These panels are designed for use in small or isolated plants containing but one generator, and are not equipped with buses, generator switch or any synchronizing devices. The panels are, therefore, unsuitable for the parallel operation of generators or for installation in a switchboard consisting of two or more panels.

Two classes of panels are catalogued (1) 76 inches high, (2) 90 inches high, the 90 inch panels having the same equipment as the 76 inch panels except for the addition of the necessary apparatus for controlling a constant current transformer with single circuit secondary.

The 90 inch panels are listed for controlling 25

NOTE.—The data in this publication are for the convenience of customers, and every effort is made to avoid error, but this Company does not guarantee their correctness, nor does it hold itself responsible for any errors or omissions in this publication. Subject to change without notice.

**Supersedes Bulletin 4711.*

and 35 light constant current transformers. The 35 light panels may be used without change in price for controlling a **50 light** transformer with single secondary, the only change being an increase in the capacity of the primary fuses.

VOLTAGE

All 76 inch panels are suitable for either 1150 or 2300 volts. The 90 inch panels are listed for 2300 volts only but may be used without change in price for controlling 1150 volt generators, the only change of equipment being in the capacity of the primary fuses for the constant current transformer. As the ampere capacity of the panels remains the same, the kilowatt rating will be reduced one-half when an 1150 volt generator is used.

FREQUENCY

Unless otherwise ordered all panels will be furnished with an equipment for 60 cycles. All panels may be used for any frequency from 60 to 125 cycles without change in price, but for frequencies less than 60 cycles a different potential transformer than that listed is required and an additional charge is made.

MATERIAL—FRAMEWORK—FINISH

All panels are blue Vermont marble 1½ inches thick with ⅜ inch bevel, and are furnished complete with a supporting framework of 1¼ inch pipe excepting that the pipe for wall braces is not included for the 90 inch panels. The framework for 76 inch panels is self supporting as shown in illustrations.

The instruments have General Electric Company's dull black finish while the supporting framework is black japanned.

CONNECTIONS

Each panel is furnished complete with necessary small wiring on the back of the panel and also with main connections of insulated wire between all apparatus comprising the equipment of the panel.

INSTRUMENT EQUIPMENT

Each panel is equipped with an ammeter in each phase of the generator, a voltmeter, and a receptacle and plug for transferring the voltmeter to any phase. The instrument equipments are, therefore, suitable for either balanced or unbalanced loads.

All ammeters are primary and are connected directly to the circuit excepting the ammeter on the 35 light arc circuit which is provided with a current transformer for insulating purposes.

The ammeters on the arc circuits have movable markers which can be set at the requisite current value so that any deviation of the current may be readily detected.

SWITCH EQUIPMENTS

Three-phase and two-phase panels are equipped with triple-pole and four-pole feeder switches respectively. These switches can be used for controlling either polyphase or two single-phase feeder circuits.

On the 90 inch panels the primary plug switches consist of the General Electric Company's standard plug switch and tubular expulsion fuse combined into a single unit, the fuses being of such capacity as to rupture the circuit only under emergency conditions equivalent to a short circuit in the transformer. The open circuiting secondary plug switches are for the purpose of disconnecting the line from the secondary of the transformer when testing for ground or open circuit.

The K-5 oil switch which has been specified under the equipment of all panels listed herein is a new switch recently developed and will shortly supersede the K-3. However, the full line of K-5 switches is not in production at the present time and the General Electric Company reserves the privilege of substituting, without notice, K-3 switches on orders which are received for any of these panels before the K-5 switch specified is in production.

RATINGS

The ampere ratings of all panels are the maximum currents which they are designed to carry for one or two hours, the corresponding kilowatt ratings being the normal capacity of the largest machines with which the panels may be used. Kilowatt ratings are based on unity power factor and on overloads of 25 per cent for one or two hours and 65 per cent momentarily. For overloads of 50 per cent for one or two hours and 100 per cent momentarily multiply the normal kilowatt rating of the generator by 1.2 and select a panel having a kilowatt rating at least equal to the product thus obtained.

For panels containing only one feeder switch the capacity of the feeder is equal to that of the generator. For panels containing two feeder switches each feeder has a capacity slightly in excess of half the generator capacity. If desired, these capacities can be modified without additional charge, the maximum allowable capacity being 150 amperes.

RHEOSTAT MECHANISM

Panels are listed:

(1) with mechanism for the exciter rheostat only and

(2) with mechanism for both generator and exciter rheostats.

It is not recommended that panels with mechanism for exciter rheostat only be used for units of greater than 200 kw. capacity.

The exciter rheostat supports are designed for mounting the rheostat directly behind the panel, and are adjustable both vertically and horizontally, thus allowing a considerable range in the dimensions of the rheostat. The panels, however, cannot be modified to meet special dimensions for rheostats not manufactured by the General Electric Company, without an additional charge being made.

Generator field rheostats designed for chain and sprocket control must always be used in connection with these panels.

DIAGRAMS OF CONNECTIONS

Dotted Sections Apply Only to 90 Inch Panels

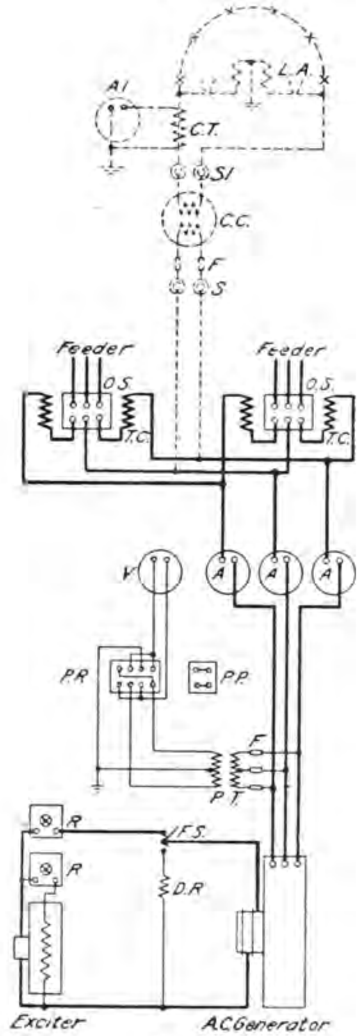


Fig. 1

Three-Phase

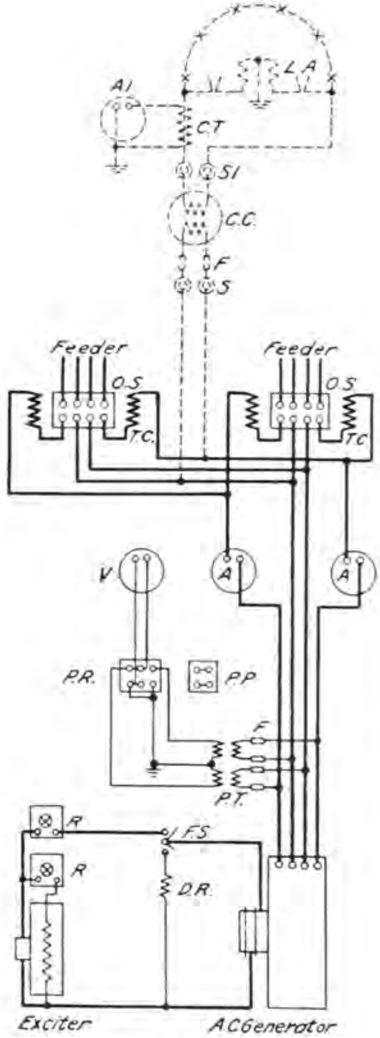


Fig. 2

Two-Phase

KEY TO SYMBOLS

A and A1 = Ammeter.
C.C. = Constant current transformer.
C.T. = Current transformer (not furnished for 25 lights).
D.R. = Discharge resistance.
F = Fuse.
F.S. = Field switch.
L.A. = Lightning arrester.
O.S. = Oil switch.
P.P. = Potential plug.
P.R. = Potential receptacle.
P.T. = Potential transformer.
R = Rheostat.
S and S1 = Plug switch.
T.C. = Oil switch trip coil.
V = Voltmeter.

THREE-PHASE PANELS—76 INCHES HIGH

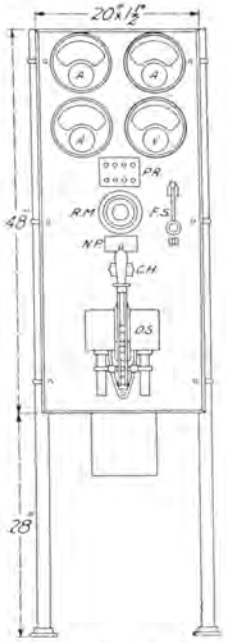


Fig. 1

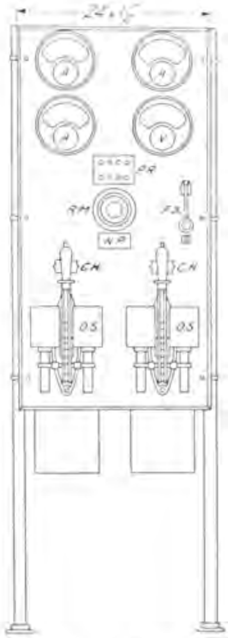


Fig. 2

EQUIPMENT

A = *Three*. . . amp. Type R6 ammeters.

V = 175 volt Type R6 voltmeter.

P.R. = 8 point potential receptacle with *one* 4 point plug.

R.M. = Concentric mechanism (for generator and exciter rheostats) or hand-wheel and mounting (for exciter rheostat only).

F.S. = S.P.S.T. 250 volt 200 amp. field switch with discharge clips (discharge resistance is not included).

N.P. = Name plate.

C.H. = *One* or *two* cardholders.

O.S. = *One* or *two* T.P.S.T. 200 amp. automatic K5 oil switches mounted on back of panel, with double series trip coil operating mechanism.

Two—50 watt 2200-1100/110 volt 60/125 cycle potential transformers and fuses.

No buses or bus supports are furnished.

KW. OF GENERATOR		AMPERE CAPACITY			CAT. NO. 1150 OR 2300 VOLTS 60 CYCLES*	
1150 Volts	2300 Volts	Panel	Each Feeder	Ammeters	With Mechanism for Exciter Rheostat Only	With Concentric Rheostat Mechanism
PANELS FIG. 1—FOR ONE FEEDER CIRCUIT						
20	40	12	12	15	104013	104019
26.5	53	16	16	20	104014	104020
40	80	25	25	30	104015	104021
53	105	30	30	40	104016	104022
80	160	50	50	60	104017	104023
105	210	65	65	80	104018	104024
130	265	80	80	100	......	104025
200	400	125	125	150	......	104026
265	530	160	160	200	......	104027
PANELS FIG. 2—FOR TWO FEEDER CIRCUITS						
20	40	12	8	15	104028	104034
26.5	53	16	10	20	104029	104035
40	80	25	15	30	104030	104036
53	105	30	20	40	104031	104037
80	160	50	30	60	104032	104038
105	210	65	40	80	104033	104039
130	265	80	50	100	......	104040
200	400	125	80	150	......	104041
265	530	160	100	200	......	104042

*Panels, with slight changes, may be used for frequencies other than 60 cycles. See General Information.

TWO-PHASE PANELS—76 INCHES HIGH

EQUIPMENT

A = *Two*. . . .amp. Type R6 ammeters.

V = 175 volt Type R6 voltmeter.

P.R. = 6 point potential receptacle with *one* 4 point plug.

R.M. = Concentric mechanism (for generator and exciter rheostats) or handwheel and mounting (for exciter rheostat only).

F.S. = S.P.S.T. 250 volt 200 amp. field switch with discharge clips (discharge resistance is not included).

N.P. = Name plate.

C.H. = *One* or *two* cardholders.

O.S. = *One* or *two* 4 P.S.T. 200 amp. automatic K5 oil switches mounted on back of panel, with double series trip coil operating mechanism.

Two—50 watt 2200-1100/110 volt 60/125 cycle potential transformers and fuses.

No buses or bus supports are furnished.

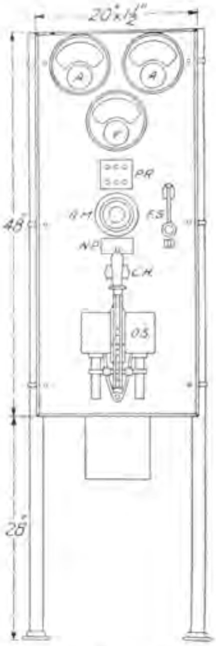


Fig. 1

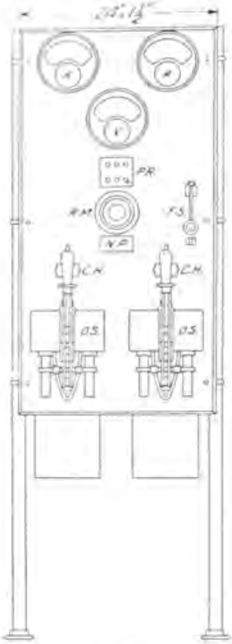


Fig. 2

KW. OF GENERATOR		AMPERE CAPACITY			CAT. NO. 1150 AND 2300 VOLTS 60 CYCLES*	
1150 Volts	2300 Volts	Panel	Each Feeder	Ammeters	With Mechanism for Exciter Rheostat Only	With Concentric Rheostat Mechanism
PANELS FIG. 1—FOR ONE FEEDER CIRCUIT						
22.5	45	12	12	15	104043	104049
30	60	16	16	20	104044	104050
45	90	25	25	30	104045	104051
60	120	30	30	40	104046	104052
90	180	50	50	60	104047	104053
120	240	65	65	80	104048	104054
150	305	80	80	100	......	104055
230	460	125	125	150	......	104056
305	610	160	160	200	......	104057
PANELS FIG. 2—FOR TWO FEEDER CIRCUITS						
22.5	45	12	8	15	104058	104064
30	60	16	10	20	104059	104065
45	90	25	15	30	104060	104066
60	120	30	20	40	104061	104067
90	180	50	30	60	104062	104068
120	240	65	40	80	104063	104069
150	305	80	50	100	......	104070
230	460	125	80	150	......	104071
305	610	160	100	200	......	104072

*Panels, with slight changes, may be used for frequencies other than 60 cycles. See General Information.

THREE-PHASE PANELS—90 INCHES HIGH

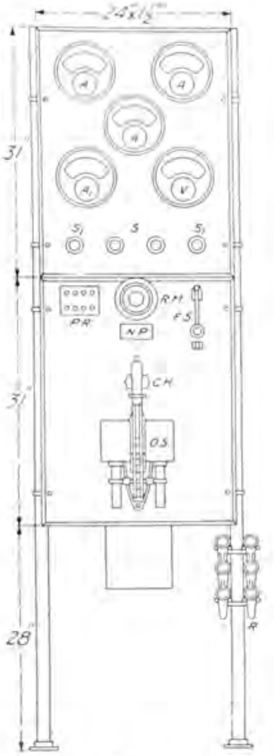


Fig. 1

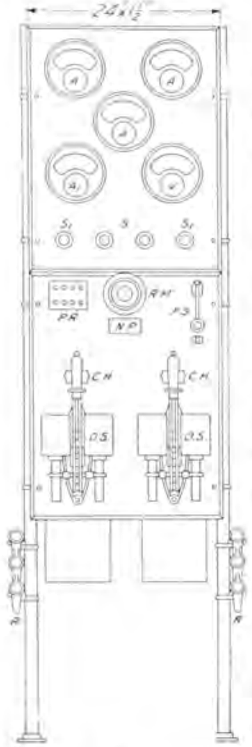


Fig. 2

EQUIPMENT

A = *Three* . . . amp. Type R6 ammeters.

A1 = 10 amp. Type R6 ammeter with movable marker.

V = 175 volt Type R6 voltmeter.

S = *Two* S.P.S.T. 2500 volt primary plug switches with plugs and fuses.

S1 = *Two* S.P. open circuiting secondary plug switches with plugs.

P.R. = 8 point potential receptacle with *one* 4 point plug.

R.M. = Concentric mechanism (for generator and exciter rheostats) or hand-wheel and mounting (for exciter rheostat only).

F.S. = S.P.S.T. 250 volt 200 amp. field switch with discharge clips (discharge resistance is not included).

N.P. = Name plate.

C.H. = *One* or *two* cardholders.

O.S. = *One* or *two* T.P.S.T. 200 amp. automatic K5 oil switches mounted on back of panel, with double series trip coil operating mechanism.

R = *Two* plug racks each for *three* plugs.

Two—50 watt 2200-1100/110 volt 60/125 cycle potential transformers and fuses.

One—Current transformer ratio 1:1 for **A1** (not furnished with 25 light panels).

No buses or bus supports are furnished.

Kw. of Gen. 2300 Volts	Ampere Capacity			Cat. No. 2300 Volts 60 Cycles*			
				With Mechanism for Exciter Rheostat Only		With Concentric Rheostat Mechanism	
	Panel	Each Feeder	Ammeters A	25 Lights	*35 Lights	25 Lights	*35 Lights
PANELS FIG. 1—FOR ONE FEEDER CIRCUIT AND ONE ARC CIRCUIT							
40	12	12	15	104073	104088	104079	104094
53	16	16	20	104074	104089	104080	104095
80	25	25	30	104075	104090	104081	104096
105	30	30	40	104076	104091	104082	104097
160	50	50	60	104077	104092	104083	104098
210	65	65	80	104078	104093	104084	104099
265	80	80	100	......	......	104085	104100
400	125	125	150	......	......	104086	104101
530	160	160	200	......	......	104087	104102
PANELS FIG. 2—FOR TWO FEEDER CIRCUITS AND ONE ARC CIRCUIT							
40	12	8	15	104103	104118	104109	104124
53	16	10	20	104104	104119	104110	104125
80	25	15	30	104105	104120	104111	104126
105	30	20	40	104106	104121	104112	104127
160	50	30	60	104107	104122	104113	104128
210	65	40	80	104108	104123	104114	104129
265	80	50	100	......	......	104115	104130
400	125	80	150	......	......	104116	104131
530	160	100	200	......	......	104117	104132

Panels are interchangeable for constant current transformers with 6.6 or 7.5 amp. secondaries.

*Panels, with slight changes, may be used for 1150 volts, for frequencies other than 60 cycles, and for 50 light single secondary constant current transformers. See General Information.

TWO-PHASE PANELS—90 INCHES HIGH

EQUIPMENT

A = *Two* . . . amp. Type R6 ammeters.

A1 = 10 amp. Type R6 ammeter with movable marker.

V = 175 volt Type R6 voltmeter.

S = *Two* S.P.S.T. 2500 volt primary plug switches with plugs and fuses.

S1 = *Two* S.P. open circuiting secondary plug switches with plugs.

P.R. = 6 point potential receptacle with *one* 4 point plug.

R.M. = Concentric mechanism (for generator and exciter rheostat) or handwheel and mounting (for exciter rheostat only).

F.S. = S.P.S.T. 250 volt 200 amp. field switch with discharge clips (discharge resistance is not included).

N.P. = Name plate

C.H. = *One* or *two* cardholders.

O.S. = *One* or *two* 4 P.S.T. 200 amp. automatic K5 oil switches mounted on back of panel, with double series trip coil operating mechanism.

R = *Two* plug racks each for three plugs.

Two—50 watt 2200-1100/110 volt 60/125 cycle potential transformers and fuses.

One—Current transformer ratio 1:1 for **A1** (not furnished for 25 light panels).

No buses or bus supports are furnished.

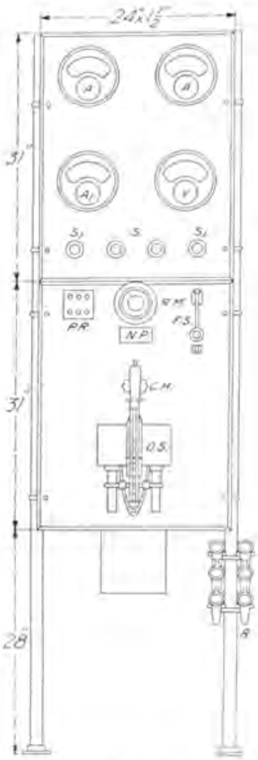


Fig. 1

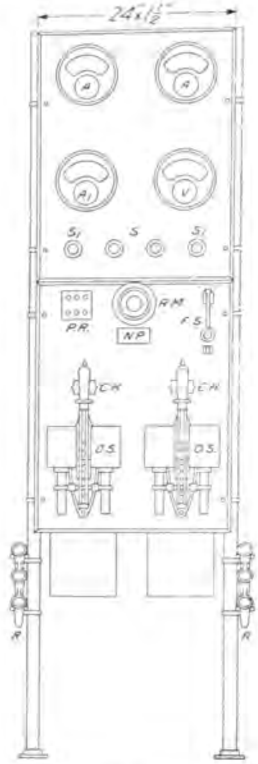


Fig. 2

Kw. of Gen. 2300 Volts	AMPERE CAPACITY			CAT. NO. 2300 VOLTS 60 CYCLES*			
				With Mechanism for Exciter Rheostat Only		With Concentric Rheostat Mechanism	
	Panel	Each Feeder	Ammeters A	25 Lights	*35 Lights	25 Lights	*35 Lights
PANELS FIG. 1—FOR ONE FEEDER CIRCUIT AND ONE ARC CIRCUIT							
45	12	12	15	104133	104148	104139	104154
60	16	16	20	104134	104149	104140	104155
90	25	25	30	104135	104150	104141	104156
120	30	30	40	104136	104151	104142	104157
180	50	50	60	104137	104152	104143	104158
240	65	65	80	104138	104153	104144	104159
305	80	80	100	......	......	104145	104160
460	125	125	150	......	......	104146	104161
610	160	160	200	......	......	104147	104162
PANELS FIG. 2—FOR TWO FEEDER CIRCUITS AND ONE ARC CIRCUIT							
45	12	8	15	104163	104178	104169	104184
60	16	10	20	104164	104179	104170	104185
90	25	15	30	104165	104180	104171	104186
120	30	20	40	104166	104181	104172	104187
180	50	30	60	104167	104182	104173	104188
240	65	40	80	104168	104183	104174	104189
305	80	50	100	......	......	104175	104190
460	125	80	150	......	......	104176	104191
610	160	100	200	......	......	104177	104192

Panels are interchangeable for constant current transformers with 6.6 or 7.5 amp. secondaries.

*Panels, with slight changes, may be used for 1150 volts, for frequencies other than 60 cycles, and for 50 light single secondary constant current transformers. See General Information.

GENERAL ELECTRIC COMPANY

PRINCIPAL OFFICES, SCHENECTADY, N. Y.

SALES OFFICES

(Address nearest office)

BOSTON, MASS.	84 State Street
NEW YORK, N. Y.	30 Church Street
Syracuse, N. Y.	Post-Standard Building
Buffalo, N. Y.	Ellicott Square Building
New Haven, Conn.	Malley Building
PHILADELPHIA, PA.	Witherspoon Building
Baltimore, Md.	Electrical Building
Charlotte, N. C.	Trust Building
Charleston, W. Va.	Charleston National Bank Building
Erie, Pa.	632 State Street
Pittsburg, Pa.	Park Building
Richmond, Va.	712 Mutual Building
Roanoke, Va.	Strickland Building
ATLANTA, GA.	Empire Building
Birmingham, Ala.	Brown-Marx Building
Macon, Ga.	Grand Building
New Orleans, La.	Maison-Blanche Building
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Columbus, Ohio	Columbus Savings & Trust Building
Cleveland, Ohio	Citizens Building
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Memphis, Tenn.	Randolph Building
Nashville, Tenn.	Stahlman Building
Indianapolis, Ind.	Traction Terminal Building
CHICAGO, ILL.	Monadnock Building
Detroit, Mich.	Majestic Building (Office of Soliciting Agent)
St. Louis, Mo.	Wainwright Building
Kansas City, Mo.	Dwight Building
Butte, Montana	Phœnix Building
Minneapolis, Minn.	410-412 Third Ave., North
DENVER, COLO.	First National Bank Building
Salt Lake City, Utah	Newhouse Building
SAN FRANCISCO, CAL.	Union Trust Building
Los Angeles, Cal.	124 West Fourth Street
Portland, Ore.	Electric Building
Seattle, Wash.	Colman Building
Spokane, Wash.	Paulsen Building

For TEXAS and OKLAHOMA Business refer to
General Electric Company of Texas,

Dallas, Tex.	Praetorian Building
El Paso, Tex.	Chamber of Commerce Building
Oklahoma City, Okla.	Insurance Building

FOREIGN

FOREIGN DEPARTMENT,
Schenectady, N. Y., and 30 Church St., New York, N. Y.
London Office, 83 Cannon St., London, E. C., England

General Electric Company
Schenectady, N.Y.
RAILWAY DEPARTMENT

December, 1910 — Copyright, 1910 by General Electric Company — *Bulletin No. 4808*

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

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 &

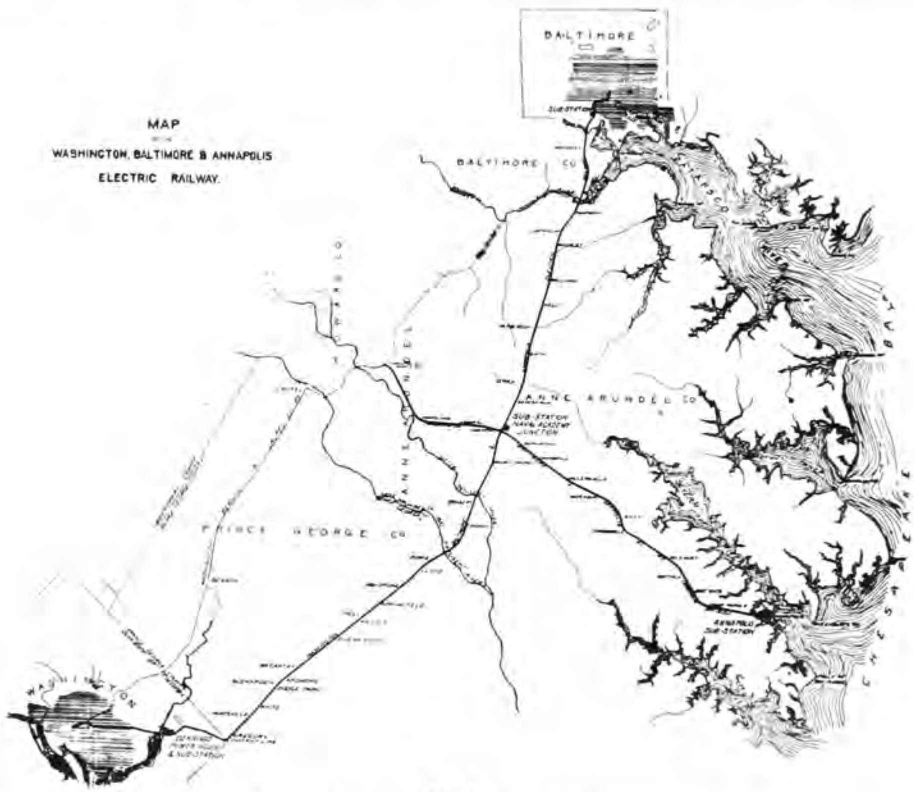


Fig. 1
MAP OF THE WASHINGTON, BALTIMORE & ANNAPOLIS RAILWAY

* Reprint of article by John R. Hewett in *General Electric Review*.

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 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.

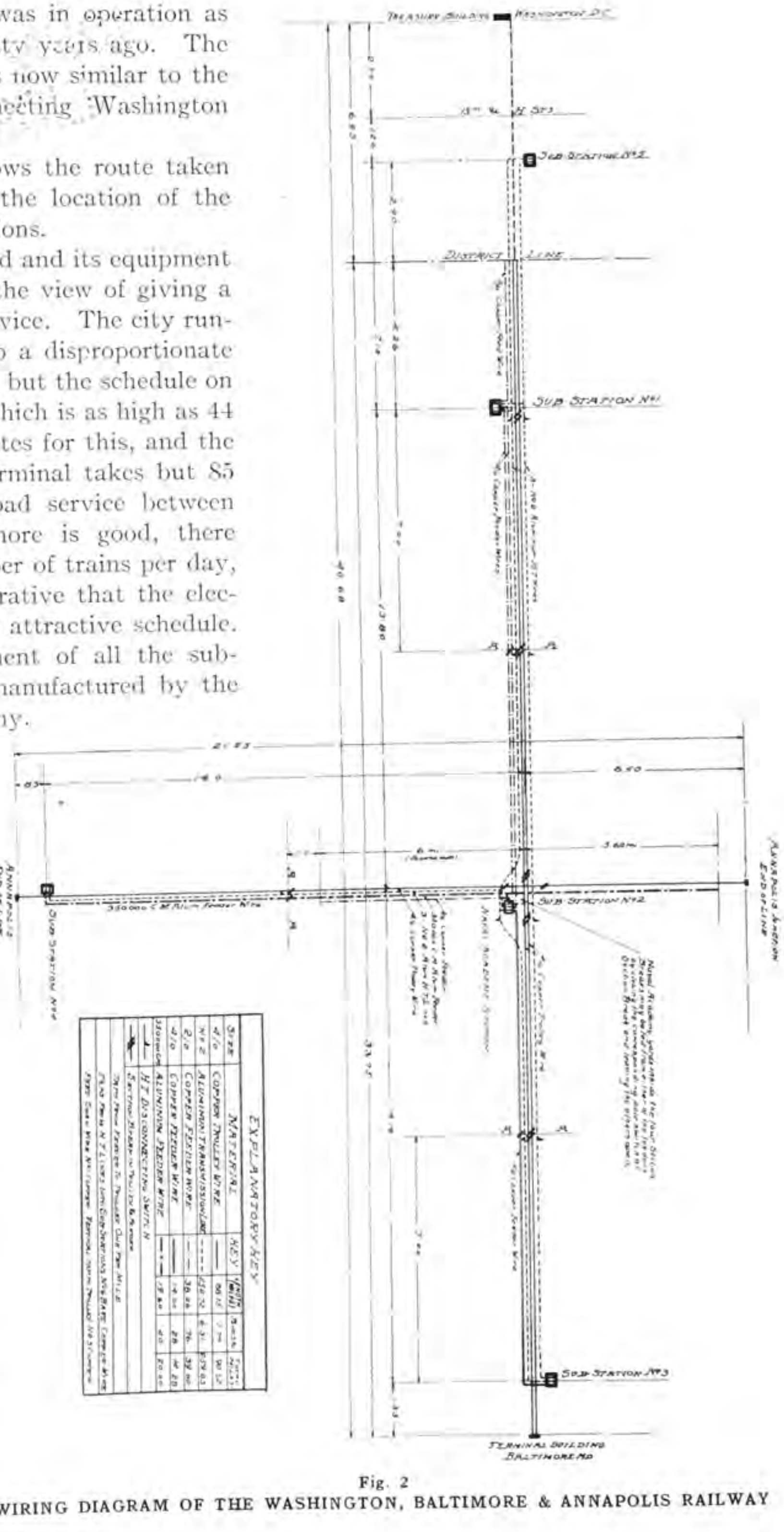


Fig. 2
WIRING DIAGRAM OF THE WASHINGTON, BALTIMORE & ANNAPOLIS RAILWAY

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.

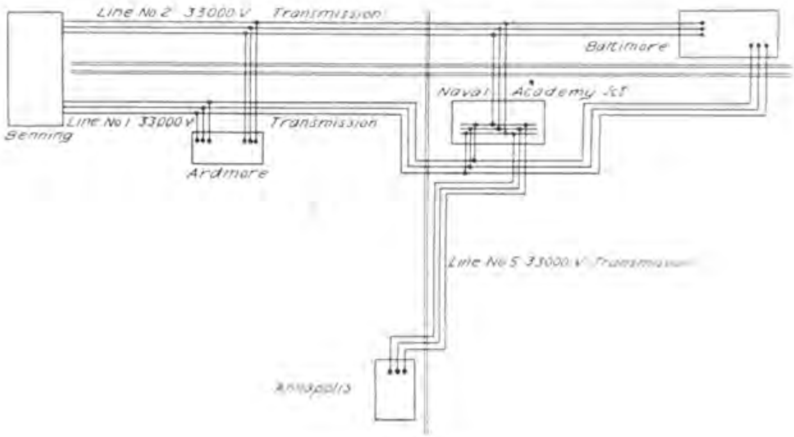


Fig. 3
DIAGRAM OF TRANSMISSION LINE

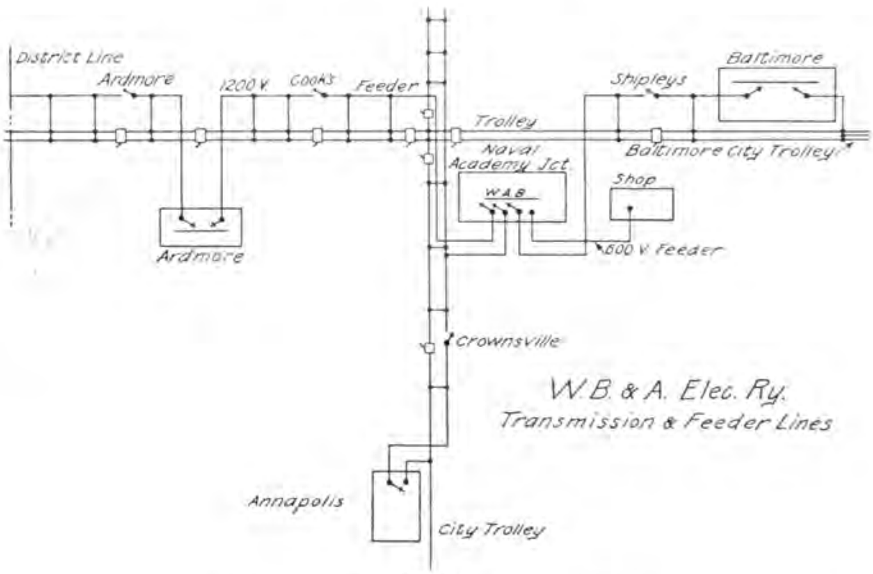


Fig. 4
DIAGRAM OF TROLLEY AND FEEDER LINES

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.

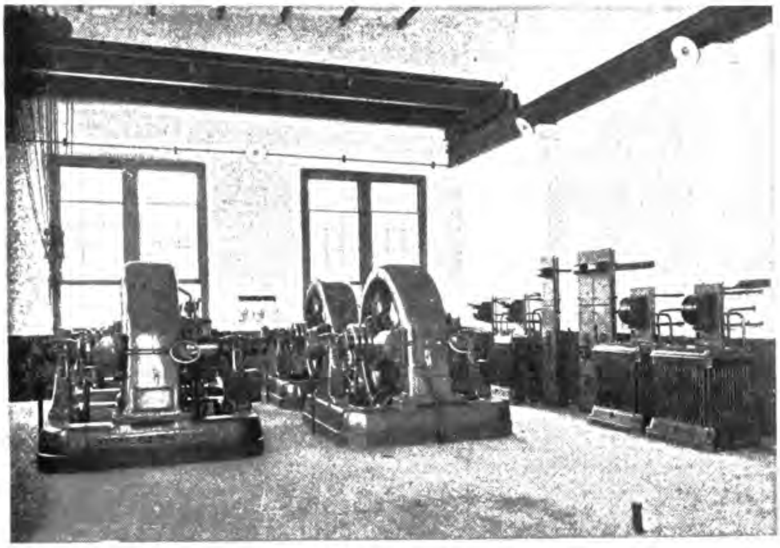


Fig. 5
MAIN SECTION, ARDMORE SUBSTATION

Ardmore Substation

The Ardmore substation is the only one which was 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, while Figs. 7 and 8 show respectively a section and plan of this substation.

Both of the 33,000 volt transmission lines are tapped into the Ardmore substation, and switching arrangements are provided to permit of either of the lines being used. 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.

The more important items of the equipment are as follows:

Four TC4-300-750-600/1200 volt compound wound rotary converters.
Four 45 kv-a. oil-cooled reactive coils.
Six H25-160-19,100/33,000 volt, "Y" 370/370 volt oil-cooled transformers.

The switchboard consists of the following:
Two 33,000 volt, three-phase incoming line panels.
Two 33,000 volt, 600 kw. rotary converter panels.
Two 33,000 volt aluminum cell lightning arresters.
Two 600 kw. 1200 volt d.c. converter panels.
Two 8 amp., 1200 volt d.c. feeder panels.
One 750/1200 volt, D2 voltmeter on swinging bracket.

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 barns and an air compressor for car barn use.

Both transmission lines are tapped into this substation and 1200 volt feeders extend from

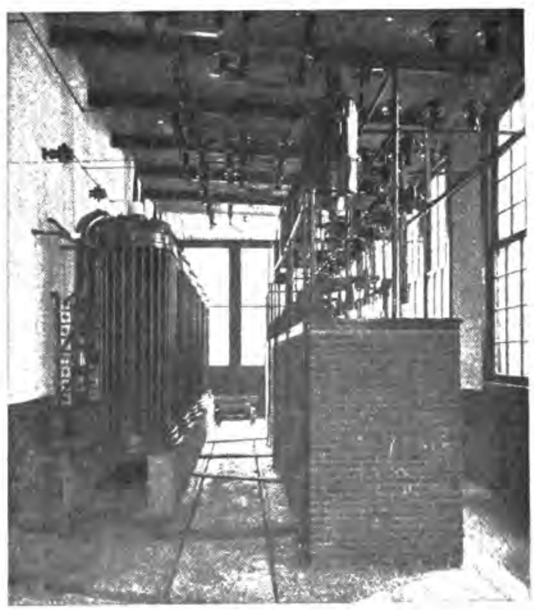


Fig. 6
HIGH TENSION COMPARTMENT, ARDMORE SUBSTATION

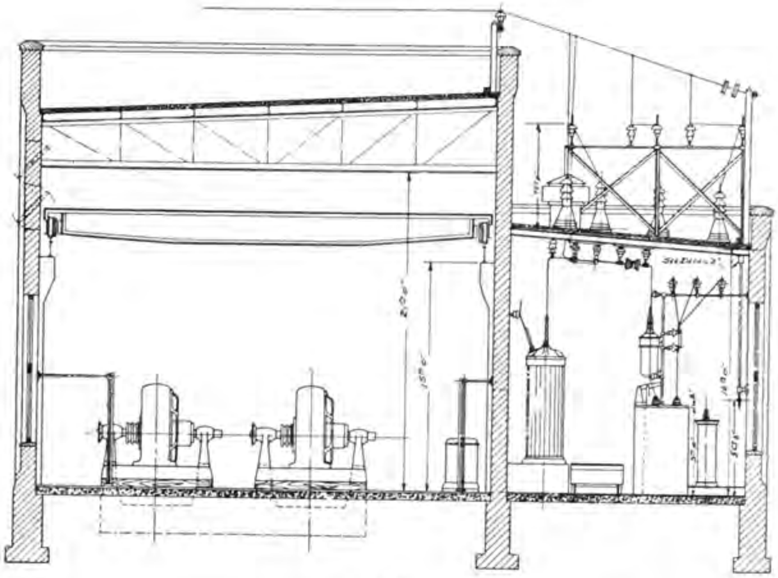


Fig. 7
TRANSVERSE SECTION, ARDMORE SUBSTATION

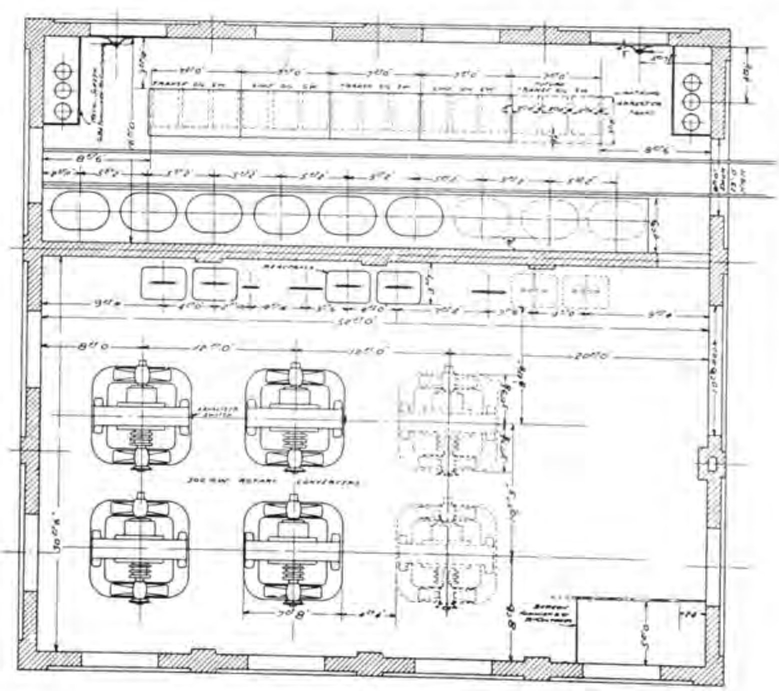


Fig. 8
PLAN, ARDMORE SUBSTATION

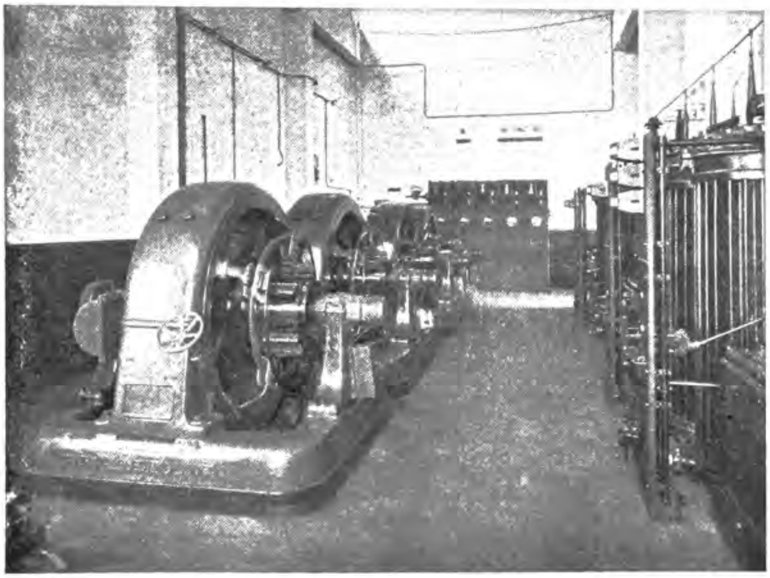


Fig. 9
MAIN SECTION, NAVAL ACADEMY STATION

it in the direction of Washington, Baltimore, Annapolis and Annapolis Junction.

Figs. 9 and 10 are interior views of the machine room and high tension compartment respectively. One of the rotary converters is not shown in Fig. 9. Fig. 11 is an exterior view of the substation, while Fig. 12 was taken on 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.

The more important items of equipment for this substation are:

Five TC4-300-750-600/1200 volt compound wound rotary converters.
Four 45 kv-a. oil-cooled reactive coils.
Seven H25-160-33,000 "Y" 370/370 volt oil-cooled transformers.

The switchboard consists of the following:

Two 33,000 volt incoming line panels.
One 33,000 volt, three-phase outgoing line panel.
Two 33,000 volt, 600 kw. a.c. rotary converter panels.
Three 33,000 volt aluminum cell lightning arresters.
Two 600 kw., 1200 volt d.c. rotary panels.
Three 1000 amp., 1200 volt d.c. feeder panels.
One 750/1200 volt D2 voltmeter on swinging bracket.

Figs. 13 and 14 show a transverse section and a plan of this substation.

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. 16. The illustration, Fig. 15, 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. 17.

The more important items of equipment are:

Four TC4-300-750-600/1200 volt compound wound rotary converters.

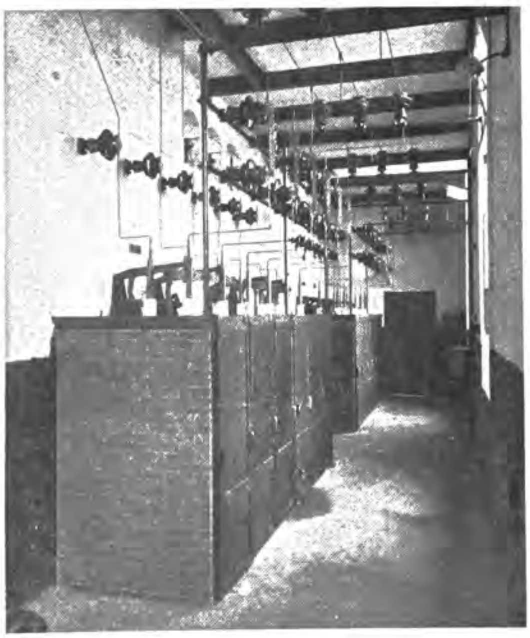


Fig. 10
HIGH TENSION COMPARTMENT, NAVAL ACADEMY SUBSTATION

Four 45 kv-a. oil-cooled reactive coils.
Six H25-160-33,000 "Y" 370/370 volt oil-cooled transformers.

The switchboard consists of the following:

Two 33,000 volt incoming line panels.
Two 33,000 volt, 600 kw. a.c. rotary converter panels.
Two 3000 volt aluminum cell lightning arresters.
Two 600 kw., 1200 volt d.c. rotary panels.
Two 800 amp., 1200 volt d.c. feeder panels.
One 750/1500 volt D2 voltmeter on swinging bracket.

Fig. 11
NAVAL ACADEMY SUBSTATION

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.

Substation Apparatus

All of the electrical apparatus in the substations was designed, manufactured and installed by the General Electric Company.

Fig. 12
HIGH TENSION WIRING ON ROOF OF NAVAL ACADEMY SUBSTATION

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 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.

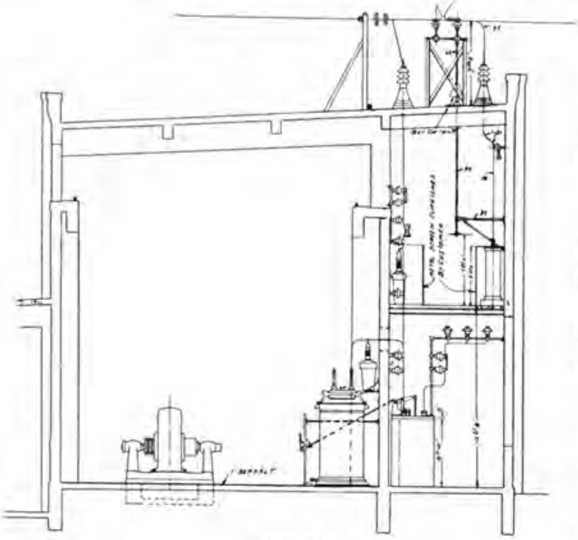


Fig. 13
TRANSVERSE SECTION, NAVAL ACADEMY JUNCTION SUBSTATION

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 graphite brushes employed on the alternating current side decrease the amount of 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.

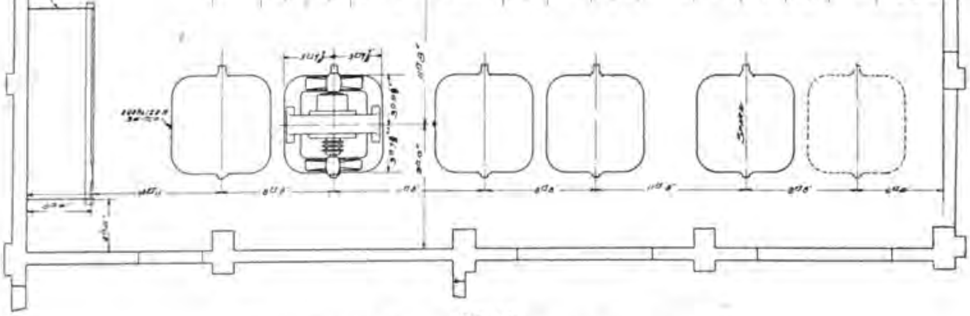


Fig. 14
PLAN, NAVAL ACADEMY JUNCTION SUBSTATION

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.

Type H units, 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.

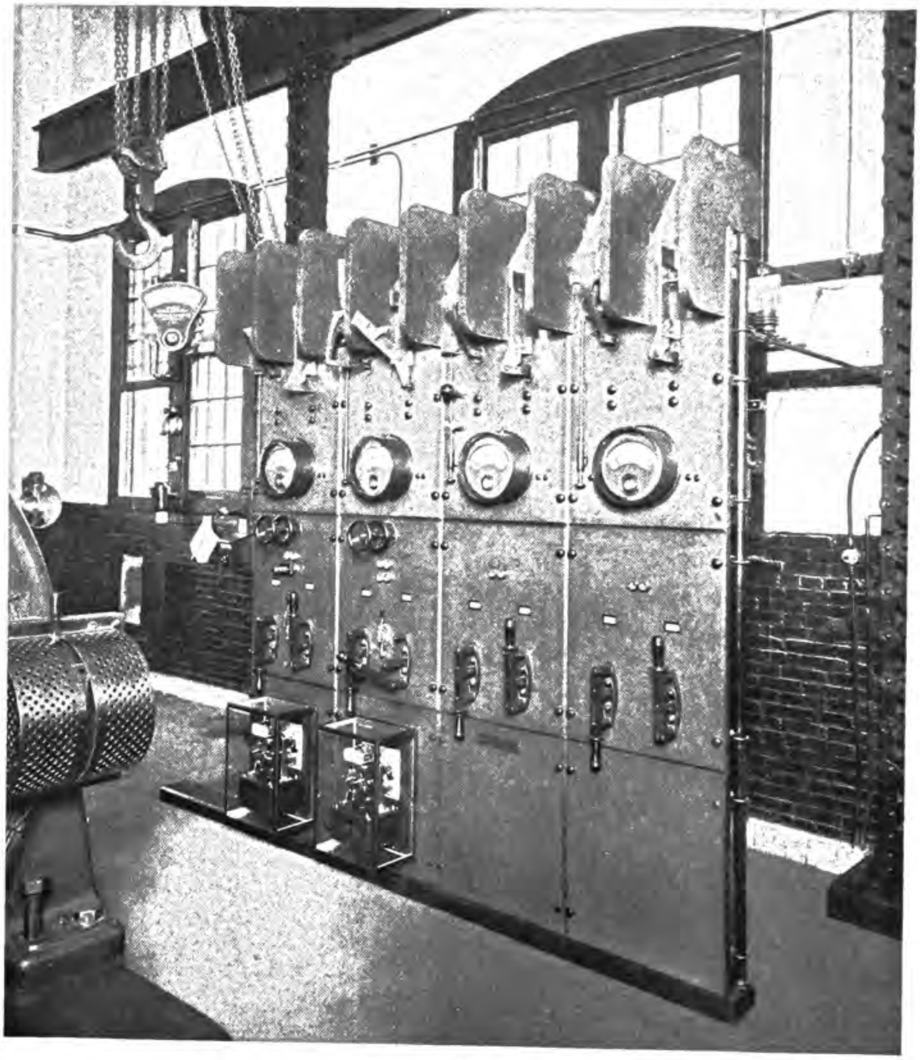


Fig. 15
1200 VOLT SWITCHBOARD IN THE BALTIMORE SUBSTATION

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.

The switching arrangements are of special interest, as the high tension direct current boards are of standard General Electric

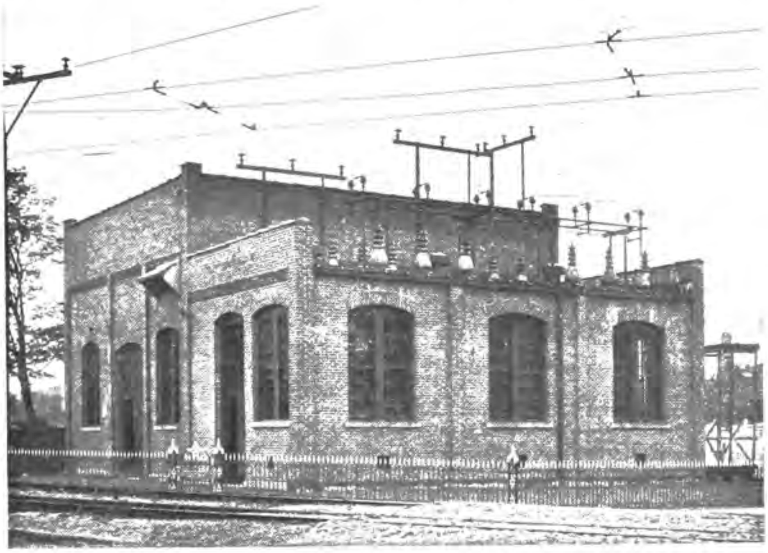


Fig. 16
BALTIMORE SUBSTATION

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, that of 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

design, specifically made for 1200 volt work, with two machines in series.

The direct current switchboard of the Baltimore substation is illustrated in Fig. 15. 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 contacts

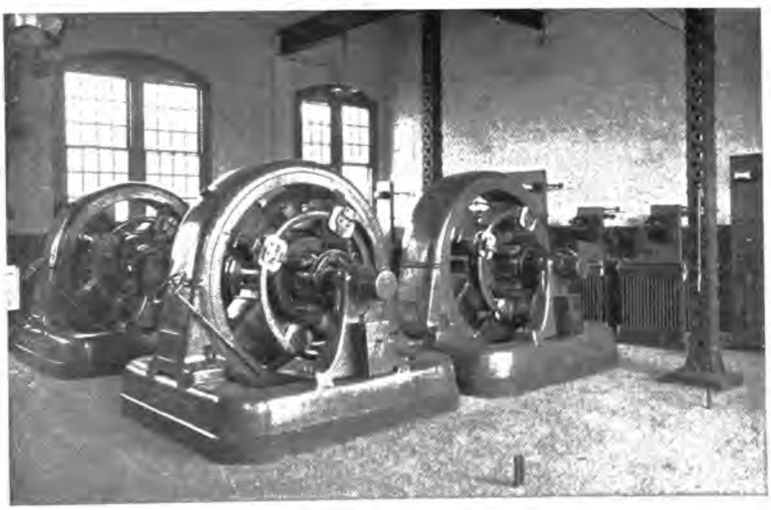


Fig. 17
INTERIOR OF BALTIMORE SUBSTATION

to operate on the tripping pin of the breaker.

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 1200 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 connected 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.

All the panels are made in three sections, 24 inches wide, the top section being 40 inches in height, the middle section 31 inches, and the bottom section 28 inches. All bolt

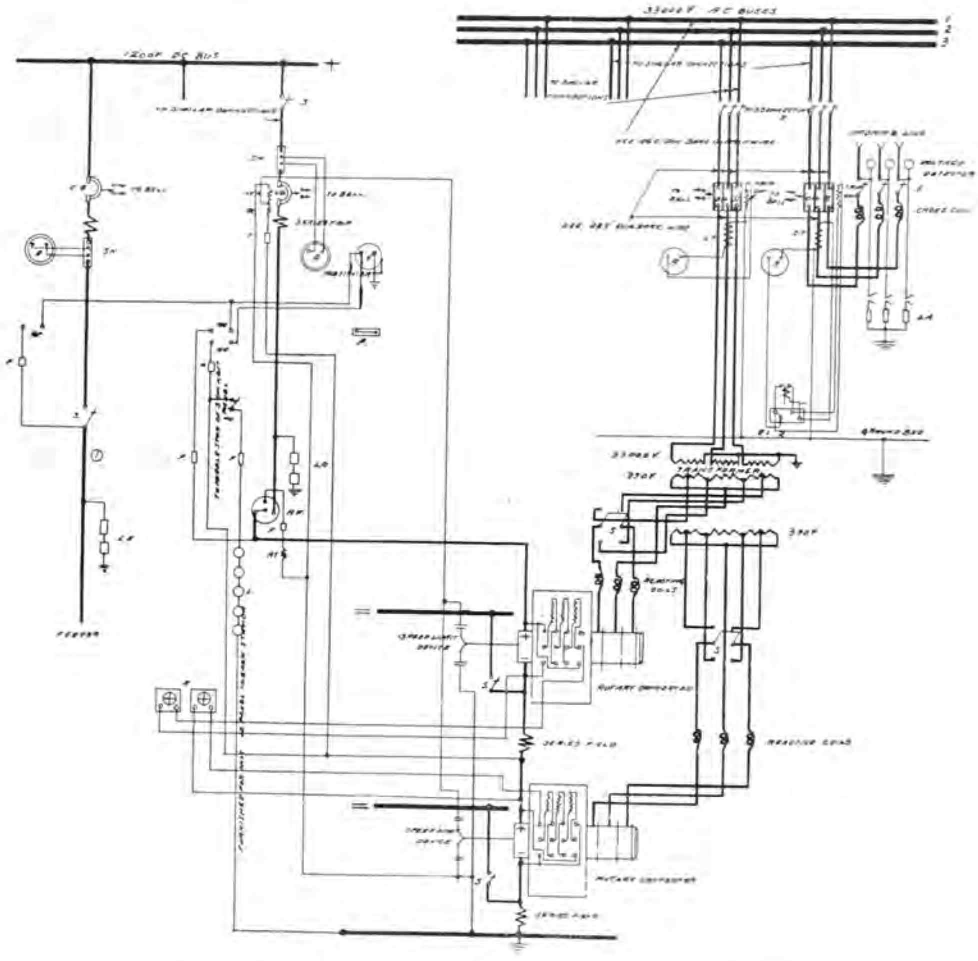


Fig. 18
SWITCHBOARD WIRING DIAGRAM BALTIMORE SUBSTATION

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.

The switchboard wiring diagram shown in Fig. 18 gives full details of the manner in which the electrical connections are made.

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 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

Fig. 19
THREE CAR TRAIN

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 cubic feet 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.

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 as follows:

Fig. 20
FIVE CAR TRAIN

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.

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

Service Equipments

The service equipments comprise in general the same apparatus as the passenger cars, with the exception that the motors are of

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.

4808-14 Washington, Baltimore & Annapolis 1200 Volt D.C. Railway

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	3 ft. 1 in.	3 ft. 1 in.

Figs. 19, 20 and 21 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 3/8 inches.

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 the 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.

In the tunnels near Westport 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 centre by other U bolts. The messenger is insulated and anchored at both ends of the tunnel.

Section insulators are used where the 1200 volt trolley and 600 volt trolleys meet. The city of Baltimore now permits a 1200 volt

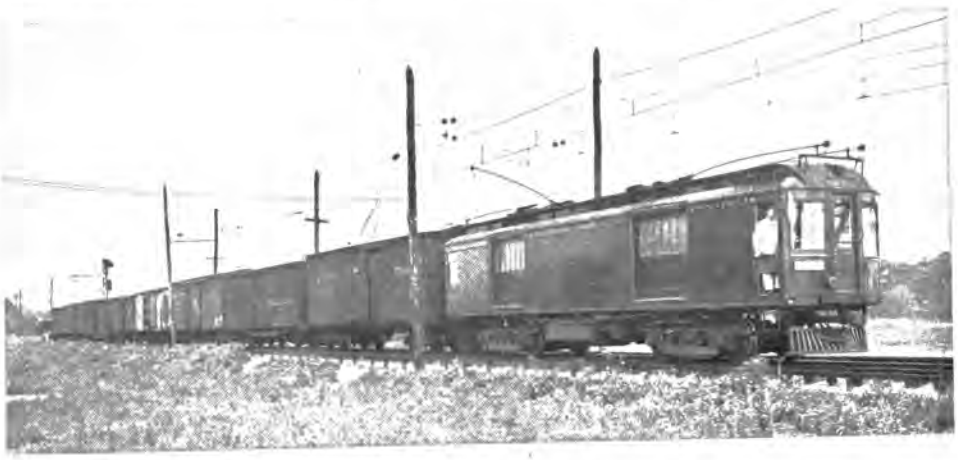


Fig. 21
EXPRESS CAR AND FREIGHT TRAIN

trolley as far as Lombard and Green streets, and the city of Annapolis permits a 1200 volt trolley running entirely around the town.

The general appearance of the catenary construction will be seen in Fig. 22.

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 (six 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 pounds 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 eight degrees under the B. & O. Railway but excluding this there are no curves of over four 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.

Fig. 22
VIEW ALONG RIGHT OF WAY

A feature of special 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 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.

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 passengers changing cars at this point.

General Electric Company

Schenectady, N.Y.

POWER AND MINING DEPARTMENT

December, 1910 *Copyright, 1910 by General Electric Company* **Bulletin No. 4810*

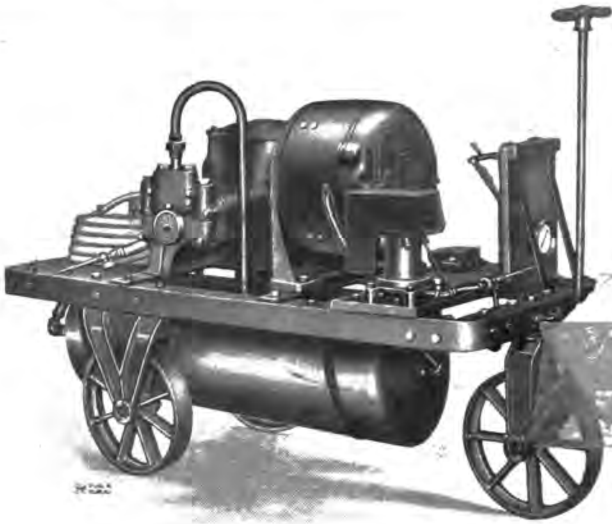
PORTABLE AND STATIONARY AIR COMPRESSOR SETS

To meet the demands of factory service, power stations, car barns and many other industrial plants, the General Electric Company has developed a line of air compressors having piston displacements of from 15 to 100 cubic feet per minute. In cases where it is not feasible to install a system of piping, the portable air compressor set here described and illustrated will prove most useful. An outfit of this kind is especially valuable in small and medium sized power stations where it is necessary to use an air-blast to blow out the interior parts of the generating or motor equipment which cannot be reached by any other means. In garages for inflating tires, and in factories, car barns, etc., occasionally requiring a portable drill, or other pneumatic tools, this extremely flexible source of power is indispensable.

PORTABLE SET

The essential parts of the portable set are as follows:

Truck
Motor-driven air compressor
Intake strainer
Air compressor governor
Switch and fuses
Pressure gauge
Safety valve
Storage reservoir
Stop cock
Hose with nozzle
Coupler for electrical connection to a source of power.



PORTABLE AIR COMPRESSOR SET

NOTE.—The data in this publication is for the convenience of customers, and every effort is made to avoid error, but this Company does not guarantee their correctness, nor does it hold itself responsible for any errors or omissions in this publication. Subject to change without notice.
**Supersedes 4490A.*

Truck

To facilitate handling, this set is mounted on a three-wheel truck, the single wheel in front carrying a handle which permits of easy transfer and turning sharp corners. The frame work is of angle iron bound together at the corners by malleable iron castings; the wheel supports are also of malleable iron, forming a ground work of unusual stiffness. A sheet iron plate carrying four posts occupies the rear of the truck convenient for coiling the hose when not in use.

Compressor

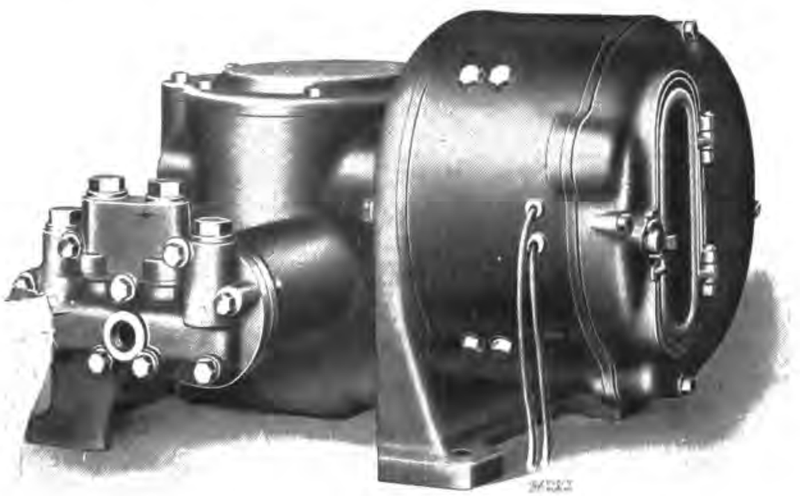
The compressors furnished with these sets are of standard General Electric pattern, single acting, single stage, with horizontal cylinders. Connection to the motor is made through a gear and pinion having accurately cut herringbone teeth. This construction is well illustrated in the exploded views.

The accompanying cuts show assembled and exploded views of this compressor equipped with direct current motor. A more complete description may be found in Bulletin No. 4699, Motor-Driven Air Compressors.

The portable set may be equipped with either CP-27, CP-28 or CPI-28 compressors, the piston displacement in the first case being 15 cubic feet per minute and in the other two 25 cubic feet per minute. The normal maximum working pressure for each of these machines is 90 lbs. per square inch. As may be seen from an inspection of the tables at the back of this bulletin the three above named types of compressors may be equipped with motors suitable for any commercial circuit.

The air supply is drawn through a strainer which is attached to the cylinder head and contains curled hair to prevent the entrance of dust and dirt.

The CP-27 and CP-28 compressors are driven by direct current series motors wound for either 600, 250 or 125 volt circuits and the CPI-28 compressor by a squirrel cage induction motor wound for 550, 440, 220 or 110 volts either two- or three-phase for either 60, 40 or 25 cycles. Heating guarantees on these motors are in all cases based on the assumption of intermittent service, that is, running five out of every ten minutes. In every detail the mechanical and electrical parts of these compressors are of the highest class of workmanship. Especial attention is called to the



CP-27 MOTOR-DRIVEN AIR COMPRESSOR

liberal proportions of the bearings and to the rugged design of the motor.

Governor

In order to maintain an air pressure within specified limits, the standard governors described below are used. The function of this governor is to close the motor circuit when the pressure falls below a predetermined value and to open the circuit when the pressure rises to another predetermined value. Adjustment can easily be made by means of two screws located in the upper part of the governor frame. Unless otherwise specified all governors are adjusted before shipment for a cutting out pressure of 65 lbs. and a cutting in pressure of 55 lbs. Any other setting, up to 100 lbs. cutting out pressure can be obtained, the range between the cutting out and cutting in pressures in case of the MC, MG and MH governors being 10 lbs. For use on CPI-28 (induction motor-driven) compressors the governor is furnished with two contacts for opening two of the connecting leads.

Safety Valve

To guard against an excessively high pressure which might result from accident to the controlling apparatus, a safety valve is supplied. These valves are similar to the pop safety valve used in steam practice and, unless otherwise specified, are adjusted to open at 100 lbs. pressure. An adjusting screw in the upper part of the valve allows this release pressure to be varied as conditions require.

Reservoir

The storage reservoir is 18 inches in diameter, 60 inches long and is located below the truck frame, thus keeping the center of gravity of the set low and insuring stability to the equipment. The capacity of the reservoir is approximately 8½ cubic feet and is sufficient to maintain a steady supply of air through the outlet nozzle for ordinary service such as operating pneumatic tools or for cleaning purposes. A drain cock is placed in the bottom of the reservoir to drain off any water or sediment that may collect.

CP-27 AIR COMPRESSOR

Hose

For reaching out-of-the-way places a length of 25 feet of air hose is provided, together with a nozzle and stop cock for controlling the supply of air.

For connecting to the source of power suitable couplers are supplied located near the switch and fuses.

The overall dimensions of the portable set are:

Length (not including handle)	6 ft., 8½ in.
Width	2 ft., 8 in.
Height	3 ft., 9 in.
Clearance between end of drain cock and floor	2½ in.
Approx. net weight	1600 lbs.

STATIONARY SETS

For central stations, garages, car barns or factories where the use of compressed air is sufficiently extensive to warrant a stationary plant with permanent piping, etc., the General Electric Company is producing a variety of compressor sets suitable for operating from supply mains of any standard voltage or frequency. In all General Electric compressors tubular valves are used which are seated by gravity and therefore require no springs.

CP-23 and CPI-23

This type of compressor is single acting, single stage and has two cylinders. The motor is designed for intermittent service rated on half time basis (5 minutes on and 5 minutes off), and is geared to the compressor by means of herringbone gears shown in the exploded view.

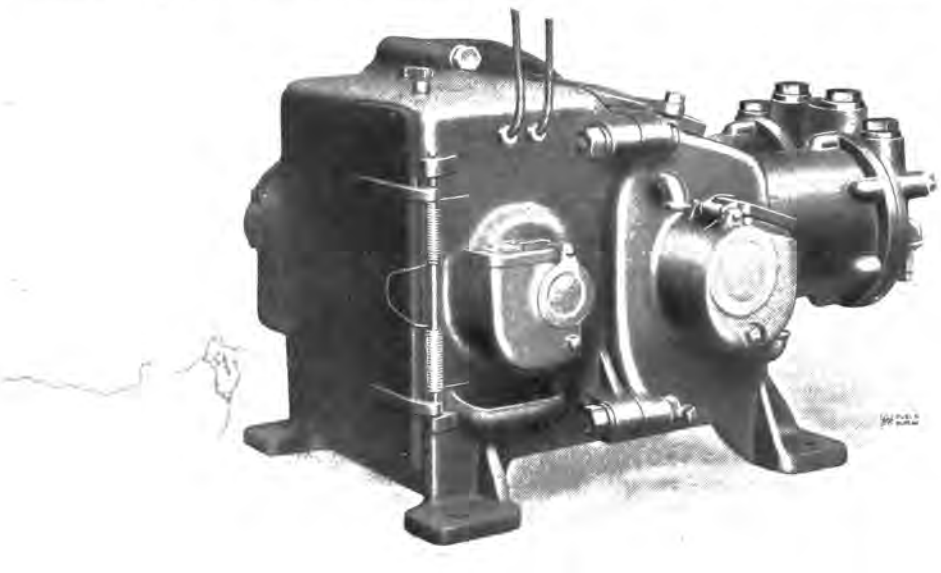
A well, formed in the compressor frame immediately below the gear, furnishes an oil reservoir for lubricating all working parts automatically. Oil may be supplied through an oil filler hole fitted with a thumbscrew plug. By this scheme of lubrication the use of waste or oil rings is avoided and there are no pipes or holes to clog up with sediment or thick oil. The oiling system is positive in action and continuously delivers oil to the bearings which flows back into the well, after doing its work.

CP-26 and CPI-26

For use in plants of larger capacity a four cylinder set is used, having two horizontal and two vertical cylinders. This compressor is also single acting but the air is compressed in two stages. The motor is designed for continuous service without undue heating.

CP-27, CP-28, CPI-28, CP-30 and CPI-30

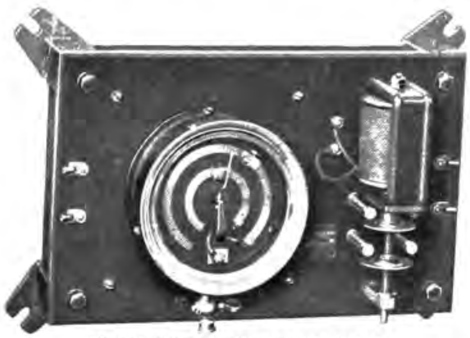
The design of the compressor for these sets is well shown in the exploded view of the CP-27. It has two horizontal cylinders, geared between the cranks and is single stage, single acting. The motors are rated on the half time basis as in the CP-23 set.



CP-23 AIR COMPRESSOR

AUXILIARY EQUIPMENT

In order to maintain a predetermined pressure in the air reservoirs, a line of governors is manufactured in several sizes and types, adapted to the various compressor sets. Their action is entirely automatic, depending upon the air pressure in the reservoir, and no starting box or external resistance is required.



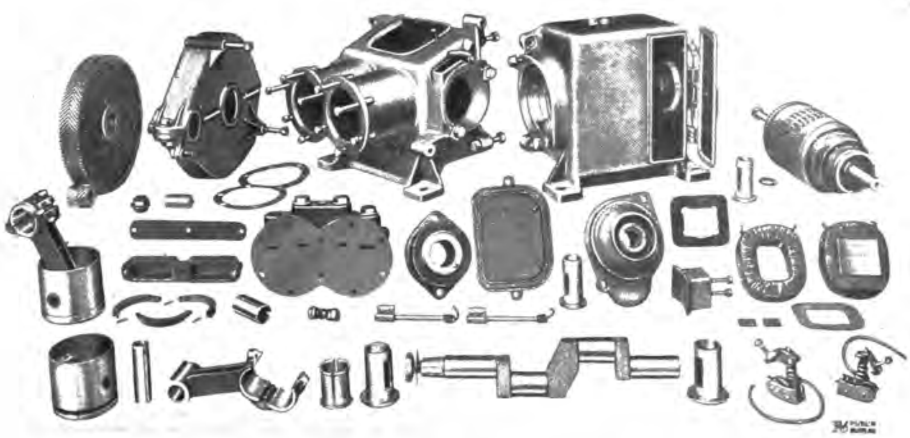
CR-225 PRESSURE GOVERNOR

The MC governor is designed for direct current circuits and is used with motors of the CP-27, CP-28 and CP-30 compressors operating from 600 or 250 volts circuits, and CP-23 compressor when used on 600 volt circuits.

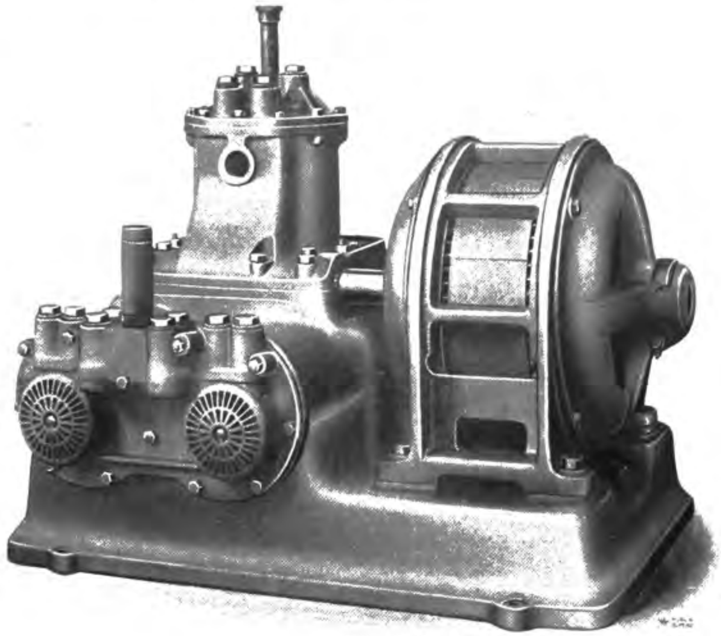
AIR COMPRESSOR GOVERNOR, TYPE MC

The MH governor is similar to the above, differing only in its larger current capacity, and is used with the motors of the CP-27, CP-28 and CP-30 compressors when driven from 125 volt circuits; with the CP-23 compressor when driven from 250 volt circuits; and with the CP-26 compressor when driven from 600 or 250 volt circuits.

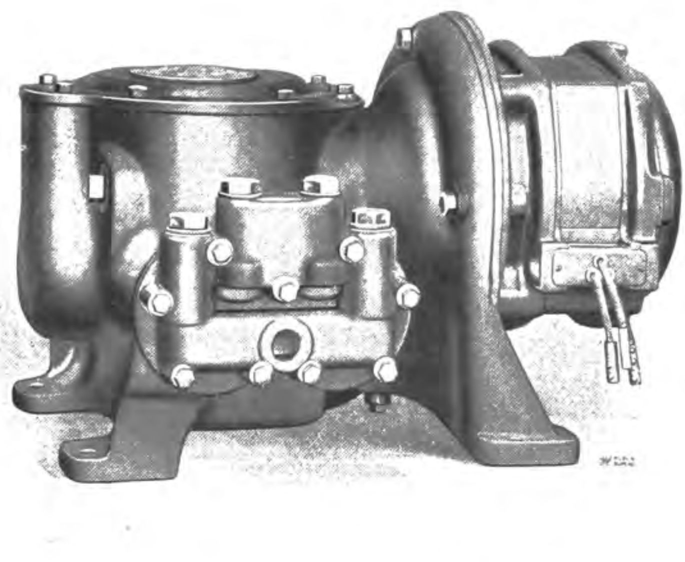
For use with alternating current motors the MG governor has been designed, having two contacts instead of one. In other respects it is similar to the MC governor. This governor is used with the mot[illegible] of the CPI-28, CPI-30 compressors, on all v[illegible]tages, and with the CPI-23 and CPI-26 compressor when the



DETAILS OF CP-23 AIR COMPRESSOR SET



CPI-26 AIR COMPRESSOR SET



CPI-28 AIR COMPRESSOR SET

motors are operated from 440 to 550 volt circuits.

For all other motors the CR-225 governor is used in connection with a single-pole contactor for the direct current sets, and a double-pole contactor for the alternating current sets. This type of control apparatus consists of a gauge type governor actuating a relay which, in turn, operates the contactors in the main circuit.

The illustration on page 5 shows the CR-225 governor and relay mounted on a slate base.

The CR-225 governor with contactors, may be used, however, for any compressor set, either alternating or direct current, when a range of pressure smaller than 10 lbs. is required. The range of this governor is approximately, from 3 to 5 lbs., depending on the size. This applies to governors up to 130 lbs. maximum cutting out pressure.

In Ordering Stationary Compressor Sets Always Specify the Following:

Compressor—Displacement in cubic feet per minute, voltage, frequency and number of phases.

Governor—Type, maximum cutting out pressure, and if CR-225, give range.

Reservoir—Size and number, or service for which the air will be used, whereupon recommendations and quotations can be made.

Safety valve—Desired setting if other than standard.

Switch and fuses.

Pressure gauge.

Drain cock.

Stop cock.

APPROXIMATE GENERAL DIMENSIONS, WEIGHTS, SPEEDS, ETC.

	CP-27	CP-28	CPI-28	CP-30	CPI-30	CP-23	CPI-23	CP-26	CPI-26
Piston displacement, cu. ft. per min.	15	25	25	35	35	50	50	100	[illegible]
Max. press. lbs. per sq. in.	90	90	90	90	90	90	90	[illegible]	[illegible]
Voltage	300 250 125	600 250 125	550 440 220 110	600	550 440 220 110	550 250	550 440 220 110	600	[illegible] 440 220 110
Cylinder diam. in.	4⅛	4¾	4¾	5½	5½	7¾	7¾	10¼ 5¾	10¼ 5¾
Stroke, inches	4⅞	6	6	7	7	5	5	6	6
R.p.m. compressor	200	203	203	182	182	183	183	175	175
R.p.m. motor	1094	1110	*750 †1200 ‡1200	1027	*750 † 800 ‡ 900	1100	*750 †800 ‡900	723	*750 † 800 ‡ 900
Length overall, in.	29	34	35	37	38	38	46	54	55
Width overall, in.	25	29	29	33	33	35	36	38	38
Height overall, in.	18	21	21	24	24	23	30	37	38
Approx. weight, lbs.	627	880	800	1240	1130	1460	2050	2900	2800
Approx. kw. input	2.5	4.2	4.5	6	6.3	8.8	9	19	20

CP compressors are for use on d.c. circuits. The motors are series wound.

CPI compressors are for use on a.c. circuits and are equipped with squirrel cage induction motor of two- or three-phase, 60, 40 and 25 cycles.

* Synchronous speed of 25 cycle induction motor.

† Synchronous speed of 40 cycle induction motor.

‡ Synchronous speed of 60 cycle induction motor.

In cases where the d.c. operating voltages vary from the listed voltage within 10 per cent, the piston displacement will vary in direct proportion.

GENERAL ELECTRIC COMPANY

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Indianapolis, Ind.	Traction-Terminal Building
CHICAGO, ILL.	Monadnock Building
Detroit, Mich.	Majestic Building (Office of Soliciting Agent)
St. Louis, Mo.	Wa[illegible] Building
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Oklahoma City, Okla.	Insurance Building

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FOREIGN DEPARTMENT,
Schenectady, N. Y., and 30 Church St., New York, N. Y.
London Office, 83 Cannon St., London, E. C., England

General Electric Company
Schenectady, N.Y.

POWER AND MINING DEPARTMENT

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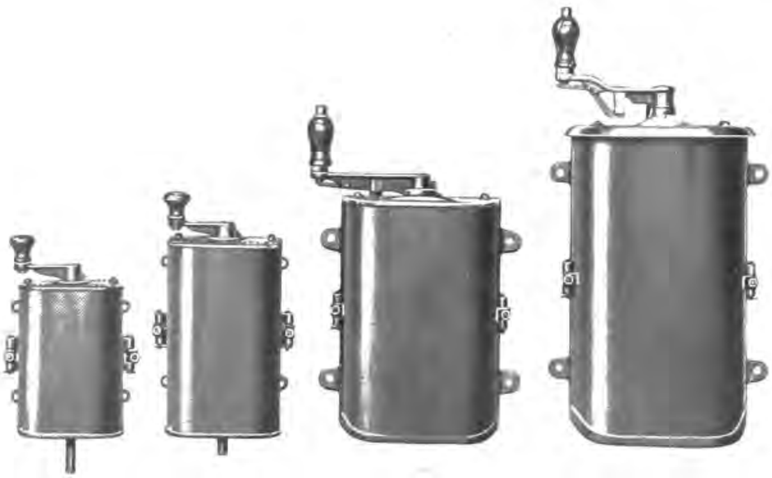
DRUM CONTROLLERS FOR INDUSTRIAL SERVICE

For the control of electric motors used in operating machinery where frequent service is required, drum type controllers have been found to give much better satisfaction than other types and are especially recommended for the operation of machine tools, cranes, hoists and similar types of apparatus.



R136-A R116-A R118-A R98-A
DRUM CONTROLLERS, ADJUSTABLE SPEED DC MOTORS

Descriptions contained in this bulletin are intended to include all standard forms of drum controllers built by the General Electric Company which are suitable for operating machinery and sufficient information to enable an intelligent selection to be made for any particular class of work. This information is arranged in sections according to the various classes of service, in order to facilitate the selection of the proper type of controller. For this reason the same controller has in some cases been listed in two or more sections giving different ratings according to the specific conditions.

In the design of these controllers especial attention has been paid to their ability to open the motor circuit under all conditions of load, without undue wear, and without sacrificing accessibility for inspection and repairs. In order to insure safety to the operator the electrical and mechanical features of design have received careful consideration with view to their being operated by inexperienced persons.

Frame

The frame which is of good quality iron, constitutes the back and base of the controller

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Supersedes No. 4600.

and is cast in one piece; the top is also of cast iron in controllers not using the magnetic blowout, but a brass top is used in the types employing this device.

Cylinder

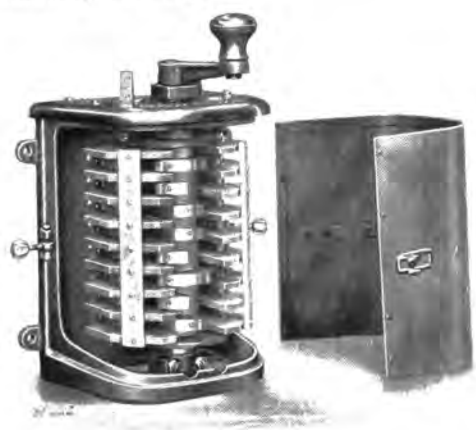
The cylinder shaft is a bar of hexagon steel, the ends of which are turned to a circular cross section to fit into the bearings. This shaft is covered with an insulation of laminated fiber and shellac, then steam heated and moulded into shape.

The contact segment supports are of brass, each section cast in a solid piece and fitted over the shaft. These sections are separated by insulating collars and firmly held in position by set screws. A flat steel spring underneath the point of the set screw prevents injury to the shaft insulation.

The contact segments are of copper fitted to the brass casting and secured by countersunk screws to prevent wearing away of the screw heads. The segment screws have special tapered heads which prevents them from working loose. This construction is very compact and durable eliminating the troubles experienced in controllers having many small parts assembled with screws and insulating bushings.

PARTS OF CONTROLLER CYLINDER, TYPE R118-A

R122-A CONTROLLER



T40 CONTROLLER

Fingers

The fingers are of drop forged copper with springs of phosphor bronze, and in order to insure perfect alignment and accurate contact they are fitted with adjusting screws and lock nuts. For field control points the fingers are similar in construction to those used in the armature circuits.

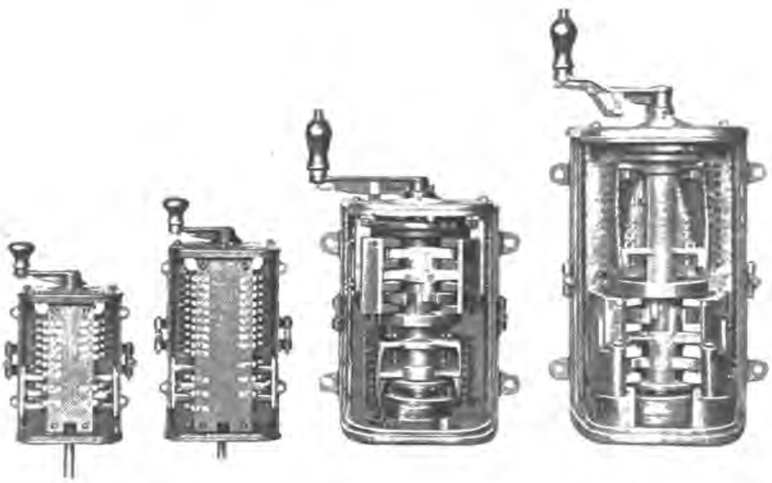
Finger Board

The finger board or supporting block for the stationary contacts is of kiln dried hard wood, impregnated with a moisture-proof compound.

versed except when the main cylinders are at the off position.

Covers

The covers are made of heavy sheet iron lined with asbestos. This lining prevents possible contact with live parts and also minimizes danger from fire. These covers are well fitted to the frame, protecting the parts from dust and mechanical injury, and



DRUM CONTROLLERS, ADJUSTABLE SPEED DC MOTORS (Covers Removed)

are also easily removed to allow ready access for inspection. When designed for use in extremely dusty places such as cement mills covers are furnished fitted with felt gaskets.

Magnetic Blowout Coils

Magnetic blowout coils are used on all controllers designed for 550 volt service, and on types designed for lower voltages requiring more than 60 amperes normal capacity. The coils are wound with either copper wire or flat strips of sufficient capacity to carry full load current continuously without undue heating, and after being wound they are treated with an insulating compound making them moisture-proof.

Interlocks

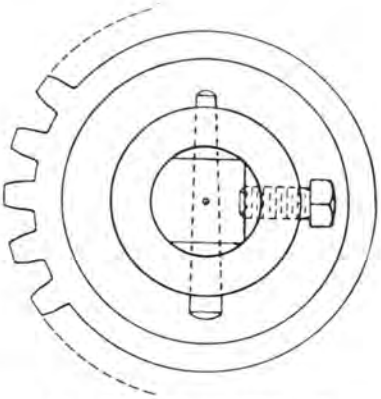
All controllers with separate reversing cylinders are provided with mechanical interlocks to prevent the motors from being re-

Interchangeability

A careful record of the serial numbers of all controllers is kept. This, in conjunction with a strict avoidance of modification in design after standardization, insures the interchangeability of parts.

Gear Drive

When it is desired to operate drum controllers through gears or sprockets, the handle may be removed and pinion readily attached, as the shafts are accurately finished to standard diameters. The shaft of the



PINION FOR REMOTE CONTROL OF DRUM CONTROLLER

R136-A and R116-A controller is extended through the bottom to facilitate operating them either by the handle or through gearing as desired.

Machine Tool Controllers

All drum controllers for machine tools are now built for reverse operation. When non-reversing controllers are desired, a stop

TYPE R118-A CONTROLLER-STOP ON CAP PLATE IN POSITION FOR NON-REVERSIBLE OPERATION

is screwed into the controller cap plate, against which the handle strikes at off position. This stop is shipped with all controllers, and is underneath the cap plate inside the controller. It is thus easily removed and placed on the top, when it is desired to operate the motor in only one direction.

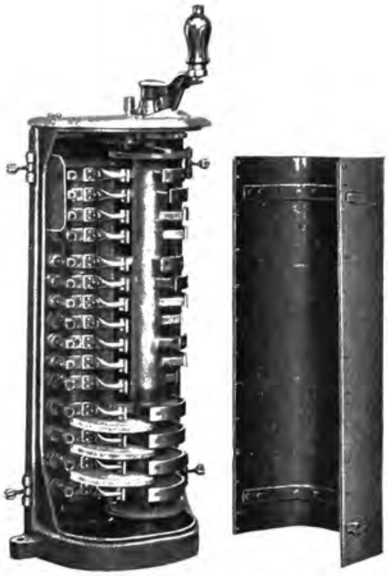
The R135 controller is an exception to the above and is non-reversing, having been designed for part armature and part field control. It is therefore suitable where a greater number of starting points is desired than is afforded by other controllers.

When overload and no-voltage protection are required in connection with drum con-

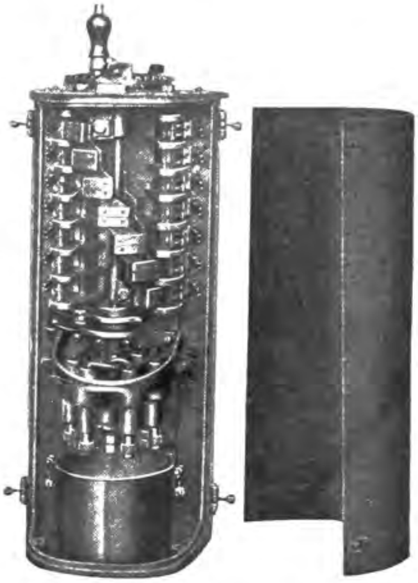
CR251 PANEL

trollers, a CR251 panel should be used. This panel consists of a double-pole circuit breaker, a single-pole contactor and two fuses, all mounted on a slate base, provided with feet for convenient installation.

The circuit breaker and fuses provide protection against overload, and the contactor furnishes no-voltage protection. The operation of these panels depends essentially upon an electrical interlock between the no-voltage contactor and the drum controller. When the controller handle is moved to the first point the solenoid of the contactor is energized closing the contactor and completing the armature circuit. As greater current is required to close the contactor than to hold it closed, a high resistance is cut in series with the contactor coil when the controller handle

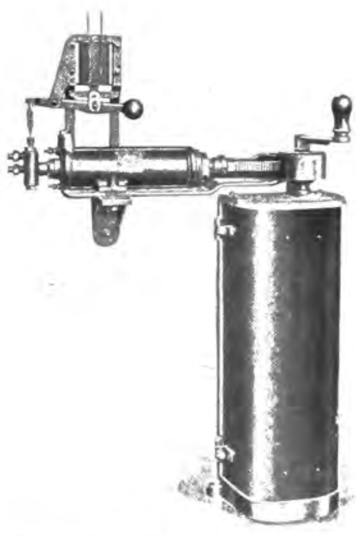


T-10-J CONTROLLER

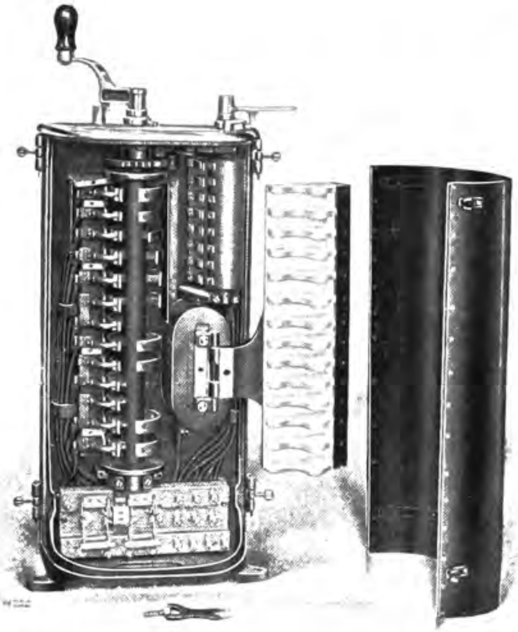


T-36-A CONTROLLER

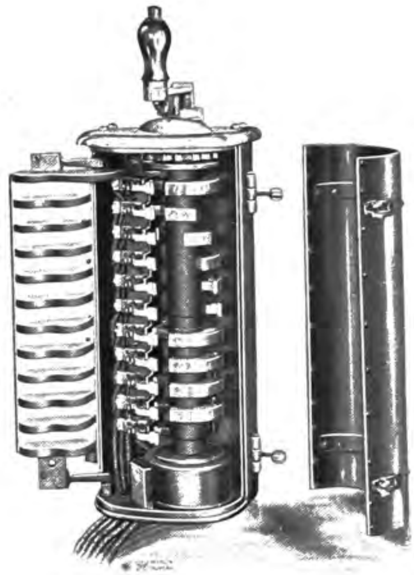
T-1 FORM H CONTROLLER



T-10 CONTROLLER WITH MASON REGULATOR



K-27 CONTROLLER



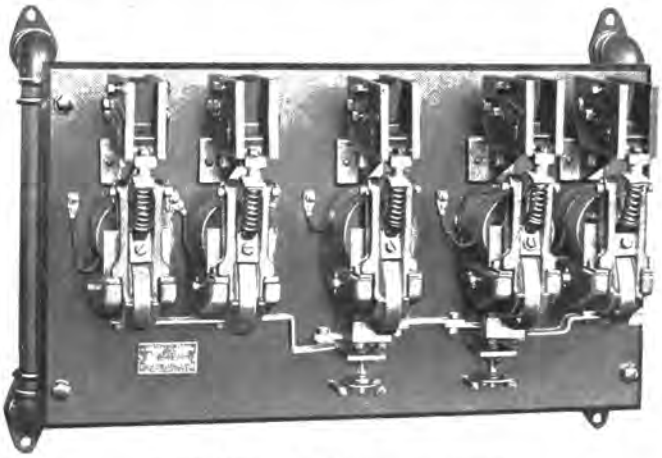
R28-A CONTROLLER

T-41 CONTROLLER

T-28 CONTROLLER

is moved beyond the first point. The contactor is thus prevented from closing in case of a return of voltage after failure until the controller is returned to the first point. This device is designed for use with shunt and compound wound motors.

For adjustable speed motors of greater capacity than can be operated by the R98 controller, a drum type controller is not satisfactory for frequent operation. A contactor panel is therefore recommended for carrying the armature current of large motors, and a C236-A master controller for operating the contactors and providing the necessary points for field control. The panel may be mounted on the wall or in any convenient place while the master controller may be mounted on the machine frame.



TYPE MCR53-A CONTACTOR PANEL

MINING LOCOMOTIVE SERVICE

Type	Max. H.P. Capacity Each Motor		Points		No. Motors	No. Handles	Net Weight	Remarks
	230 Volts	550 Volts	Series	Parallel				
D.C. MOTORS—REVERSIBLE								
R 37-C	25	50	5	5	2	2	175	Used on metallic circuits.
R 86-E	25	50	5	5	2	2	175	Leads through holes in back of frame.
R 86-F	15	35	5	5	2	2	175	Smaller blowout coil, otherwise same as R86-E.
R109-B	50	100	6	6	2	2	290	
R111-B	25	50	6	6	4	2		
R112-B	80	160	6	6	2	2	325	
R113-B	40	80	6	6	3	2	325	
R114-B	40	80	6	6	4	2	325	

NOTE.—On above controllers the reverse switch has two positions—forward and reverse. The change in connections from series to parallel is accomplished by throwing the reverse switch to second position.

4811–8 Drum Controllers for Industrial Service

MACHINE TOOL SERVICE

Type	Max. H.P. Capacity 115 Volts	230 Volts	550 Volts	Points Forward Start-ing	Run-ning	Points Reverse Start-ing	Run-ning	Net Weight Lb.	Remarks
D.C. MOTORS—REVERSIBLE—ADJUSTABLE SPEED									
R136-A	3	5		1	15	1	15	50	No magnetic blowout. Supplied with field rheostat on back if desired.
R116-A	5	10	..	2	18	2	18	55	No magnetic blowout, otherwise same as R126-A.
R126-A	5	10	15	2	18	2	18	58	Supplied with field rheostat on back if desired.
R130-A	12	15	..	3	18	3	18	92	No magnetic blowout, otherwise same as R118-A.
R118-A	12	20	40	3	18	3	18	98	Supplied with field rheostat on back if desired.
R98-A	20	35	70	3	24	3	24	120	Cannot be used with no-voltage panel, otherwise same as R98-B
R98-B	20	35	70	3	21	3	21	120	
R135-A	12	15	..	7	10	..	..	92	Non-reversible, no magnetic blowout. Cannot be used with no-voltage panel, otherwise same as R118-A.
D.C. MOTORS—REVERSIBLE—CONSTANT SPEED (ARMATURE POINTS ONLY)									
R134	5	7½	..	1	1	1	1	35	Drum type reversing switch, no magnetic blowout, no resistance points, with or without spring return to off position. Supplied with handle or for rope operation. For raising and lowering cross rail, etc.
R122-A	6	12	20	4	1	4	1	52	May be used for armature control.
R28-V	8	15	30	4	1	4	1	95	May be used for armature control.
R27-M	12	20	40	7	1	7	1	195	May be used for armature control.
R32-G	15	30	60	7	1	7	1	195	May be used for armature control.
R115-A	25	50	100	9	1	9	1	225	May be used for armature control.

CONTACTOR PANELS

D.C. MOTORS—REVERSIBLE AND NON-REVERSIBLE—ADJUSTABLE SPEED

Max. H.P. Capacity 115 Volts	230 Volts	550 Volts	Master Controller 115 and 230 Volts	550 Volts	Points Start-ing	Run-ning	Contactors Revers-ible	Non-reversible	Remarks
40	50	100	C236-A	C236-A	3	18	7	4	These panels can be arranged for wall mounting or on pipe supports for floor mounting.
75	100	200	C236-A	C236-A	4	18	8	5	
..	150	...	C236-A	...	5	18	9	6	An additional section can be added for mounting circuit breakers, ammeter or volt-meter.
..	225	...	C236-A	...	5	18	9	6	

A.C. MOTORS—SLIP RING TYPE—REVERSING AND NON-REVERSING

Type	Current per Phase		Maximum Voltage		Points		Net Weight	Remarks
	Primary	Secondary	Primary	Secondary	Forward	Reverse		
THREE-PHASE								
*R134	35	...	550	...	1	1	35	Drum type reversing switch, no magnetic blowout, no resistance point, with or without spring return to off position. Supplied with handle or for rope operation. For raising and lowering cross rails.
T 1-H	115	115	550	550	8	8	85	
T 1-T	115	115	550	550	8	..	85	Non-reversing.
T10-J	150	150	550	550	11	11	115	Starts motor with single-phase secondary.
T10-N	150	150	550	550	11	..	115	Non-reversing.
T42-D	300	300	550	550	12	12	265	
T42-E	300	300	550	550	12	..	265	Non-reversing.
T36-A	75	250	2200	550	14	14	260	Primary oil switch.
T28-A	125	500	2200	550	14	14	380	Primary oil switch.
TWO-PHASE								
T34-E	115	115	550	550	8	8	95	
T36-A	75	250	2200	550	14	14	260	Primary oil switch.
T28-A	125	500	2200	550	14	14	380	Primary oil switch.
ADJUSTABLE SPEED-CHANGEABLE POLE MOTORS THREE-PHASE								
T46-B	40	...	440	...	4	4		For constant horse-power.
T54-A	40	...	440	...	4	4		For constant torque.
STARTING DUTY—NON-REVERSIBLE THREE-PHASE								
T20-B	..	600	...	550	7	..		Standard handle.
T20-C	...	600	...	550	7	..		For switchboard use.
T29-A	...	1000	...	550	14	..		Standard handle, may also be used for regulating duty.
T29-D	...	1000	...	550	14	..		For switchboard use, may also be used for regulating duty.

NOTE.—For motors with which the above controllers are suitable, see Data Book 314.
* This controller is for use with three-phase squirrel cage type induction motors only.

4811–10 Drum Controllers for Industrial Service

CRANE AND HOIST SERVICE

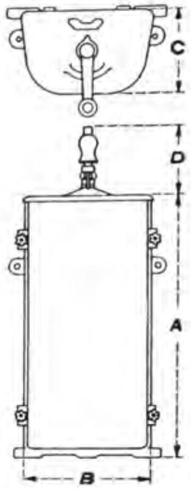
Type	Max. H.P. Capacity 115 Volts	230 Volts	550 Volts	Points Forward	Reverse	Net Weight	Remarks
D.C. MOTORS—REVERSIBLE							
*R134	5	7½	...	1	1	35	Drum type reversing switch, no resistance, with or without spring return to off position, rope or hand operation.
R122-A	6	12	20	5	5	52	Leads through bottom.
R 28-A	10	25	50	5	5	100	Leads through bottom.
R 28-V	10	25	50	5	5	95	Holes in side for leads.
R 27-A	15	35	75	8	8	200	Leads through bottom.
R 27-M	15	35	75	8	8	195	Holes in back for leads.
R 32-A	25	50	100	8	8	200	Leads through bottom.
R 32-G	25	50	100	8	8	195	Holes in back for leads.
R115-A	50	100	200	10	10	265	Holes in back for leads.
R129-A	2–25	2–50	2–100	10	10	270	Holes in back for leads.

CRANES AND HOISTS
A.C. MOTORS—SLIP RING TYPE—REVERSIBLE

Type	Maximum Current for this Service Primary	Secondary	Maximum Voltage Primary	Secondary	Points Forward	Reverse	Net Weight	Remarks
THREE-PHASE								
*R134	35	...	440	...	1	1	35	Drum type reversing switch, no resistance points, with or without spring return to off position, rope or hand operation.
T 1-H	150	150	550	550	8	8	85	Holes through side for leads, can be furnished with rope wheel.
T 10-J	200	200	550	550	11	11	155	Holes through back for leads, can be furnished with rope wheel.
T 42-C	250	250	550	550	14	14	265	Starts motor with single-phase secondary.
T 42-D	350	350	550	550	12	12	265	All three secondary phases closed on starting.
T 36-A	75	250	2200	550	14	14	260	Has oil switch for reversing.
T 28-A	125	700	2200	550	14	14	380	Has oil switch for reversing.
TWO-PHASE								
T34-E	150	150	550	550	8	8	95	Holes through back for leads, can be furnished with rope wheel.
T36-A	75	300	2200	550	14	14	260	Has oil switch for reversing.
T28-A	125	700	2200	550	14	14	380	Has oil switch for reversing.

NOTE.—For motors with which the above controllers are suitable, see Data Book 313.

*This controller for use with three-phase squirrel cage type induction motors only.



Type	"A"	"B"	"C"	"D"
R 27-M	$32\frac{5}{8}$	$13\frac{3}{8}$	$8\frac{15}{32}$	$8\frac{3}{16}$
R 28-V	$22\frac{11}{16}$	$10\frac{1}{2}$	$7\frac{15}{16}$	$7\frac{9}{32}$
R 32-G	$32\frac{5}{8}$	$13\frac{3}{8}$	$8\frac{15}{32}$	$8\frac{3}{16}$
R 37-C	$21\frac{3}{16}$	$17\frac{1}{2}$	$8\frac{1}{8}$	$8\frac{1}{2}$
R 86-E	$21\frac{3}{16}$	$17\frac{1}{2}$	$8\frac{1}{8}$	$8\frac{1}{2}$
R 98-A	$21\frac{7}{16}$	$13\frac{1}{2}$	$10\frac{1}{2}$	$8\frac{3}{16}$
R109-B	23	$21\frac{1}{2}$	$9\frac{5}{8}$	$3\frac{3}{4}$
R111-B	$26\frac{11}{16}$	$21\frac{1}{2}$	$9\frac{5}{8}$	$3\frac{3}{4}$
R112-B	$30\frac{5}{8}$	$20\frac{5}{8}$	$9\frac{5}{8}$	$3\frac{3}{4}$
R113-B	$30\frac{5}{8}$	$20\frac{5}{8}$	$9\frac{5}{8}$	$3\frac{3}{4}$
R114-B	$30\frac{5}{8}$	$20\frac{5}{8}$	$9\frac{5}{8}$	$3\frac{3}{4}$
R115-A	$31\frac{9}{16}$	$16\frac{5}{8}$	$10\frac{5}{8}$	$8\frac{3}{16}$
R116-A	$13\frac{1}{8}$	$8\frac{1}{8}$	$7\frac{7}{8}$	$8\frac{3}{8}$
R118-A	$16\frac{1}{8}$	$11\frac{1}{2}$	$9\frac{5}{8}$	$6\frac{7}{16}$
R122-A	$14\frac{1}{2}$	$8\frac{5}{8}$	$7\frac{1}{8}$	$3\frac{7}{8}$
R126-A	$13\frac{1}{8}$	$8\frac{1}{8}$	$7\frac{7}{8}$	$3\frac{3}{8}$
R129-A	$31\frac{9}{16}$	$16\frac{5}{8}$	$10\frac{5}{8}$	$8\frac{3}{16}$
R130-A	$16\frac{1}{8}$	$11\frac{1}{2}$	$9\frac{5}{8}$	$6\frac{7}{16}$
R134-A	$6\frac{11}{16}$	$6\frac{3}{4}$	$5\frac{11}{16}$	$2\frac{1}{16}$
R135-A	$16\frac{1}{8}$	$11\frac{1}{2}$	$9\frac{5}{8}$	$6\frac{7}{16}$
R136	$10\frac{1}{8}$	$7\frac{1}{2}$	$7\frac{3}{8}$	$3\frac{3}{8}$
T 1-H	$22\frac{3}{4}$	$10\frac{1}{2}$	$7\frac{5}{8}$	$7\frac{1}{4}$
T 10-J	$32\frac{5}{8}$	$13\frac{3}{8}$	$8\frac{7}{8}$	$8\frac{1}{8}$
T 20-B	$22\frac{3}{4}$	$10\frac{1}{2}$	$7\frac{5}{8}$	$6\frac{1}{2}$
T 28-A	$40\frac{5}{16}$	$17\frac{3}{4}$	$24\frac{5}{8}$	$7\frac{1}{2}$
T 29-A	$40\frac{5}{16}$	$17\frac{3}{4}$	$12\frac{1}{16}$	$7\frac{1}{2}$
T 34-E	$27\frac{1}{16}$	$11\frac{5}{8}$	$6\frac{7}{8}$	$7\frac{1}{2}$
T 36-A	$40\frac{5}{16}$	$17\frac{3}{4}$	$12\frac{1}{16}$	$7\frac{1}{2}$
T 42-D	$40\frac{5}{16}$	$17\frac{3}{4}$	$12\frac{1}{16}$	$7\frac{1}{2}$
T 46-B	$15\frac{5}{8}$	$9\frac{1}{2}$	$9\frac{5}{8}$	$7\frac{3}{8}$
T 54-A	$15\frac{5}{8}$	$9\frac{1}{2}$	$9\frac{5}{8}$	$7\frac{3}{8}$
T 67-A	$32\frac{5}{8}$	$13\frac{3}{8}$	$8\frac{7}{8}$	$8\frac{1}{8}$

GENERAL ELECTRIC COMPANY

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Richmond, Va.	712 Mutual Building
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For TEXAS and OKLAHOMA Business refer to
General Electric Company of Texas,

Dallas, Tex.	Praetorian Building
El Paso, Tex.	Chamber of Commerce Building
Oklahoma City, Okla.	Insurance Building

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FOREIGN DEPARTMENT,
Schenectady, N. Y., and 30 Church St., New York, N. Y.
London Office, 83 Cannon St., London, E. C., England

General Electric Company
Schenectady, N.Y.

LIGHTING DEPARTMENT

January, 1911 *Bulletin No. 4812*

SMALL DIRECT CURRENT GENERATORS, BELTED, TYPE CVC

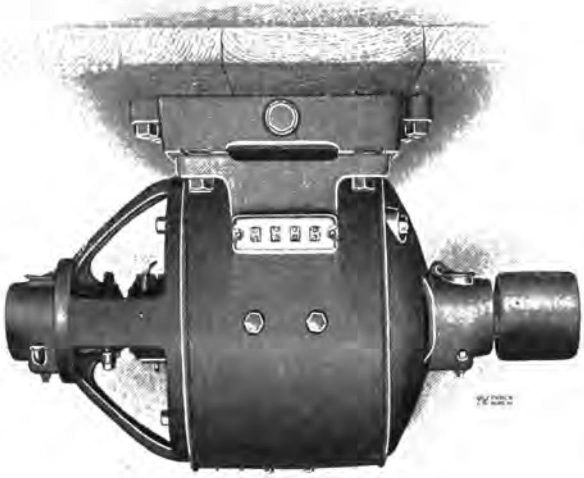
In selecting a lighting system for small plants, hotels, residences, factories or mills where the average length of the feeder circuit is 400 yards or less, and the maximum length is not greater than ¾ of a mile, it is generally conceded that direct current at 125 volts or 250 volts will give the best service. On the other hand, alternating current is better suited for longer circuits as it has the advantage of being easily stepped up by means of transformers to a higher voltage for long distance transmission with a minimum loss. The question as to whether a belted or a direct connected generator is preferable will depend on various considerations; when slow speed and noiseless operation will justify the greater cost, a generator direct connected to its prime mover should be used, such as the General Electric steam engine generator sets, marine type, described in Bulletin No. 4399, and the gasolene engine generator sets described in Bulletin No. 4707.

BELTED GENERATORS

The principal advantages of the belted type generator are its low first cost, the small amount of floor space it occupies and its adaptability. In a mill or manufacturing establishment where there already exists a shaft rotating at uniform speed this adaptability is most apparent. For example, the CVC belted generator can be installed on the floor, wall or ceiling. This enables it to be used in crowded locations and in many places where a generator of different construction could not be readily installed.

CVC GENERATOR

NOTE: The data in this publication are for the convenience of customers, and every effort is made to avoid error, but this Company does not guarantee their correctness, nor does it hold itself responsible for any errors or omissions in this publication. Subject to change without notice.



CVC GENERATOR INSTALLED ON CEILING

SLIDING BASE AND BELT TIGHTENERS

The belt is tightened by means of the sliding base shown herewith. In cases where the diameter of the driving pulley is more than five times greater than the diameter of the generator pulley, the sliding base should be omitted, and a belt tightener supplied. A sliding base, however, should be used whenever practicable as it is cheaper. The deciding factor is the arc of contact of the belt on the generator pulley which should not be less than 165 degrees. A belt tightener should be used, as shown on page 3, in those cases where the belt centers, i.e., the distance between the centers of the pulleys, is very short as without it, the arc of contact of the belt on the generator pulley will be so small as to cause an excessive belt slip. Under normal conditions a 2 per cent belt slip is to be expected at full load.

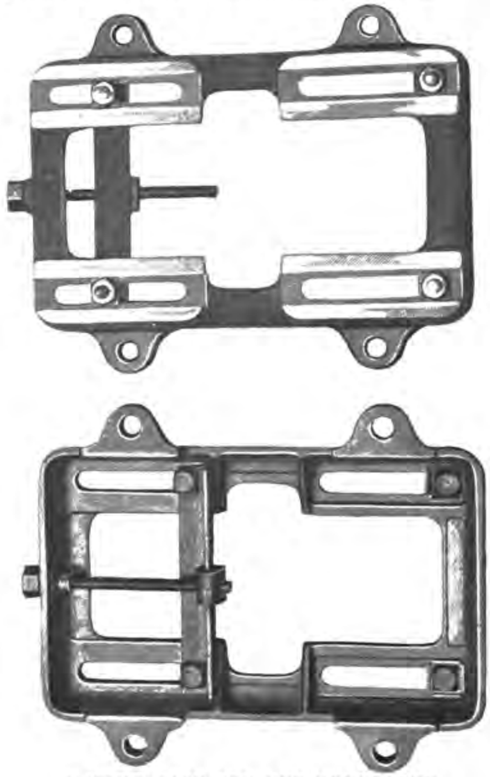
COMMUTATING POLES

All users of direct current apparatus will agree that the question of prime importance is that of good commutation. To secure satisfactory commutation on an ordinary generator it is necessary to shift the brushes with every change of load.

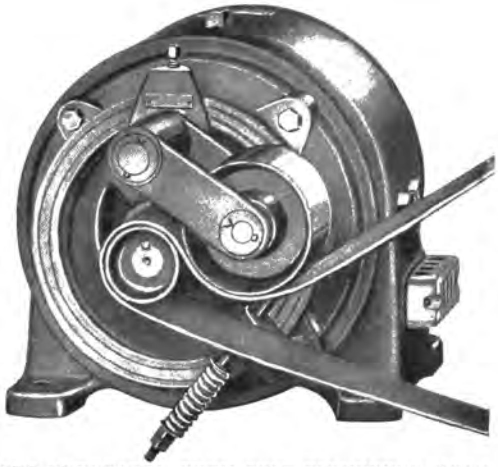
The brush position for satisfactory commutation is known as the "electrical neutral." To keep the brushes always on this neutral a shift of 2 or 3 commutator bars is necessary between the no-load and full-load points. On a commutating pole generator, however, the brush position for full-load and no-load is identical, and no brush shift is necessary to insure satisfactory commutation.

By eliminating the sparking, the heating of the generator is reduced, and pitting of the brushes and commutator bars avoided.

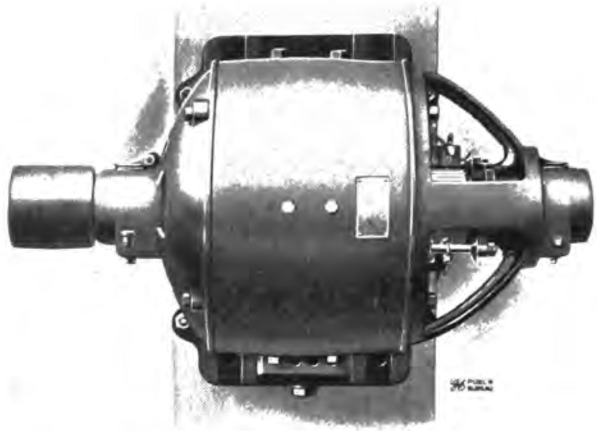
With these points in mind the General Electric Company has designed and is manufacturing a full line of direct current generators in capacities of from 3 kilowatts to 20 kilowatts at moderate speeds, and 1¼ kilowatts to 14 kilowatts at slow speeds. Excepting the 1¼ kilowatt generator these machines all have commutating poles.



SLIDING BASE FOR CVC GENERATOR



CVC GENERATOR WITH BELT TIGHTENER HEAD

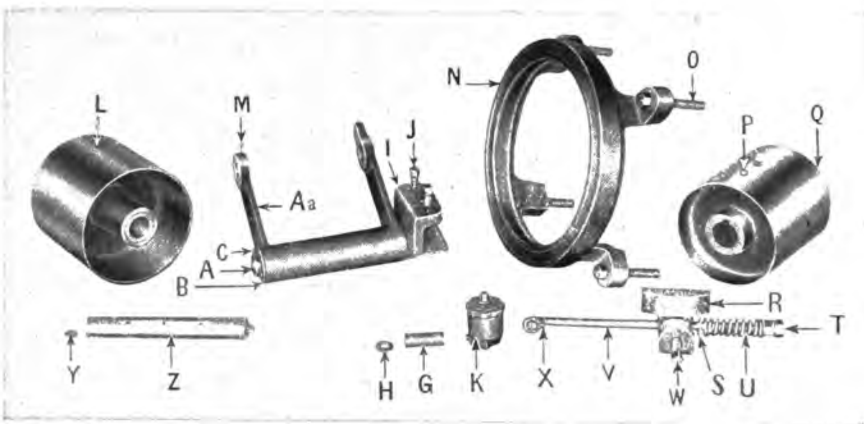


CVC GENERATOR MOUNTED ON WALL

DIMENSIONS, RATINGS AND PARTS OF STANDARD CVC GENERATORS

The table on page 10, gives the ratings, weights and principle dimensions of the standard CVC compound wound generators which are designed to give either 125 or 250 volts at full load.

To determine the size of a generator required for lighting we should figure on a standard, carbon filament 16 candle-power incandescent lamp consuming 50 watts. This means 20 lamps per kilowatt of generator rating.



BELT TIGHTENER ATTACHMENT FOR CVC GENERATORS—FRAMES 1/4 TO 15

A Stud for rocker
B Washer for rocker stud
C Spring cotter for rocker stud
D + Adjusting spring
E + Clamp for adjusting spring
F + Clamping screw for spring clamp
G§ Arguto lining
H§ Arguto washer
I Rocker slide
J Set screw for rocker slide
K* Grease cup
L Idler pulley
M Spring cotter for idler stud
N Supporting bracket
O Bracket cap screw
P Pulley set screw
Q Pulley
R† Clamp for guide rod
S† Guide rod washer
T† Guide rod nut
U† Guide rod spring
V† Guide rod
W† Set screw for guide rod clamp
X† Spring cotter or guide rod
Y* §Pipe plug for idler stud
Z* Stud for rocker and idler pulley
Aa Rocker for idler pulley

* For 7½ to 15 frames † For 2 to 15 frames § From ¼ to 5 frames

+For ¼ to 1 frames

In ordering give name of part and Serial No. of generator Omit reference letter.

FRAME

The generator frame and pole cores are made of soft steel of high permeability. The pole faces are built up of thin laminated steel sheets riveted together and are secured to the pole cores by means of heavy flat-headed machine screws. The extensions on these pole pieces serve to hold the field coils firmly in place, preventing any tendency to vibrate and thus preventing mechanical wear of the field coil insulation. The pole pieces are securely fastened to seats machined on the inside of the magnet frame by hexagon headed cap screws, so that they may be readily removed when necessary.

The good quality of the material used in the frame and pole pieces, together with the short magnetic circuit, reduce iron losses to a minimum, and allow of high efficiencies being obtained in these generators.

ARMATURE AND FIELD

The armature core is built up of steel laminations, japanned to prevent eddy currents. In the larger sizes the assembled core is provided with air ducts for ventilation. Two cast iron spiders which extend as flanges to support the armature coils clamp the laminations tightly together.

The pulley end armature head is supplied with three projecting prongs drilled and tapped, to which a fan is screwed. The fan, which is ring shaped and punched from sheet metal, has its blades cut from the ring, bent at right angles and turned inwardly. The introduction of this ventilating feature materially reduces the heating of these machines.

CVC GENERATOR ARMATURE

FIELD COIL FOR MAIN POLES

FIELD COIL FOR COMMUTATING POLES

The completed armature is thoroughly insulated so that it is impervious to moisture and practically indestructible, except under extreme overloads.

The armature coils are form wound, of insulated copper wire, and are thoroughly insulated and tested to avoid possibility of short circuits. The coils are securely held in toothed slots punched in the armature discs and extend out over the end flanges. They are bound by band wires to prevent vibration or movement of the coils. This form of winding provides a large radiating surface for the armature conductors, and consequently reduces the heating. The individual coils can be readily removed and replaced when necessary.

The field coils are thoroughly insulated, compact and can be readily removed, as previously explained, by taking out the pole pieces. Each coil is subjected to a special treatment which renders it practically impervious to moisture.

PULLEY END BEARING BRACKET

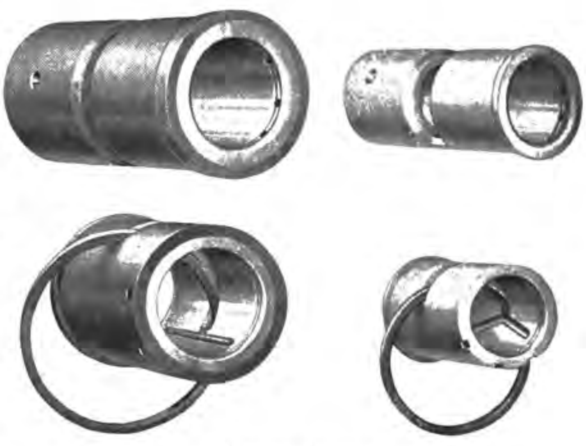
COMMUTATOR END BEARING BRACKET

BEARINGS AND BEARING BRACKETS

The CVC generators are designed with bearings of ample size to insure cool running and lubricated automatically by rings revolving on the shaft and dipping into oil wells of liberal capacity. The bearing linings for the smaller sizes are made of special composition bearing metal in one piece while for the three larger sizes the linings are of the babbitted cast iron type. The linings are held in position by the bearing heads which are securely bolted to the frame.

Generators can be adapted for wall or ceiling installation by turning the bearing heads 90 or 180 degrees, so that the cap screw holding the bearing linings will be vertically above the shaft. This adjustment is readily made by removing the bolts holding the bearing brackets to the frame and turning the bearing head on the shaft without having to remove the armature.

The bearing brackets for these CVC generators are so designed that they not only insure protection to the windings from external injury, but permit ready access to



BEARING LININGS

the brush-holder and commutator: They also afford the best possible means for securing the maximum ventilation by means of the fan previously mentioned.

Great care has been taken to avoid a construction which would result in allowing the formation of air pockets. The shape and construction of the arms on the commutator end do not permit the hot air which is thrown from the internal parts of the motor by the fan to be deflected back against the commutator; it is thrown directly out through the openings, the warm air from the commutator being carried along and expelled at the same time.

BRUSH-HOLDER RIGGING

The pulley end bearing bracket is very nearly solid, the area of the openings (four in number) and their position relative to the fan on the armature, being carefully selected to derive the greatest benefit from a ventilation standpoint.

The two bearing brackets are also interchangeable so that the position of the commutator and the pulley can be reversed relatively to the frame. This is specially important where the generator has to be fastened to the wall or ceiling, as the terminal block of the machine will always be accessible and the generator can be driven from that end of the machine which is most convenient.

BRUSH-HOLDER COMPLETE

COMMUTATOR AND BRUSH-HOLDERS

The commutator segments are made of carefully selected hard drawn copper. The mica between the segments is selected so as to wear evenly with the copper and the armature conductors are soldered directly into slots provided in the segments.

The brush-holder is of substantial construction and embodies all those features necessary in a first-class brush-holder. It is so attached to the brush-holder stud as to permit of its easy removal without disturbing any other brush-holders mounted upon the same stud, or any of the stud connections.

The brushes are of high grade carbon and slide in finished box guides. They are supplied with flexible copper pigtails of ample current carrying capacity and are held firmly against the commutator by a lever arm, which gives practically a uniform pressure throughout the whole wearing depth of the brush. An auxiliary spring of sufficient flexibility attached to the lower side of this lever, is used to allow the brushes to respond quickly

BRUSHES

to any irregularities of the commutator surface due to wear, thus preventing jumping and consequent sparking.

The brush-holder studs are of a novel and excellent design, being so mounted as to give a high insulation value between the current carrying parts of the stud and the brush-holder yoke.

It should be particularly noted that the stud holding nut at the back of the brush-holder yoke is dead, thus eliminating to a great extent the possibility of short circuiting between studs and making the machine safer to handle.

SPEED, VOLTAGE AND CAPACITY

The slow speeds at which the CVC generators operate minimize friction losses, but the machines are somewhat heavier and therefore more expensive to construct than machines of the same output and higher speed.

Standard CVC generators are compound wound, 125 to 125 volts and 250 to 250 volts full load, as shown in the table on page 10. The ratings are conservative and the machines will run at full load without undue rise of temperature of any part.

Standard CVC generators will deliver their output continuously without the temperature of any part rising more than 40 degrees C.

CVC BALANCER SET

above the surrounding air on the windings and 45 degrees C. on the commutator. They will operate for two hours at 25 per cent overload with a temperature rise not exceeding 55 degrees C. on the windings and 60 degrees C. on the commutator, or, they will stand momentary overloads of 50 per cent without injurious heating.

BALANCER SETS

These generators are particularly well adapted for use as balancer sets for three-wire systems. In such cases the design adopted is simple and compact, as shown in the accompanying illustrations. Two standard generator frames are riveted together through spacing blocks, and both armatures are mounted on a

CVC BALANCER SET DISASSEMBLED

common shaft which dispenses with the necessity of a third bearing common to this type of unit, and at the same time simplifies the construction and economizes floor space. The shaft between the armatures is strengthened by means of an intermediate armature head which increases the section, and therefore, the strength at the point of maximum deflection.

A fan is provided mounted between the armatures so as to draw in a sufficient volume of air through the interior portions of the two machines to keep the heating of all parts within conservative limits. Although these sets are enclosed in the middle, the same heating will be guaranteed as in standard CVC generators and the efficiencies are high.

The balancer sets can be placed across a three-wire 250 volt system and will compensate for unbalanced load in either side of the system. When the load is balanced, both machines operate as unloaded motors, but when unbalanced, one machine operates as a generator and the other as a motor, the combined current of the two machines compensating for the increased load on the generator side. Balancer sets are flat compounded so as to keep the voltage on each side equal, irrespective of the load.

These balancer sets afford a very convenient method for obtaining a neutral on three-wire systems, and can be used in systems of large capacity provided the amount of unbalancing between the two sets on the system does not necessitate a neutral current beyond the capacity of the set. To avoid misunderstanding, it is advisable when ordering these machines to give the voltage across the outside wires and the amount of current in the neutral, rather than the kilowatt capacity.

EXPLODED VIEW OF CVC GENERATOR

EXCITERS

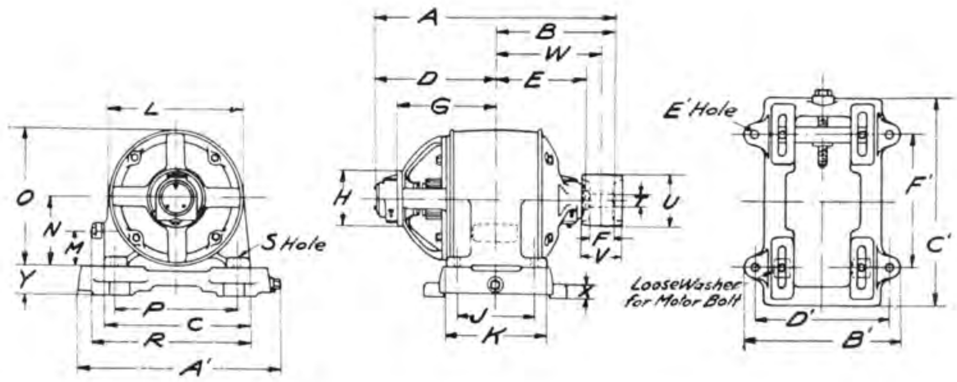
When large alternating current or direct current generators have their voltages automatically controlled by a voltage regulator, experience has shown that close regulation is best secured by means of a Type TA or TD regulator. If there is a sudden increase of load (due possibly to several elevators being started simultaneously) there is a momentary variation of voltage, resulting in a perceptible flicker of the incandescent lights. Automatic generator voltage regulators, Type TA or TD (formerly called Tirrill regulators), are universally recognized as absolutely necessary in such a case. The regulator maintains a constant voltage by varying the field current of the exciter, whose armature supplies current to the large generator field.

Obviously, therefore, an exciter must be capable of operating over a wide range of voltage without excessive sparking and also must respond quickly to changes in its field current. These requirements are taken into consideration in building the CVC exciters. As the sole manufacturers of the TA and TD regulators the General Electric Company is in the best position to know the requirements of a Tirrill regulator exciter.

The experience of 20 years has been utilized in constructing this new line. The results are that the CVC machines are equally serviceable as exciters for use with Tirrill regulators, as exciters for use without Tirrill regulators, or as direct current generators possessing that stability of voltage necessary in a machine which is to supply current to incandescent lights.

4812–10 Small Direct Current Generators, Belted, Type CVC

DIMENSIONS OF CVC GENERATORS



CLASSIFICATION: Type and Class	No. of Poles	Kw.	Speed	Volts No Load	Volts Full Load	Amp.	Volts No Load	Volts Full Load	Amps.	Wt. without Base	Wt. with Base	A	B	C	D	E	F	G	H	J	K	L	M	N	O	P	R	S	W	BASE: X	Y	A'	B'	C'	D'	E'	F'	PULLEY: T	U Dia.	V Face	Keyway
CV 111	2	1¼	1550	125	125	10	250	250	5	240	275	25	12½	15½	12½	9 5/16	2⅜	10¼	6¼	8½	11	14¾	4	7¼	14 7/16	13	16 11/16	41/64	11¾	1½	2¼	20¾	15¾	20	14¼	¾	12¾	1¼	4½	3½	2 3/16 x ¼ x ⅛
CVC 111	2	2	1550	125	125	16	250	250	8	275	310	25	12½	15½	12½	9 5/16	2⅜	10¼	6¼	8½	11	14¾	4	7¼	14 7/16	13	16 11/16	41/64	11¾	1½	2¼	20¾	15¾	20	14¼	¾	12¾	1¼	4½	3½	2 3/16 x ¼ x ⅛
		3	2100	125	125	24	250	250	12																																
CVC 112	2	3	1350	125	125	24	250	250	12	400	450	28 11/16	14¼	18	14 9/16	10⅞	3¼	12 1/16	6¾	9½	12½	16¾	4½	8½	16¼	15	19 11/16	43/64	13 3/16	1½	3¼	24¾	17½	24	15¾	⅞	15½	1⅜	5	4	3 1/16 x ⅜ x 3/16
		5	1800	125	125	40	250	250	20																																
CVC 113	2	5	1200	125	125	40	250	250	20	550	600	34	16 13/16	19	17 3/16	12 3/16	3⅜	14	7¼	9½	12½	18¼	4½	9¼	18 13/16	16	20½	43/64	15¾	1½	3¼	24¾	17½	24	15¾	⅞	15½	1½	5½	5	3 9/16 x ⅜ x 3/16
		7	1800	125	125	56	250	250	28																																
CVC 114	4	6¼	1050	125	125	52	250	250	26	775	845	37	17 13/16	21	19 3/16	12 13/16	4 11/16	15 13/16	8¾	11	14½	21¾	4	11	21 11/16	17½	22 13/16	43/64	15¾	1½	3¼	27¾	19	27	17¼	¾	16¾	1⅞	8	6¾	4 9/16 x ⅜ x 3/16
		12	1800	125	125	96	250	250	48																																
CVC 115	4	9½	975	125	135	76	250	250	38	975	1100	40¼	19⅜	23	20⅞	13 13/16	5 3/16	16 13/16	9⅝	12	15½	23½	4	12	23¾	19½	24 13/16	43/64	16 3/16	1¾	3¾	33½	21¼	32¾	19½	1	20¾	2	10	7¾	5 1/16 x ½ x ¼
		14	1425	125	125	112	250	250	56																																
CVC 116	4	14	750	125	125	112	250	250	56	1300	1425	44¾	21 1/16	26	23 11/16	15	5 11/16	19 3/16	10¼	12½	16½	26⅜	4¼	13½	26 13/16	22	27 13/16	53/64	18⅝	1¾	3¾	33½	21¼	32¾	19¼	1	20¾	2¼	11	9¾	5 9/16 x ½ x ¼
		20	1200	125	125	160	250	250	80																																

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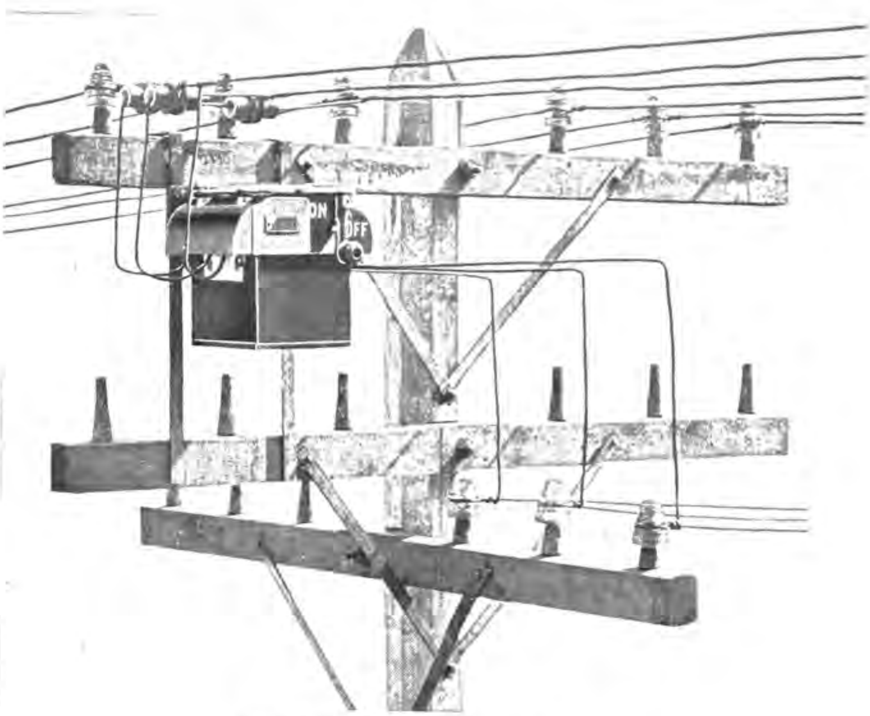
Schenectady, N.Y.

SUPPLY DEPARTMENT

January, 1911 *Bulletin No. 4813*

TYPE F FORM P OIL BREAK SWITCHES FOR POLE LINE SERVICE

The Type F Form P oil break switch has been developed primarily for outdoor pole line service and finds its most important application in that connection. It is adapted to use on alternating current series arc systems, for sectionalizing feeder systems, cutting in and out transformers, and similar classes of service requiring a switch to be operated under load. In many instances the use of a Form P switch in connection with a transformer will obviate the necessity of bringing high tension lines into the building. This switch introduces no complications in wiring and, on account of the very convenient construction of the frame, and the method of supporting the switch, it can be very easily installed.



TYPE F FORM P OIL BREAK SWITCH

The General Electric Company does not recommend the use of automatic switches for outdoor service, due to the effect of excessive cold on the automatic features, and the tendency of the oil to thicken or congeal at very low temperatures. While the thickening of the oil does not perceptibly interfere with the operation of a hand-operated switch, an automatic switch may be delayed or even prevented from opening due to the fact that it depends in a large measure upon gravity as the actuating force in opening. If automatic switches are required it is recommended that they be placed in the station where they will not be subjected to extremes in temperature.

Fig. 2

Construction

The switch, with the exception of the handle and crank, is enclosed in a cast iron weatherproof frame fitted with a removable cover. This cover is grooved on the under side to fit closely to the edge of the frame over a suitable gasket, and a detachable oil vessel fits around a flange at the bottom of the frame.

The stationary contacts are flared fingers of drop-forged copper, supported from the contact blocks of the current carrying copper studs by heavy flat steel springs. The studs are supported and insulated from the frame by porcelain insulators.

The movable contacts are wedge-shaped copper blades hinged at one end. They are actuated by specially treated wooden rods connected to a shaft which in turn is operated by the crank and handle outside of the frame.

The construction of the stationary and movable contacts is such that the arc is ruptured between the flared portion of the stationary contacts and the upper extremity of the movable contacts, saving the actual contact surfaces from burning or pitting. This feature of contruction insures clean contact surfaces and uniform contact pressure, and does not retard the opening of the switch.

The frame is so arranged that the switch can be mounted on a flat surface, or, by the use of strap iron hooks, on transmission pole cross arms, in a manner similar to that usually employed for mounting pole type transformers. (See Fig. 1.)

The oil vessel is of sheet metal with an insulation lining, and with barriers between the switch poles. It is securely attached to the frame but may be readily removed when desired. A horizontal red stripe on the oil receptacle (See Fig. 3) indicates the *exact* height to which the vessel should be filled, since proper air space above the oil is necessary for successful operation, and at the same time the contact surfaces should be completely submerged.

Sizes

The Form P switches are built in three sizes for use on 4500, 7500 and 15,000 volt circuits. The method of bringing the leads into the switch varies somewhat according to the voltage, but in every case they enter through porcelain bushings protected from the weather by the overhang of the frame (Fig. 1). The 4500 volt size is designed for use with insulated wire; while the bushings furnished with the 7500 and 15,000 volt size allow the use of bare wire.

Oil

For Form P oil break switches, the General Electric Company recommends the use of No. 6 transil oil, which has been developed especially for oil switch service. This oil is particularly adapted to this work because of its resistance to carbonizing and its high flashing point. For pole line switches, used in extremely cold climates, the General Electric Company can furnish a special oil adapted to this service.

Rupturing Capacities of Form P Switches

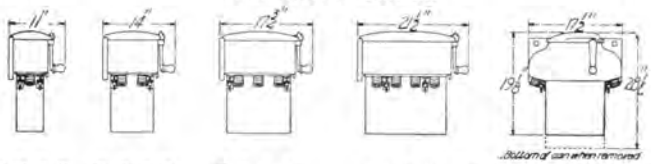
These switches have been designed to meet the average conditions of rupturing capacities on systems not exceeding 15,000 volts (see table). While an oil switch may be insulated for a given potential and designed to carry a definite current, it should not be understood that the switch will necessarily rupture that amount of normal energy, equivalent to the volt and ampere rating of the switch, in the event of a short circuit. Any source of electrical energy may have power greatly in excess of its normal capacity, and the switch may therefore be required to interrupt not merely the normal energy delivered to the circuit in which it is connected; but the entire power which may be developed under short circuit conditions by all generators and synchronous apparatus, in parallel, which are connected to the system. Under short circuit conditions, synchronous generators develop instantaneously many times their normal full load capacity, while the sustained short circuit current will be approximately two and one-half to three times normal.

Fig. 3

4500 VOLT SWITCHES

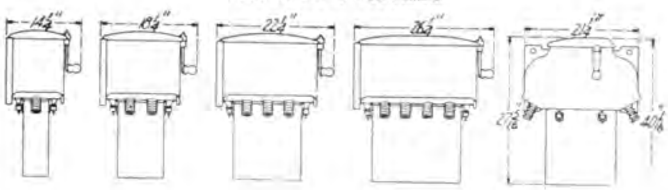
D. P. S. T. T. P. S. T. 4-P. S. T. COMMON END VIEW

7500 VOLT SWITCHES



S. P. S. T. D. P. S. T. T. P. S. T. 4-P. S. T. COMMON END VIEW

1500 VOLT SWITCHES



S. P. S. T. D. P. S. T. T. P. S. T. 4-P. S. T. COMMON END VIEW

Poles and Throw	Ampere Capacity	Voltage	Rupturing Capacity Kw.	Wt. in Lb. Boxed	Cat. No.	List Price
D.P.S.T.	100	4500	3000	125	44950	$33.00
T.P.S.T.	100	4500	4000	175	44951	40.00
4P.S.T.	100	4500	6000	225	44952	50.00
S.P.S.T.	200	7500	1500	175	59184	35.00
D.P.S.T.	200	7500	3000	200	59185	50.00
T.P.S.T.	200	7500	4000	250	59186	64.00
4P.S.T.	200	7500	6000	275	59187	80.00
S.P.S.T.	200	15000	1500	250	59188	60.00
D.P.S.T.	200	15000	3000	300	59189	82.00
T.P.S.T.	200	15000	4000	350	59190	102.00
4P.S.T.	200	15000	6000	400	59191	122.00

On alternating current railway systems, sectionalizing switches frequently are required to remain in the open position except when held closed. The 7500 volt and 15,000 volt, Form P switches can be arranged to release automatically as soon as the hand is removed, for an additional list price of $8.00.

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General Electric Company
Schenectady, N.Y.

SUPPLY DEPARTMENT

January, 1911 | | *Bulletin No. 4814*

FIELD RHEOSTATS, TYPE F

The selection of a field rheostat for a direct or alternating current generator should be made with great care. The three following essential points should be taken into consideration in making a choice; first, durability of construction thereby giving long operating life; second, low heating limits which allow of longer life to the insulation and materially reduce the fire hazard; and third, adaptability to handle the necessary range of variation in the field resistance, as failure in operation on the part of the rheostat means the shutting down of the generator. General Electric field rheostats have these energy in the form of heat, it is of special importance that their installation be studied from a standpoint of allowing ample ventilation and plenty of air space from any adjacent woodwork.

In order to minimize as much as possible the danger of breakage during transportation, many of the types of rheostats are packed with cardboard and excelsior which should be carefully removed before the apparatus is placed in service.

An important factor contributing to the continued success of any manually- or automatically-operated device is that the

Fig. 1
CR174 FIELD RHEOSTATS FOR MOUNTING ON FRONT OF SWITCHBOARD PANEL

primary features embodied in their construction.

An important requisite of a field rheostat is a sufficient number of divisions to give proper regulation of voltage, or to accurately adjust the speed of motors when the rheostats are used for that purpose. Before leaving the factory, all rheostats are thoroughly tested to make sure that they are free from electrical and mechanical defects. As they dissipate mechanism shall be kept clean and the bearings lubricated by an approved oil that will not deteriorate and interfere with the free action of the moving parts.

CR174 FIELD RHEOSTATS, TYPE F

These field rheostats embody all the essential features necessary for taking care of the field regulation of generators of moderate capacity. They are exceptionally rugged and occupy a minimum amount of space.

NOTE.—The data in this publication are for the convenience of customers, and every effort is made to avoid error, but this Company does not guarantee their correctness, nor does it hold itself responsible for any errors or omissions in this publication. Subject to change without notice.

As shown in Figs. 1 and 2, the construction of these field rheostats is in the form of plates with one or more assembled on common tie rods. This type includes ten-inch, twelve-inch, and fifteen-inch plates. The standard line employs ten-inch single, twelve-inch in combination of one or two and the fifteen-inch up to six plates. When more than one plate is used the standard method is to connect them in multiple as shown in Fig. 3.

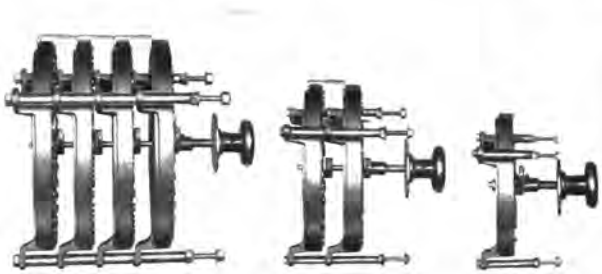


Fig. 2
CR174 FIELD RHEOSTATS FOR MOUNTING ON BACK OF SWITCHBOARD PANELS

The resistance coils for this type are of special alloy with a negligible temperature coefficient thus maintaining a constant resistance when in service. The coils are fastened in a compound base and protected by a special cement which is an excellent heat conductor and electrical insulator, the whole being fireproof throughout.

These rheostats are provided with buttons of ample contact surface and their arrangement with large clearance prevents an accumulation of dirt to cause short circuits.

Each size of rheostat is provided with a proportionately large number of steps. The ten-inch plates have 35, the twelve-inch plates 50, and the fifteen-inch plates 70 divisions of resistance.

In case of damage to any individual plate it may be replaced at a small expense. Each rheostat is provided with a handwheel of highly polished black material, thus conforming in finish to the present standard in switchboard instruments. Polished brass handwheels can be supplied if desired.

A drilling template is supplied with each rheostat to assist in switchboard mounting.

The standard rheostats are designed for use on 125, 250 and 550 volt circuits.

A clockwise rotation of the handwheel cuts in the resistance.

Sprocket-driven CR174 field rheostats are frequently furnished, using fifteen-inch plates (Fig. 4) which make a very compact self-contained construction.

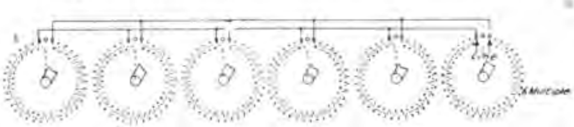


Fig. 3
CONNECTIONS OF CR174 FIELD RHEOSTATS

METHODS OF OPERATION

Oftentimes it is necessary to include more resistance for a given maximum current than can be embodied in the CR174 rheostats. This requires a rheostat of quite different design where the construction will readily permit of varying the number and size of the resistance units to suit conditions.

The "tube" and "grid" type of rheostats combine all the necessary features to meet these requirements.

With these types of rheostats four different methods of operation are applicable, i.e., sprocket, gear, ratchet and motor drive. The motor drive, however, is generally

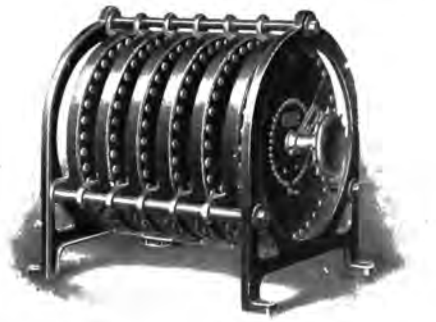


Fig. 4
SPROCKET-DRIVEN CR174 FIELD RHEOSTAT

employed where the switch is of large capacity, exceeding 350 amperes. In such rheostats iron grid resistance units are used.

All field rheostats, except those designed for mounting directly on the panel, are provided with insulating bushings in the feet.

Fig. 5
FORM P4 FIELD RHEOSTAT

The standard method of control for most rheostats not mounted on the panel is by chain and sprocket drive. There is, however, considerable choice in the standard operating mechanism.

FORM P FIELD RHEOSTATS, TYPE F

The Form P rheostats combine all the necessary features to meet the most exacting requirements.

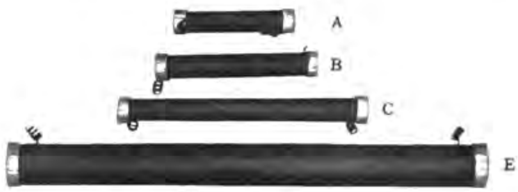


Fig. 6
FORM P TUBES—A, B, C AND E SIZES

The resistance (Form P units) consists of several units grouped together with ample allowance for ventilation.

The resistance material is wound on a cylindrical fireproof body and the whole coated with a protecting compound. Both

Fig. 7
FORM P5 FIELD RHEOSTAT, TYPE F

ends are insulated from the supporting framework by porcelain bushings. (Fig. 6.)

Rheostats containing the A, B and C size units can be rated as high as 25 amperes and are designed for mounting directly on the panel. This construction is not recommended, however, for small field rheostats, such as the CR174, "plate rheostats," are the most economical for this kind of service.

For the larger capacities where the Type E size units are used the standard maximum rating may be 50 amperes. These rheostats are made remote control, either by chain and sprocket, bevel gear or electric drive.

The dial switches on these rheostats have a large number of contacts and are especially rugged where the leads from the resistance are attached. The parts are mounted on a slate base and the switch arm is insulated from the shaft and operating mechanism. The arm is equipped with copper plunger brushes which are firmly pressed against the contact buttons by springs, thereby forming an excellent contact. This form of construction secures a maximum conductivity with a minimum amount of friction. (Fig. 9.) In addition to the switch arm insulation the toothed rims of all sprocket wheels, whether on the rheostat or part of the operating mechanism, are insulated from the hub.

Fig. 8
FORM P6 FIELD RHEOSTAT, TYPE F

Fig. 10
CR177 FORM C4 FIELD RHEOSTAT

Fig. 9
DIAL SWITCH FOR FORMS P AND C FIELD RHEOSTATS

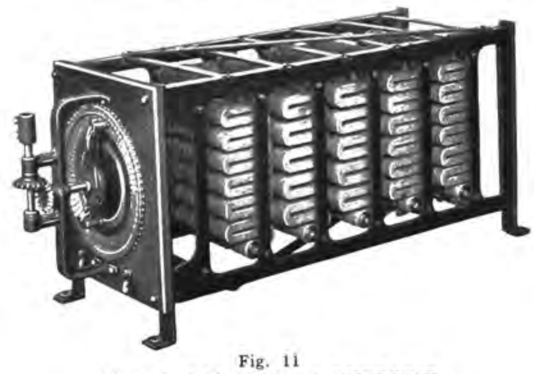


Fig. 11
CR177 FORM C5 FIELD RHEOSTAT

CR177 FIELD RHEOSTATS, TYPE F

Above the capacity of Form P units iron grid resistance is used. This construction is well adapted to carry heavy currents without deterioration through continued service. The grid units are insulated from the supporting framework with mica insulation, and the dial switches are of the plunger brush type. (Fig. 9.) These rheostats are usually arranged for sprocket or gear control.

If the rheostat with a desired combination of resistance is not listed for any particular voltage, say 110 or 220 volts, one with a proper resistance and ampere capacity but for a higher voltage can be used. A rheostat, however, should not be used on a voltage much greater than its nominal rating.

CR178 SOLENOID-OPERATED FIELD RHEOSTATS

In many installations it is not possible to locate the rheostat so that the dial switch can be operated from a handwheel on the panel. CR178 electrically-operated field rheostats are the same as CR177 sprocket-driven rheostats, except that they are provided with an electrically-operated ratchet switch (Fig. 13) instead of the sprocket-driven switch. (Fig. 10.) It is possible to locate these rheostats in any part of the station and control the generator voltage by the use of a single-pole double-throw switch on the panel. In ordering this type of rheostat the method of mounting should always be given, as the solenoids are designed to operate below the switch dial only.

Fig. 12
CR178 FORM C6 FIELD RHEOSTATS, TYPE F

These electrically-operated switches are known separately from the rheostat as CR 179. The smaller sizes are also adaptable to the rheostats with the Form P resistance. (Fig. 8.)

CR179 SOLENOID OPERATED FIELD RHEOSTAT SWITCHES

These switches (CR179) are designed particularly for remote control of rheostats having a maximum capacity from 25 to 350 amperes, and their use is recommended instead of motor- or hand-operated switches. Their use is not limited, however, to the operation of field rheostats, but can be employed for cutting in or out resistance from a remote point where the automatic "no voltage" or "overload release" features are not necessary.

All standard switches have coils wound for 125 volts. If this potential is not available they can be wound for a two to one ratio up to 250 volts or any fixed voltage up to 600 volts. The dial switches are designed for standard voltages up to and including 600 volts and are made in five sizes, viz:

25 amperes with 30 divisions
50 amperes with 70 divisions
100 amperes with 65 divisions
200 amperes with 46 divisions
350 amperes with 40 divisions

Fig. 13
CR179 100 AMPERE RATCHET-DRIVEN FIELD RHEOSTAT SWITCH

Operation

The switch arm is carried around by pawls which engage the knurled rim of a wheel to which the switch arm is rigidly fastened. These pawls are controlled by a core actuated in common by the solenoids AA. (Fig. 14.) When the solenoids are de-energized the pawls are disengaged and in their normal position rest equidistant from the solenoids as shown in Fig. 13. To cut resistance into the field, close to the left the single-pole switch B. (Fig. 14.) This energizes the left-hand sole-

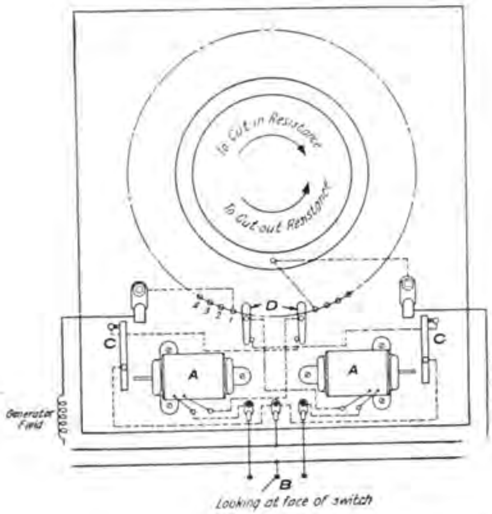


Fig. 14
CONNECTIONS OF CR179 SOLENOID-OPERATED RATCHET-DRIVEN FIELD RHEOSTAT SWITCH

noid, engages the left-hand pawl and moves the dial switch in a clockwise direction. When the solenoid core has reached its extreme point of travel, the winding of the solenoid is automatically open-circuited by the small switch C, and the pawl is immediately pulled to its neutral position by a spring, automatically closing the circuit of the solenoid switch by the small switch C. The same cycle of operation is then repeated until the switch B is opened. If it be desired to cut resistance out of the field circuit the single-pole switch B should be closed to the right—when the same cycle of operation is performed and the dial switch moves in a counter-clockwise instead of a clockwise direction. Each end of the switch dial is provided with a limit switch D (Fig. 14) which is automatically operated by the switch arm to open the circuit of the solenoid when the resistance is entirely cut in or out. The purpose of this limit switch, D, is simply to protect the apparatus in case the controlling circuit is left closed when the dial switch has reached its extreme point of travel in either direction.

Regulation

With this type of electrically-operated switch, perfect and reliable adjustment of the rheostat resistance can be obtained at a minimum cost of apparatus. It is evident from the construction of the switch that there are no heavy high speed revolving parts which will continue to cut in or out resistance after the main control circuit has been opened. In other words, the exact desired amount of resistance can be cut in or out of the circuit.

Fig. 15
MOTOR-OPERATED FIELD RHEOSTAT, TYPE F

Advantages

Some of the advantages of this type of switch as compared with motor-operated switches can be summarized as follows:

Costs less
Closer regulation
Less space required
Lighter
Can be made self-contained
Easier to duplicate parts for repairs
Requires less attention

MOTOR-DRIVEN FIELD RHEOSTAT

For field circuits above 350 amperes the motor-operated type of rheostat (Fig. 15) is the most practical, as the heavy contact on the dial switch is not easily overcome with the solenoid or handwheel control. The standard switch includes a series wound 115 volt motor with a field winding enabling the dial switch to be operated in either direction by a single-pole double-throw controlling switch. The switch base is mounted on pipe supports in order that all moving parts and connections may be readily accessible. As in the CR179 switches, each end of the switch dial is provided with a limit switch which is automatically operated by the switch arm to open the motor circuit.

4814-8 Field Rheostats, Type F

DIMENSIONS CR174 FIELD RHEOSTATS, TYPE F

125 VOLTS

Cat. No. Front of Panel	Cat. No. Back of Panel	Ohms	Ampere Capacity First Step	Ampere Capacity Last Step	Ohms of Field to which Rheostat is Suited	No. of Plates in Multiple	* Diam. in In. of Plates
43576	43577	300	.5	.25	300–250	1	10
43578	43579	240	.63	.32	250–200	1	10
43580	43581	200	.75	.38	200–165	1	10
43582	43583	150	1	.5	165–125	1	10
43584	43585	120	1.25	.63	125–100	1	10
43586	43587	100	1.5	.75	100– 80	1	10
43588	43589	75	2	1	80–60	1	10
43590	43591	60	2.5	1.25	60–50	1	10
43592	43593	50	3	1.5	50–40	1	10
43594	43595	37.5	4	2	40–30	1	10
43596	43597	30	5	2.5	30–25	1	12
43598	43599	25	6	3	25–20	1	12
43600	43601	18.8	8	4.	20–16	1	12
43602	43603	15	10	5	16–13	1	15
64636	64637	12.5	12.5	6.3	13–10	2	12
43606	43607	9.4	16	8	10–8	2	12
43608	43609	7.5	20	10	8–6.5	2	15
64638	64639	6.3	25	12.5	6.5–6	3	15
43612	43613	5	30	15	5–4.2	3	15
43614	43615	3.75	40	20	4.2–3.1	4	15
43616	43617	3	50	25	3.1–2.5	5	15
43618	43619	2.5	60	30	2.5–2.1	6	15

250 VOLTS

Cat. No. Front of Panel	Cat. No. Back of Panel	Ohms	Ampere Capacity First Step	Ampere Capacity Last Step	Ohms of Field to which Rheostat is Suited	No. of Plates in Multiple	* Diam. in In. of Plates
43620	43621	300	1	.5	300–250	1	10
43622	43623	240	1.25	.63	250–200	1	10
43624	43625	200	1.5	.75	200–165	1	10
43626	43627	150	2	1	165–125	1	10
43628	43629	120	2.5	1.25	125–100	1	12
43630	43631	100	3	1.5	100– 85	1	12
43632	43633	75	4	2	85–63	1	12
43634	43635	60	5	2.5	63–50	1	15
43636	43637	48	6.3	3.2	50–40	1	15
43638	43639	37.5	8	4	40–30	2	12
43640	43641	30	10	5	30–25	2	15
43642	43643	25	12.5	6.3	25–20	2	15
43644	43645	20	15	7.5	20–16.5	3	15
43646	43647	15	20	10	16.5–12.5	4	15
43648	43649	12	25	12.5	12.5–10	5	15
43650	43651	10	30	15	10–8.3	6	15

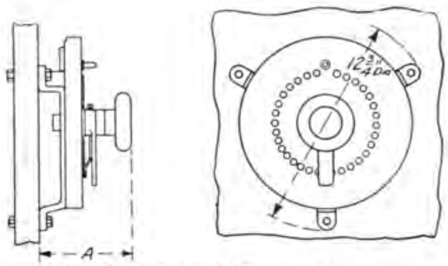
*Ten-inch plates have 36 contact buttons, 12-inch plates have 51 contact buttons, and 15-inch plates have 71 contact buttons.

DIMENSIONS CR174 FIELD RHEOSTATS, TYPE F—Continued

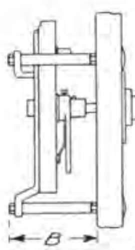
CAT. NO.		Ohms	AMPERE CAPACITY		Ohms of Field to which Rheostat is Suited	No. of Plates in Multiple	* Diam. in In. of Plates
Front of Panel	Back of Panel		First Step	Last Step			
550 VOLTS							
49144	49145	2000	.6	.3	1000–830	1	15
49146	49147	1600	.7	.35	830–700	1	15
49148	49149	1300	.76	.38	700–650	1	15
49150	49151	1000	.84	.40	650–600	1	12
49152	49153	800	.9	.45	600–550	1	12
43652	43653	600	1	.5	550–500	1	10
43654	43655	480	1.25	63	500–400	1	10
43656	43657	400	1.5	.75	400–330	1	12
43658	43659	300	2	1	330–250	1	12
43660	43661	250	2.5	1.25	250–200	1	15
43662	43663	200	3	1.5	200–165	1	15
43664	43665	150	4	2	165–125	2	12
43666	43667	125	5	2.5	125–100	2	15
43668	43669	100	6	3	100– 85	2	15
43670	43671	82	7.5	3.8	85–65	3	15
43672	43673	60	10	5	65–50	4	15
43674	43675	50	12.5	6.3	50–40	5	15
43676	43677	40	15	7.5	40–35	6	15

* Ten-inch plates have 36 contact buttons, 12-inch plates have 51 contact buttons, and 15-inch plates have 71 contact buttons.

10-INCH PLATE



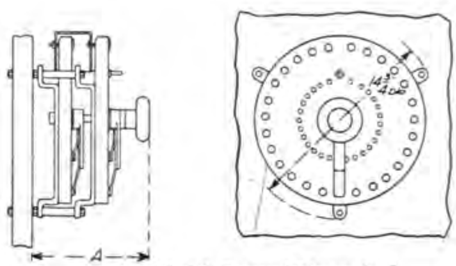
Front of Board Rheostat



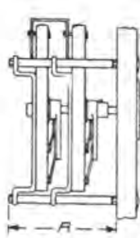
Back of Board Rheostat

No. of Plates	DIMENSIONS IN INCHES	
	A	B
1	$5\frac{1}{2}$	$4\frac{5}{16}$
2	$8\frac{11}{16}$	$7\frac{5}{8}$

12-INCH PLATE

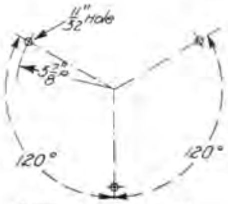


Front of Board Rheostat

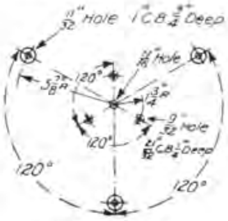


Back of Board Rheostat

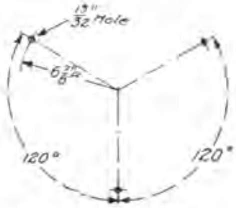
No. of Plates	DIMENSIONS IN INCHES	
	A	B
1	$5\frac{1}{2}$	$4\frac{5}{8}$
3	$8\frac{11}{16}$	$7\frac{3}{8}$



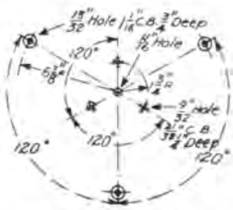
Drilling for Front of Board Rheostat



Drilling for Back of Board Rheostat



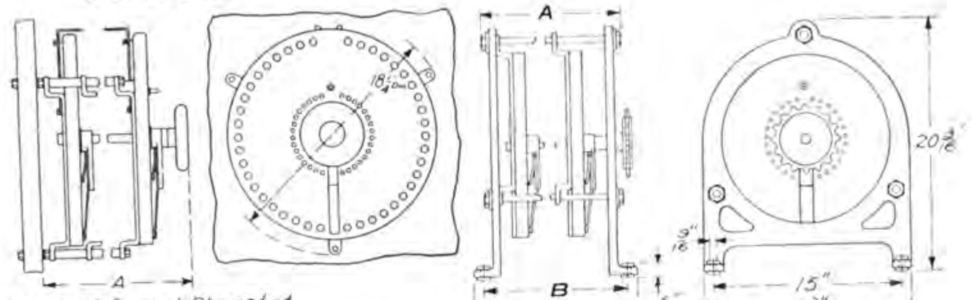
Drilling for Front of Board Rheostat



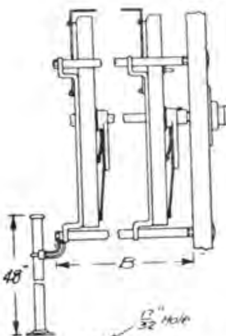
Drilling for Back of Board Rheostat

DIMENSION CR174 FIELD RHEOSTATS, TYPE F—Continued

15-INCH PLATE



Front of Board Rheostat

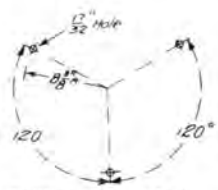


Back of Board Rheostat

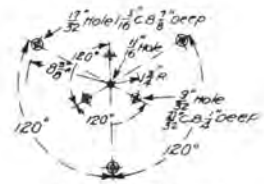
No. of Plates	DIMENSIONS IN INCHES	
	A	B
1	$5\frac{1}{2}$	$4\frac{3}{4}$
2	$8\frac{13}{16}$	$7\frac{1}{2}$
3	$11\frac{5}{16}$	$10\frac{1}{4}$
4	$14\frac{1}{16}$	13
5	$17\frac{1}{16}$	$15\frac{3}{4}$
6	$19\frac{11}{16}$	$18\frac{1}{2}$

No. of Plates	DIMENSIONS IN INCHES		
	A	B	C
1	$5\frac{7}{8}$	$6\frac{5}{16}$	$7\frac{7}{8}$
2	$8\frac{5}{8}$	$9\frac{1}{16}$	$10\frac{5}{8}$
3	$11\frac{3}{8}$	$11\frac{13}{16}$	$13\frac{3}{8}$

No. of Plates	DIMENSIONS IN INCHES		
	A	B	C
4	$14\frac{1}{8}$	$14\frac{9}{16}$	$16\frac{1}{8}$
5	$16\frac{7}{8}$	$17\frac{5}{16}$	$18\frac{7}{8}$
6	$19\frac{5}{8}$	$20\frac{1}{16}$	$21\frac{5}{8}$



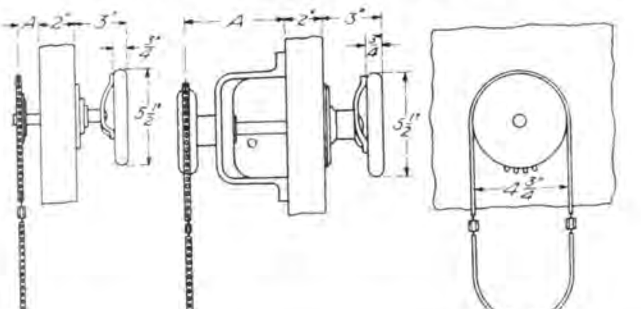
Drilling for Front of Board Rheostat



Drilling for Back of Board Rheostat

The support shown on the extreme left of illustration is furnished only with five- and six-plate back of panel rheostats.

OPERATING MECHANISMS FOR SPROCKET-DRIVEN RHEOSTATS



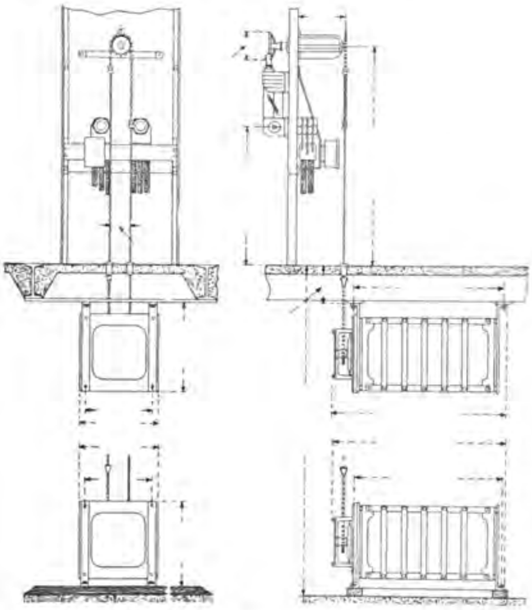
The above diagram illustrates the general appearance and gives outline dimensions of standard operating mechanisms furnished with CR177 (Type F) rheostats.

Requisitions should state clearly which style is required.

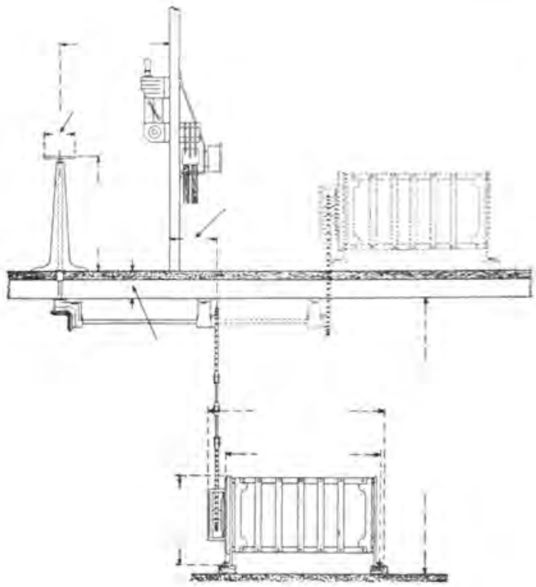
OPERATING MECHANISMS FOR SPROCKET-DRIVEN RHEOSTATS—Continued

Cat. No.	Description	Cat. No.	Description
49492	"A" Dimensions—⅜ in.	49495	"A" Dimensions—6⅜ in.
49493	"A" Dimensions—1¼ in.	49496	"A" Dimensions—12 in.
49494	"A" Dimensions—3¾ in.	49497	"A" Dimensions—16½ in.

Catalogue number of operating mechanisms includes handwheel, sprocket wheel support, dial plate, shaft and chain.



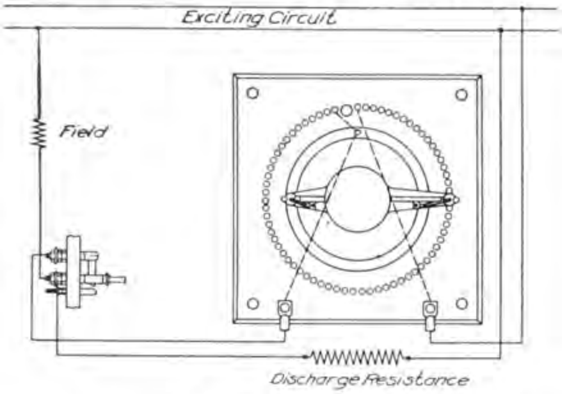
Rheostat Operated from Switchboard

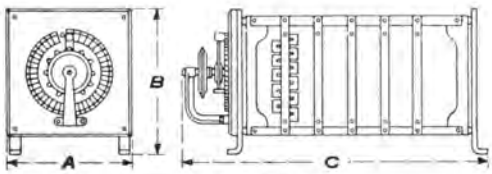


Rheostat Operated from Pedestal

4814-12 Field Rheostats, Type F

DIMENSIONS CR177 FORM C FIELD RHEOSTATS, TYPE F





125 VOLTS

Resis. in Ohms	MAX. AMPS.		APPROXIMATE DIMENSIONS IN INCHES PER BOX			Boxes per Rheostat	Switch Contacts
	First Step	Last Step	A	B	C		
2	80	40	18½	20	42	1	70
1.5	100	50	18½	23	45	1	70
1.2	125	62.5	18½	23	62	1	48
1	150	75	20	24	64	1	48
.75	200	100	20	24	64	1	48
.6	250	125	20	24	76	1	40
.5	300	150	20	24	56	2	40
.43	350	175	20	24	70	2	40

250 VOLTS

Resis. in Ohms	First Step	Last Step	A	B	C	Boxes per Rheostat	Switch Contacts
7.5	40	20	18½	20	48	1	74
6	50	25	20	20	48	1	74
5	60	30	20	20	48	1	70
4	80	40	20	20	64	1	70
3	100	50	20	24	67	1	70
2.5	125	62.5	20	24	76	1	48
2	150	75	20	24	56	2	48
1.5	200	100	20	24	70	2	48
1.25	250	125	20	24	76	2	40
1	300	150	20	24	67	3	40
.83	350	175	20	24	76	3	40

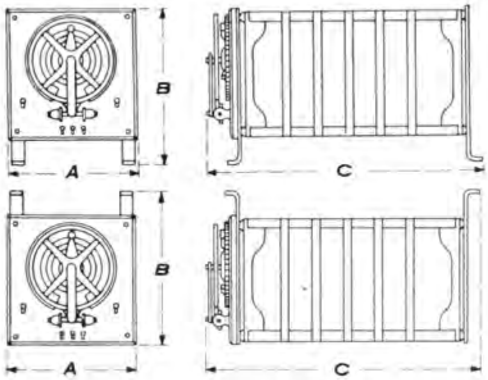
DIMENSIONS CR177 FORM C FIELD RHEOSTATS, TYPE F—Continued

Resis. in Ohms	Max. Amps. First Step	Max. Amps. Last Step	Approximate Dimensions in Inches per Box A	B	C	Boxes per Rheostat	Switch Contacts
500 VOLTS							
12	50	25	20	20	48	2	74
10	60	30	20	20	48	2	70
7.5	80	40	20	20	64	2	70
6	100	50	20	24	70	2	70
5	125	62.5	20	24	64	3	48
4	150	75	20	24	70	3	48
3	200	100	20	24	70	4	48
2.5	250	125	20	24	76	4	40

DIMENSIONS CR178 RATCHET-DRIVEN FIELD RHEOSTATS, TYPE F

Resis. in Ohms	Max. Amps. First Step	Max. Amps. Last Step	Boxes per Rheostat	Switch Contacts
125 VOLTS				
2	80	40	1	65
1.5	100	50	1	65
1.2	125	62.5	1	46
1	150	75	1	46
.75	200	100	1	46
.6	250	125	1	40
.5	300	150	2	40
.43	350	175	2	40
250 VOLTS				
7.5	40	20	1	70
6	50	25	1	70
5	60	30	1	65
4	80	40	1	65
3	100	50	1	65
2.5	125	62.5	1	46
2	150	75	2	46
1.5	200	100	2	46
1.25	250	125	2	40
1	300	150	3	40
.85	350	175	3	40
500 VOLTS				
12	50	25	2	70
10	60	30	2	65
7.5	80	40	2	65
6	100	50	2	65
5	125	62.5	3	46
4	150	75	3	46
3	200	100	4	46
2.5	250	125	4	40

DIMENSIONS CR178 RATCHET-DRIVEN FIELD RHEOSTATS, TYPE F—Continued



125 VOLTS

Resis. in Ohms	Max. Amps. First Step	Max. Amps. Last Step	Approx. Dimensions in Inches per Box A	B	C	Boxes per Rheostat
2	80	40	18½	20	40	1
1.5	100	50	18½	20	42	1
1.2	125	62.5	18½	20	60	1
1	150	75	20	24	62	1
.75	200	100	20	24	62	1
.6	250	125	20	24	74	1
.5	300	150	20	24	54	2
.43	350	175	20	24	68	2

250 VOLTS

Resis. in Ohms	Max. Amps. First Step	Max. Amps. Last Step	A	B	C	Boxes per Rheostat
7.5	40	20	18½	20	46	1
6	50	25	20	20	46	1
5	60	30	20	20	46	1
4	80	40	20	20	62	1
3	100	50	20	24	65	1
2.5	125	62.5	20	24	74	1
2	150	75	20	24	54	2
1.5	200	100	20	24	68	2
1.25	250	125	20	24	74	2
1	300	150	20	24	65	3
.85	350	175	20	24	74	3

500 VOLTS

Resis. in Ohms	Max. Amps. First Step	Max. Amps. Last Step	A	B	C	Boxes per Rheostat
12	50	25	20	20	46	2
10	60	30	20	20	46	2
7.5	80	40	20	20	62	2
6	100	50	20	24	68	2
5	125	62.5	20	24	62	3
4	150	75	20	24	68	3
3	200	100	20	24	68	4
2.5	250	125	20	24	74	4

DIMENSIONS CR179 RATCHET-DRIVEN FIELD RHEOSTAT SWITCHES, TYPE F

The following table gives dimensions for different sizes of the solenoid-operated ratchet-driven field rheostat switch illustrated in Figs. 13 and 14, the letter A being the width, B the height, and C the thickness of the panel:

Capacity in Amperes	DIMENSIONS IN INCHES			Divisions
	A	B	C	
25	13	13	1	30
50	18½	18½	1	70
100	18½	18½	1	65
200	20	18½	1	46
350	20	21	1	40

GENERAL ELECTRIC COMPANY

PRINCIPAL OFFICES, SCHENECTADY, N. Y.

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Erie, Pa.	632 State Street
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ATLANTA, GA.	Empire Building
Birmingham, Ala.	Brown-Marx Building
Macon, Ga.	Grand Building
New Orleans, La.	Maison-Blanche Building
CINCINNATI, OHIO	Provident Bank Building
Columbus, Ohio	Columbus Savings & Trust Building
Cleveland, Ohio	Citizens Building
Chattanooga, Tenn.	James Building
Memphis, Tenn.	Randolph Building
Nashville, Tenn.	Stahlman Building
Indianapolis, Ind.	Traction Terminal Building
CHICAGO, ILL.	Monadnock Building
Detroit, Mich.	Majestic Building (Office of Soliciting Agent)
St. Louis, Mo.	Wainwright Building
Kansas City, Mo.	Dwight Building
Butte, Montana	Electric Building
Minneapolis, Minn.	410-412 Third Ave., North
DENVER, COLO.	First National Bank Building
Salt Lake City, Utah	Newhouse Building
SAN FRANCISCO, CAL.	Nevada Bank Building
Los Angeles, Cal.	124 West Fourth Street
Portland, Ore.	Electric Building
Seattle, Wash.	Colman Building
Spokane, Wash.	Paulsen Building

For TEXAS and OKLAHOMA Business refer to
General Electric Company of Texas,

Dallas, Tex.	Praetorian Building
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FOREIGN

FOREIGN DEPARTMENT,
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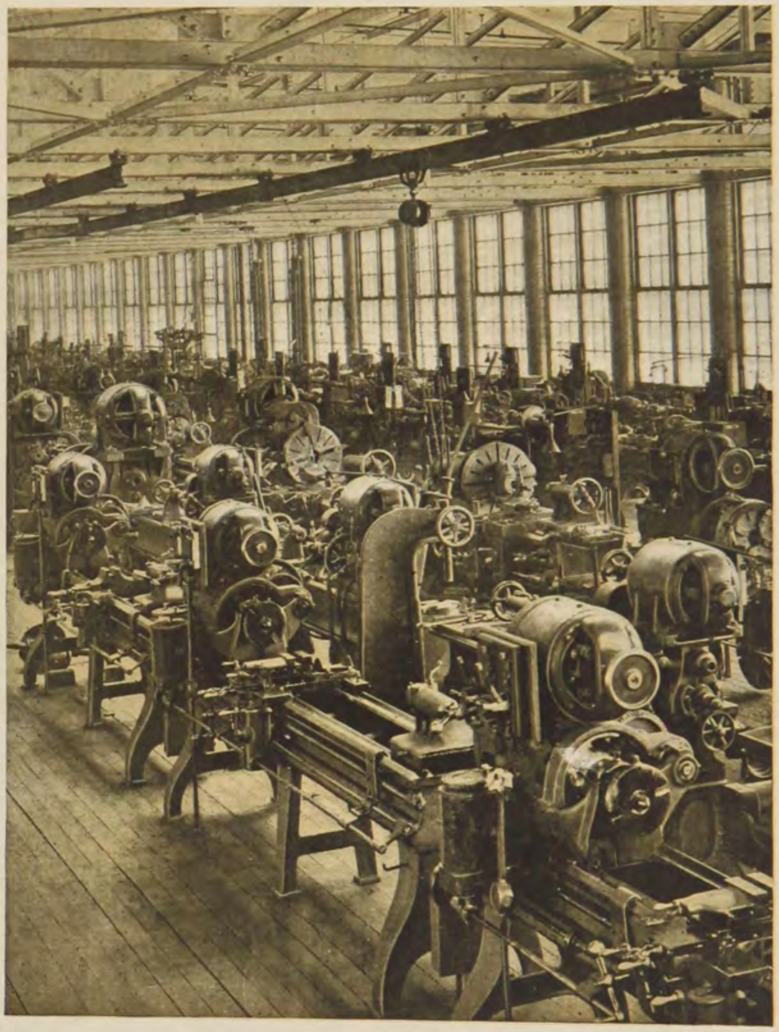
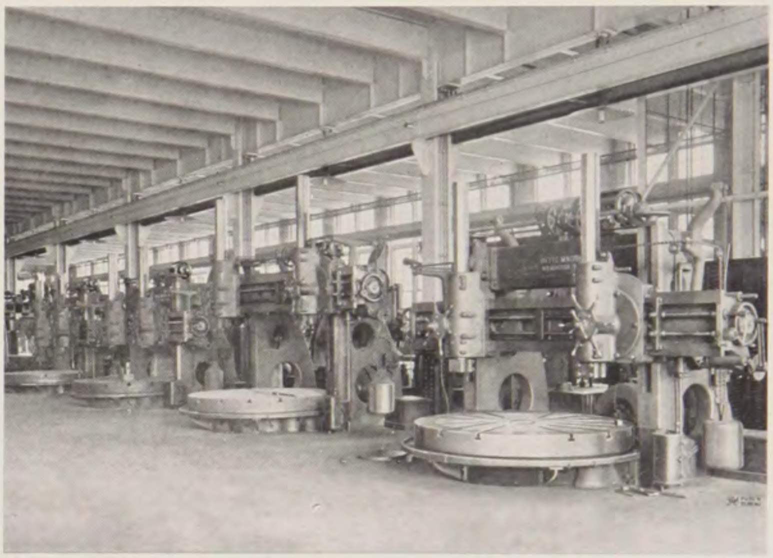
MOTOR DRIVE FOR METAL WORKING MACHINERY



GENERAL ELECTRIC COMPANY
SCHENECTADY, N.Y.

Motor Drive for Metal Working Machinery



General Electric Company

Schenectady, New York

February, 1911

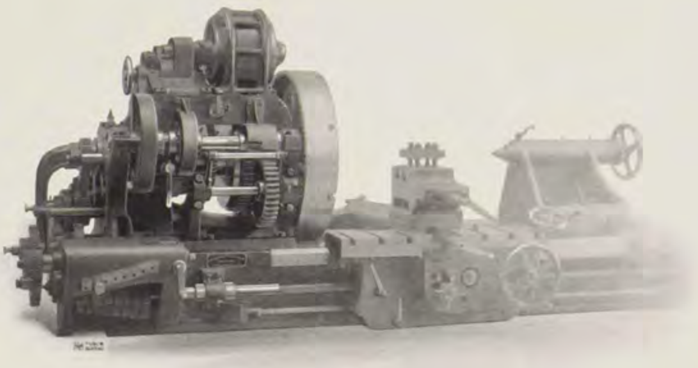
No. 4815

Supersedes 4548

hwg

COMPLETE DESCRIPTIONS AND QUOTATIONS COVERING MOTORS AND MOTOR ACCESSORIES ILLUSTRATED IN THIS PUBLICATION WILL BE PROMPTLY FORWARDED UPON REQUEST TO THE NEAREST GENERAL ELECTRIC CO. SALES OFFICE. (See listing on last page).

Motor Drive for Metal Working Machinery



JOHNSON CO. 36-IN. LATHE DRIVEN BY TYPE I-8, 20 H.P., 900 R.P.M., 60 CYCLE THREE-PHASE MOTOR

The illustrations shown herewith indicate a few of the many excellent methods of properly and economically applying either alternating or direct current motor drive to metal working machinery. Motor drive in the metal working industries having been successfully employed for a number of years and the resultant benefits now being so widely appreciated, the following brief introductory paragraphs are only intended to recall a few of the particularly salient points of merit attending the adaptation of this wonderfully efficient, flexible and economical form of power.

INCREASED PRODUCTION

One of the most important phases influencing the successful conduct of any manufacturing establishment is the amount of OUTPUT obtainable with a given personnel, tool equipment, floor space and working time. Without increasing any of these factors, the substitution of mechanical drive by the installation of electric motors has variously augmented the productive capacity of different shops from 5 to 100 per cent. In other words, a greater amount of work is produced per operative machine per day, due to maintenance of speed under varying conditions of load; the ease by which the maximum cutting speed can be sustained throughout a given operation; the advantage gained by better arrangement of machines in regard to natural or artificial lighting facilities, as well as in the readier access to and sequence of material from the unfinished to the finished state; finally, because the greater cleanliness, purer air and generally better hygienic surroundings of the motor-driven shop react favorably upon the health, cheerfulness and ACTIVITY of the operatives.

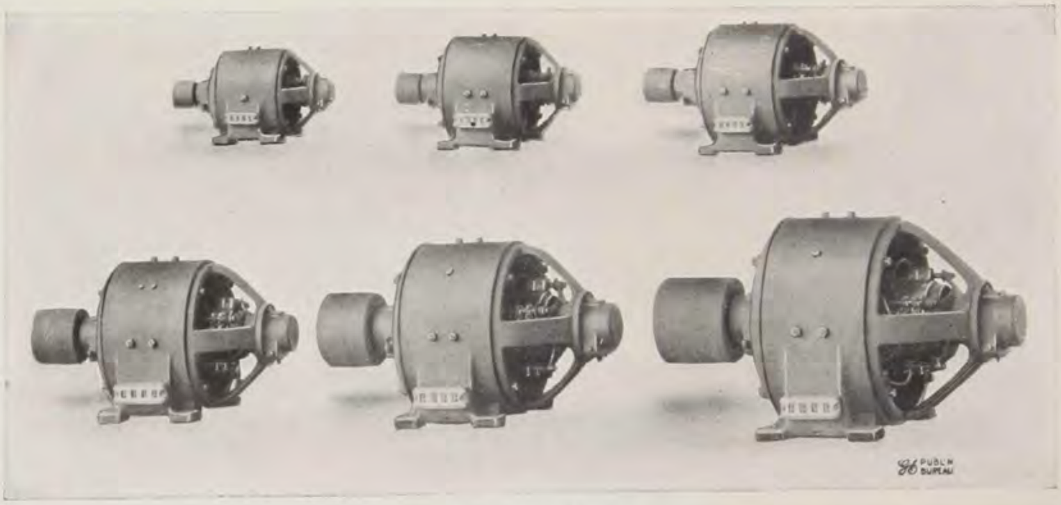
ECONOMY OF POWER While increased production is obviously the most important result attained by the installation of electric drive, it is also true that direct economies are very frequently effected in the power costs. Apart from the saving in energy made possible by the ability of the operator to shut down those machines not engaged in productive work, the elimination of shafting, belts, pulleys, idlers, etc.,—which form an indispensable part of any mechanical system of drive—must of necessity result in important power economies, especially if it is remembered that mechanical drives often consume from one-half to four times the energy required by the machines themselves. With individual motor drive the maximum power is made effective at the tool itself.

EASE OF CONTROL The many and efficient types of electric controllers now commercially available, enable the operator to vary the tool speed readily and quickly by simply moving a handle which may be conveniently located for ready manipulation.

The tendency on the part of workmen to avoid irksome belt shifts often has for result, the insistent use of incorrect cutting speeds. The physical ease accompanying electric control entirely removes this temptation, at once expediting the work and enhancing PRODUCTIVE CAPACITY.

ARRANGEMENT OF TOOLS Where individual motors are employed, the most convenient and logical location of the machines may be secured, space easily provided for additional machines, use of overhead cranes facilitated, and other requisites to a profitably conducted shop made possible.

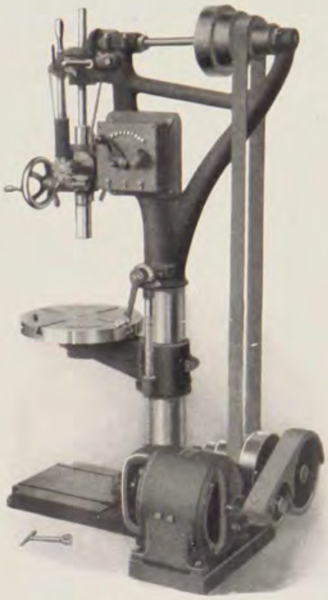
RELIABILITY Night or day, electric motors are always ready—a rush job requiring the partial use of the machine equipment can be put through without entailing disproportionate power costs. The maintenance charge for electric drive is negligible, since expensive belt renewals, oiling and care of shafting hangers, etc., are largely eliminated. All GENERAL ELECTRIC CO. motors are of simple and sturdy construction, and apart from occasional oiling, require practically no attention. As all component parts of a given size and type of G-E motor product are made strictly interchangeable and liberally stocked, replacements can be easily and promptly effected.



GROUP OF CVC MOTORS

SOME EXAMPLES OF GENERAL ELECTRIC MOTORS APPLIED TO MACHINE TOOLS

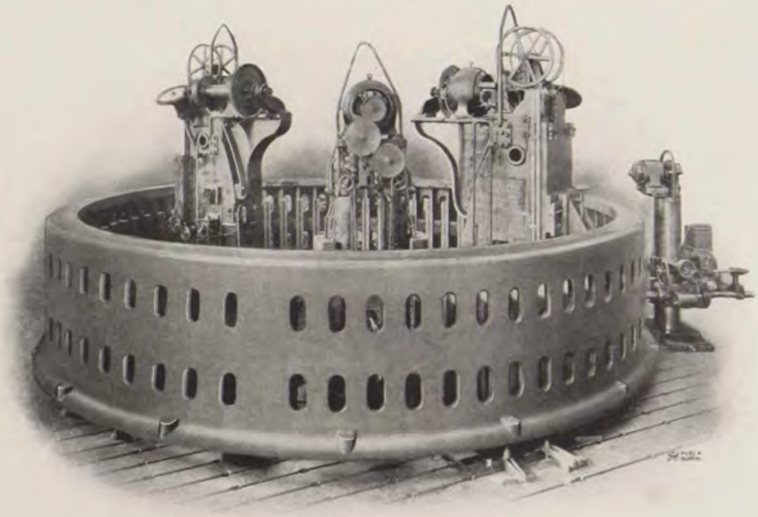
For sensitive drills and drill presses, a constant speed motor meets the usual requirements. The illustrations (pages 5 and 6) show that motors may often be applied to machines originally designed for mechanical drives, the change over being effected with practically the same simplicity and ease attendant where the apparatus is especially arranged for individual electric drive.



HAMILTON 20-IN. DRILL PRESS DRIVEN BY CQ-1, 1 H.P., 1275 R.P.M., 230 VOLT MOTOR

SNYDER 21-IN. DRILL PRESS DRIVEN BY KQ-4, 2 H.P. INDUCTION MOTOR

With individual drive only the power actually used for the work in hand is paid for. With mechanical drives, idle machines and their auxiliary transmission systems waste power and consume the profits.



APPLICATION OF INDIVIDUALLY DRIVEN TOOLS TO MACHINING FRAME CASTING OF A LARGE A.C. GENERATOR (NEWTON MACHINE TOOLS)

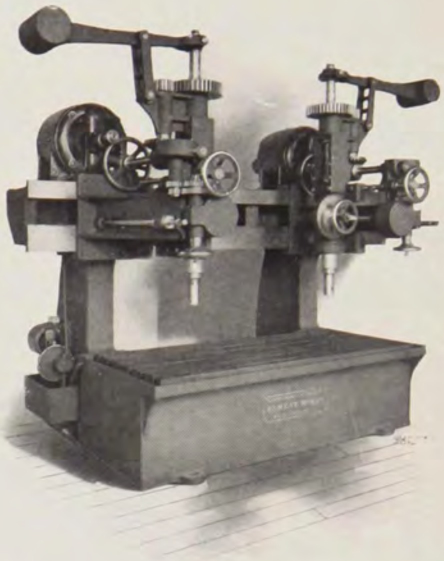
The use of portable motor-driven equipments often ENABLES THE TOOL TO BE CARRIED TO THE WORK—an important consideration where the work is of heavy character.

No idle shafting or belts necessary with drills driven by individual motors.

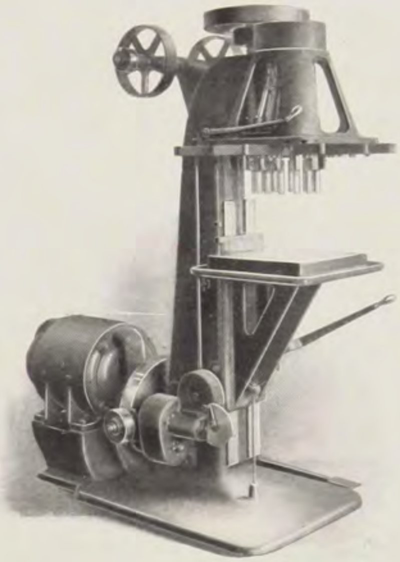
The motor and drill form a complete unit economical in floor space, easily controlled and efficiently operated.

Note compactness of outfits and facility of control.

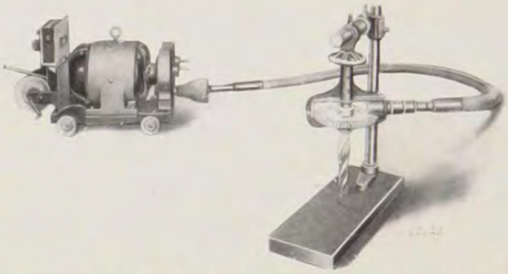
Work can be carried between individually driven machines from any direction, due to freedom from obtruding belts or shafts.



NILES-BEMENT-POND CO. DOUBLE HEADED DRILL EQUIPPED WITH TWO RL MOTORS

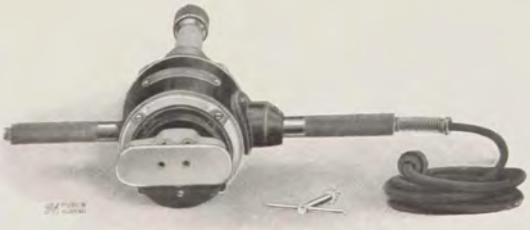


PRATT & WHITNEY MULTIPLE DRILL WITH ENCLOSED ADJUSTABLE SPEED RL MOTOR



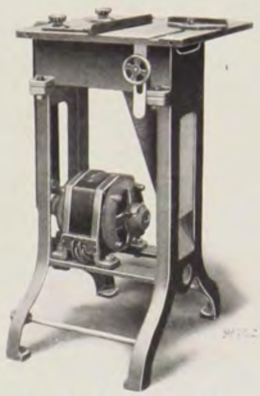
STOW FLEXIBLE SHAFT PORTABLE DRILLING OUTFIT AND CQ MOTOR

G-E portable breast drills are light in weight, easily manipulated and efficient both in current consumption and operation. These devices are indispensable in the displacement of all small drilling by costly and slow manual methods.



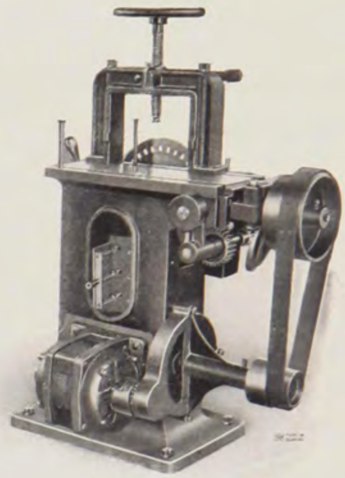
DIRECT CURRENT PORTABLE DRILL

ALTERNATING CURRENT PORTABLE DRILL

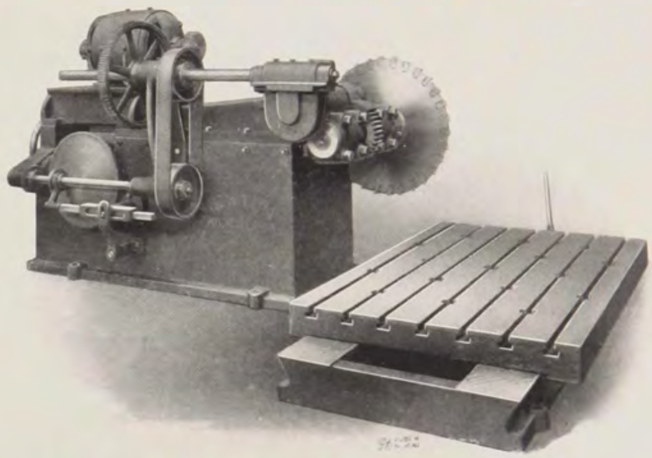


"HUB" METAL CUTTING SAW WITH KQ-4, 1 H.P., 1800 R.P.M. ALTERNATING CURRENT MOTOR

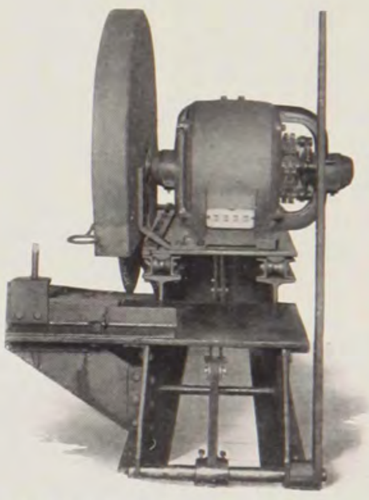
Simple and effective methods of individually driving metal saws.



HIGLEY COLD SAW DRIVEN BY KT-4, 2 H.P., 1800 R.P.M. INDUCTION MOTOR



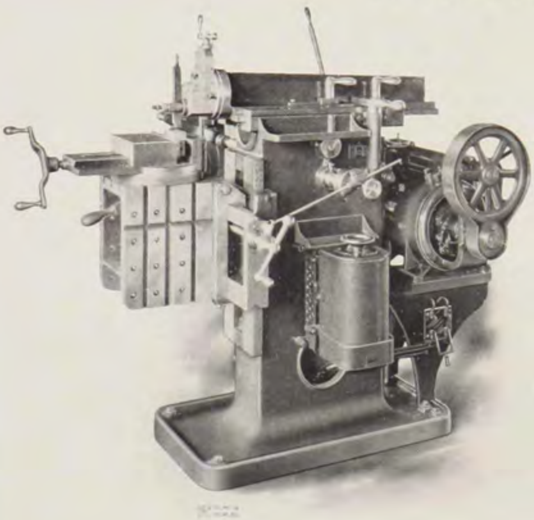
NEWTON COLD SAW DRIVEN BY RL MOTOR



THE RYERSON HIGH SPEED FRICTION SAW. SAW DISC MOUNTED ON ARMATURE SHAFT

Note the example of individual drive; motor installed on machine, easily accessible in case of necessity, yet unexposed to dirt and flying particles.

An illustration of a compact direct connected unit: entirely self-contained, no belts, gears or other driving mechanism to consume power or get out of order.

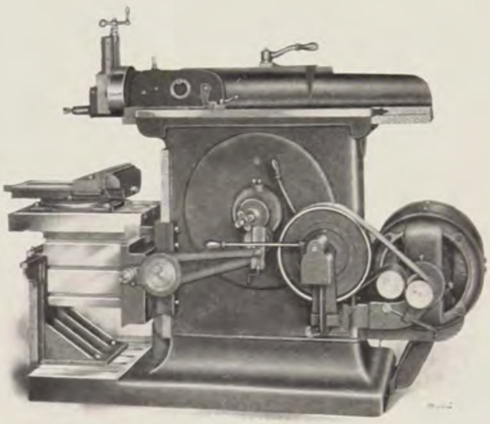


HENDY SHAPER EQUIPPED WITH RL-1, 1 H.P. MOTOR

The RL motor lends itself to direct application with well protected gearing. The conveniently located controller occupies space not required by the operator.

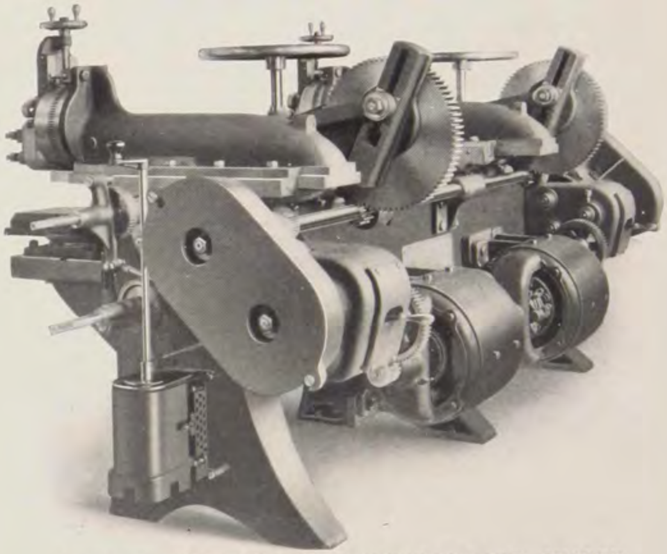
15-IN. CINCINNATI MILLING MACHINE CO. SHAPER DRIVEN BY KT-4, 3 H.P., 1800 R.P.M. INDUCTION MOTOR

An example showing the application of a constant speed induction motor, adjustable speed at the shaper head being obtained by mechanical gear change.



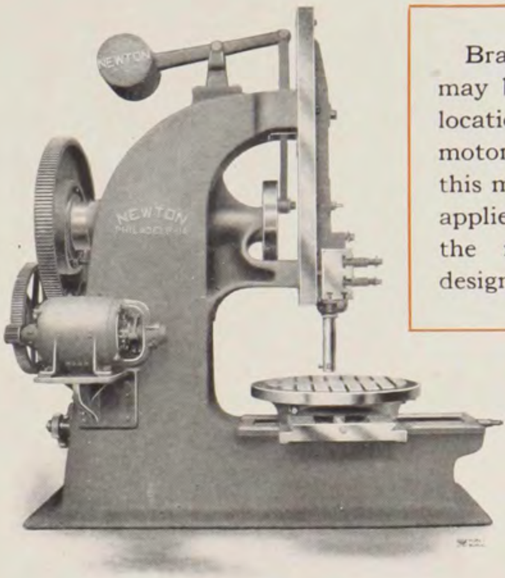
STOCKBRIDGE SHAPER DRIVEN BY RL FORM C MOTOR

Showing an application similar to the one directly above. Belt used as medium of transmission, with automatic tightener to maintain proper tension and add to flexibility of drive.



NILES-BEMENT-POND CO. DOUBLE-HEADED SHAPER WITH TWO RL MOTORS

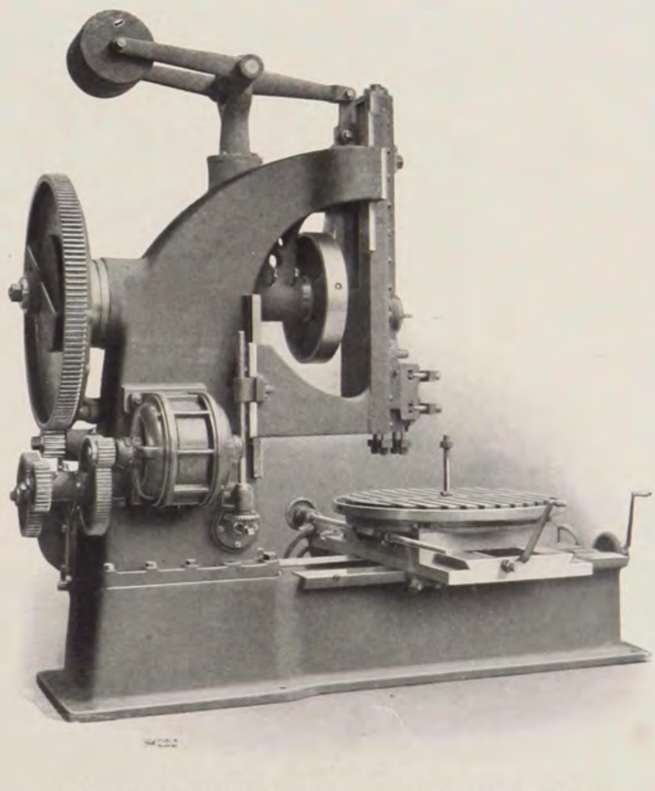
Each unit has its own individual motor mounted on the frame, thus assuring perfect alignment. Note convenience of controller handle to operator when "setting up" work.



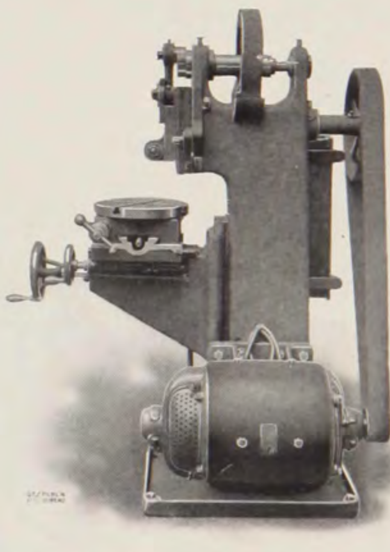
NEWTON SLOTTER DRIVEN BY RL MOTOR

Brackets or supporting pads may be attached in convenient locations to provide for gearing motors direct to machine. By this means motors may be easily applied to existing tools without the necessity of a specially designed frame.

NILES-BEMENT-POND CO. 6-IN. SLOTTER DRIVEN BY KT-4, 2 H.P., 1800 R.P.M. INDUCTION MOTOR



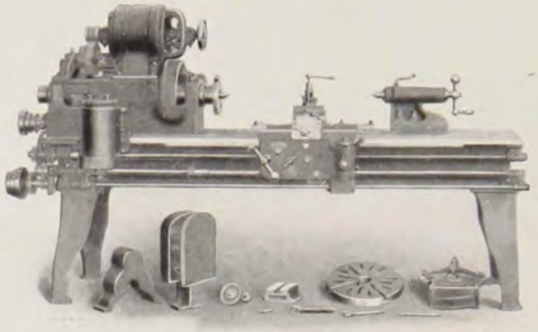
26-IN. NILES-BEMENT-POND CO. SLOTTER DRIVEN BY INDUCTION MOTOR



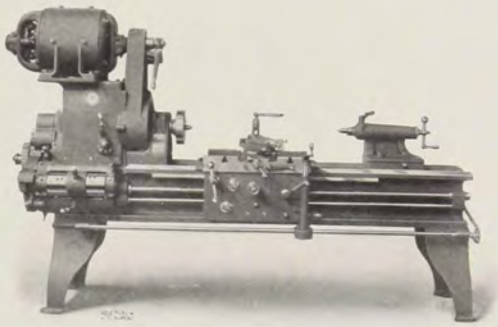
GARVIN SLOTTER DRIVEN BY RL MOTOR

This page illustrates several applications of RL adjustable speed motors to lathes. Attention is directed to the compactness of these units as well as the absence of countershafts and belts which obstruct light, waste power and interfere with the handling of work.

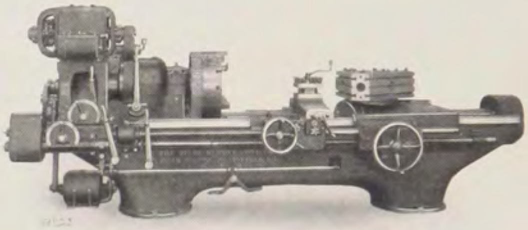
Controllers are operated from a handle on or near the apron, thus easily allowing instant manipulation of the tool.



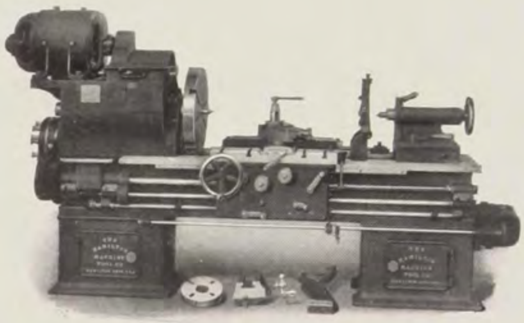
REED 16-IN. ENGINE LATHE DRIVEN BY 1 H.P RL MOTOR



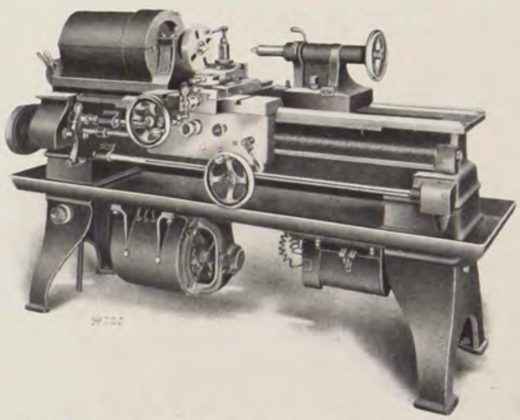
LE BLOND 18-IN. LATHE EQUIPPED WITH RL MOTOR



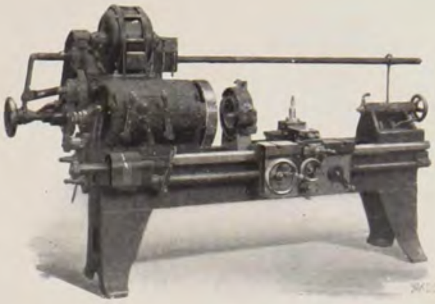
28-IN. POND LATHE EQUIPPED WITH RL MOTORS



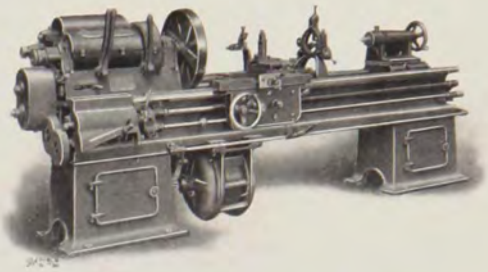
HAMILTON 22-IN. LATHE DRIVEN BY 3 H.P. RL MOTOR



FLATHER LATHE DRIVEN BY 2 H.P. RL MOTOR

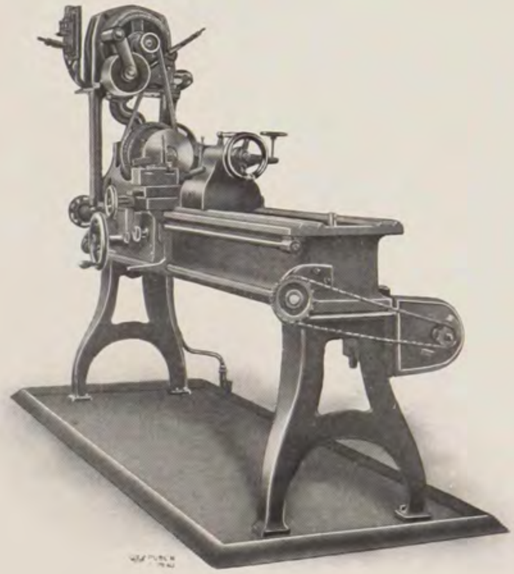


DRAPER 18-IN. ENGINE LATHE EQUIPPED WITH INDUCTION MOTOR



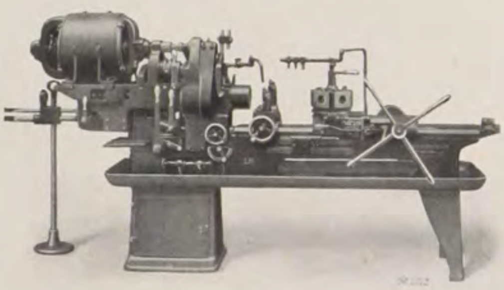
PRENTICE ENGINE LATHE EQUIPPED WITH INDUCTION MOTOR

Positive drive, positive feed, automatic control.

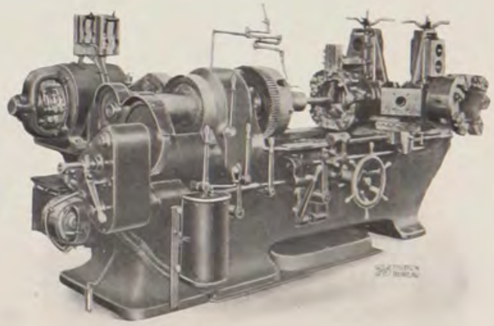


1¾ H.P. MULTI-SPEED KT MOTOR AND T-46-A CONTROLLER OPERATING 16-IN. PRATT & WHITNEY LATHE

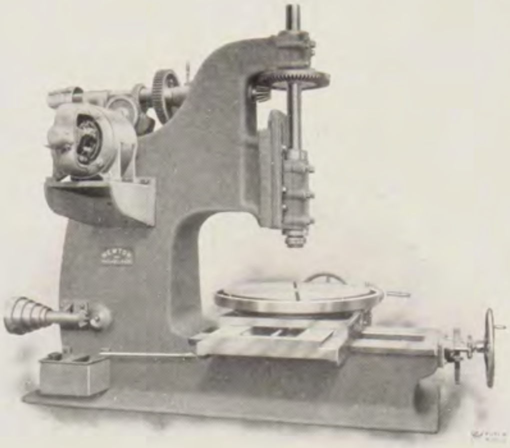
This cut illustrates a four-speed (600/900/1200/1800) reversible induction motor, especially adapted for lathes, shapers, boring mills, etc. The various speeds for a given controller setting remain fixed independent of load fluctuations within motor's rated capacity. These motors meet a wide field where alternating current is employed and the demand of the tools necessitates a range of fixed speeds. This example indicates the facility with which a machine originally designed for mechanical operation may be changed to motor drive.



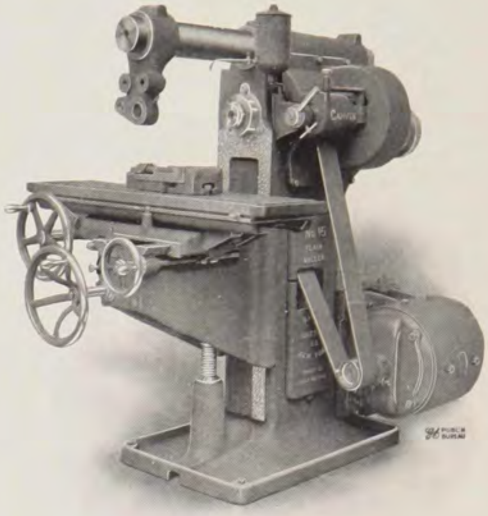
PRATT & WHITNEY 2 BY 26-IN. TURRET LATHE AND RL MOTOR



AMERICAN TURRET LATHE EQUIPPED WITH RL MOTORS

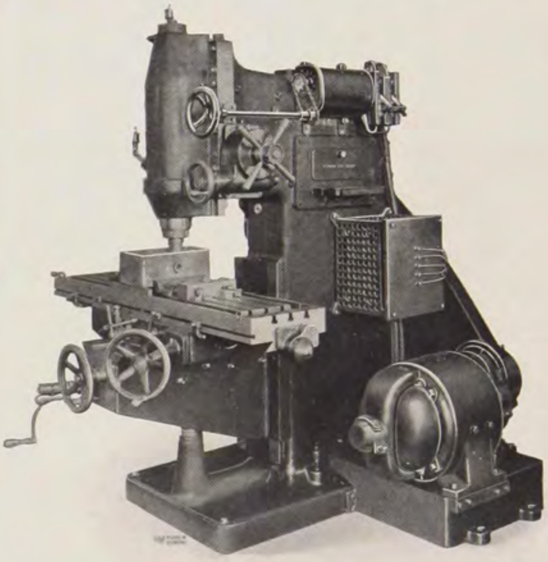


NEWTON VERTICAL MILLING MACHINE
DRIVEN BY RL MOTOR

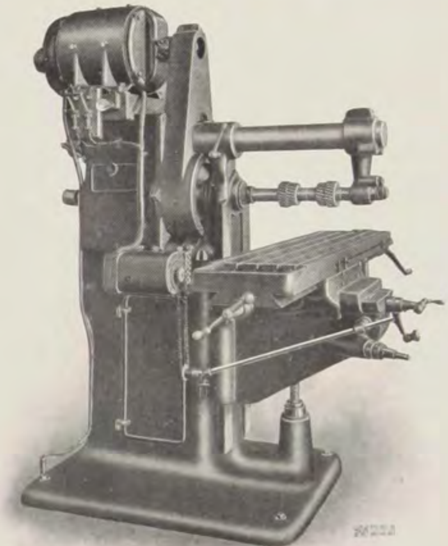


GARVIN MILLER DRIVEN BY RL MOTOR

Examples of standard milling machines equipped with individual motors. The elimination of slipping belts incident to group drives and the substitution of individual motors will increase the amount of material which may be removed by each tool in a given time, thus increasing the productive capacity of the equipment.

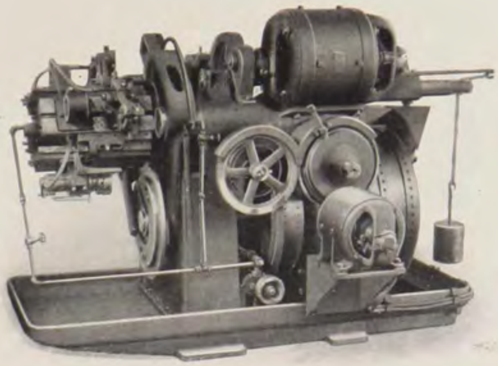


CINCINNATI VERTICAL MILLING MACHINE
DRIVEN BY CQ MOTOR

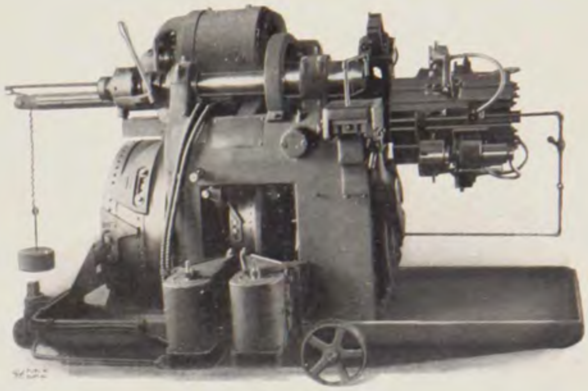


No. 4 LE BLOND MILLING MACHINE DRIVEN BY
RL 5 H.P. MOTOR

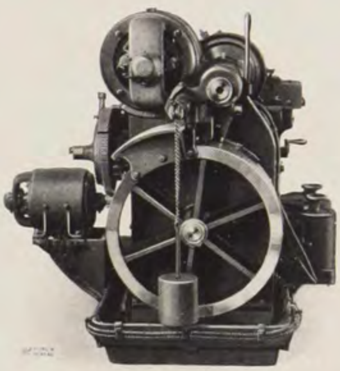
Note ingenious and unique method of linking the controller drum to operating handle of Le Blond milling machine. Application illustrates possibilities of unit motor drive for this type of machine tool.



GRIDLEY AUTOMATIC TURRET LATHE DRIVEN BY RL MOTORS



FRONT VIEW OF TURRET LATHE SHOWING AUTOMATIC CONTROL

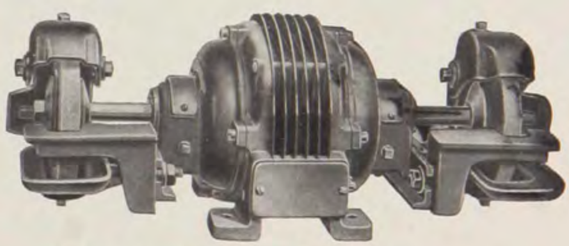


END VIEW OF TURRET LATHE

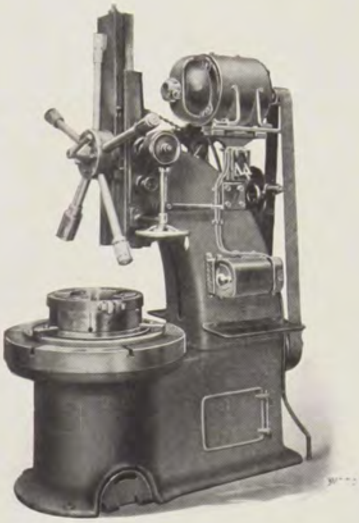
An ideal application of RL adjustable speed motors. One motor drives the spindle and is reversible to allow the backing out of a tap or running off of a die. The other motor drives the tool feed. As each driving unit operates independently with a separate controller actuated by cams on the operating cam drum, the entire range of spindle speeds from minimum to maximum may be automatically obtained. This method of drive is the realization of the ideal in speeds and feeds, a condition which may be obtained with the greatest simplicity by the application of individual motors.

BROWN & SHARPE SURFACE GRINDER DRIVEN BY INDUCTION MOTOR

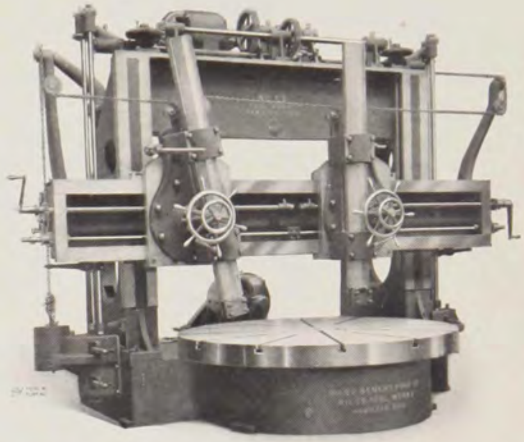
The substitution of the electric motor for the countershaft drive for grinders is of great advantage when the convenience of location of this type of tool is considered.



ALTERNATING CURRENT GRINDING MOTOR WITH A COARSE AND A FINE WHEEL FOR TOOL GRINDING



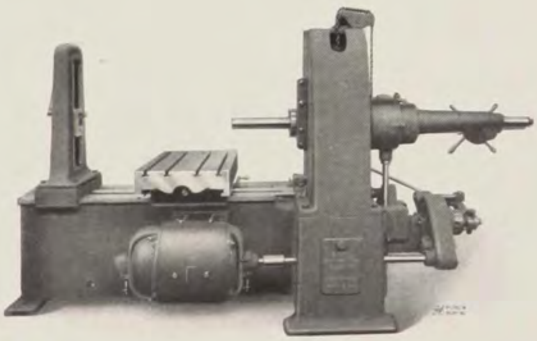
BROWN & SHARPE 36-IN. CHUCKING MACHINE DRIVEN BY RL MOTOR



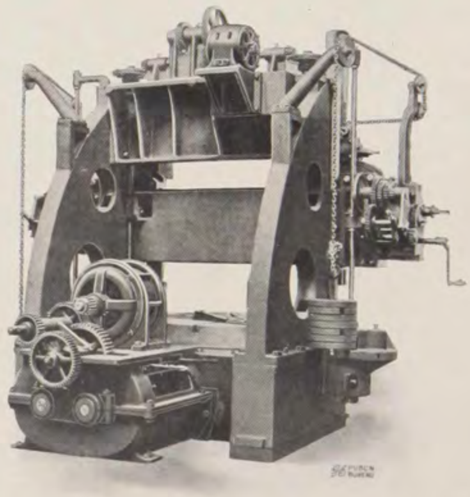
NILES-BEMENT-POND CO. BORING MILL DRIVEN BY RL AND CQ MOTORS

The application of adjustable speed motors to boring mills, particularly if heavy duty is involved, eliminates the difficulties existing where countershafts and belts are used. The elimination of countershaft drive also preserves the head-room necessary for cranes and hoists in serving the tools.

The cuts demonstrate that motors usually require no additional floor space when mounted on the frame of the machine, or on brackets attached to the frame.

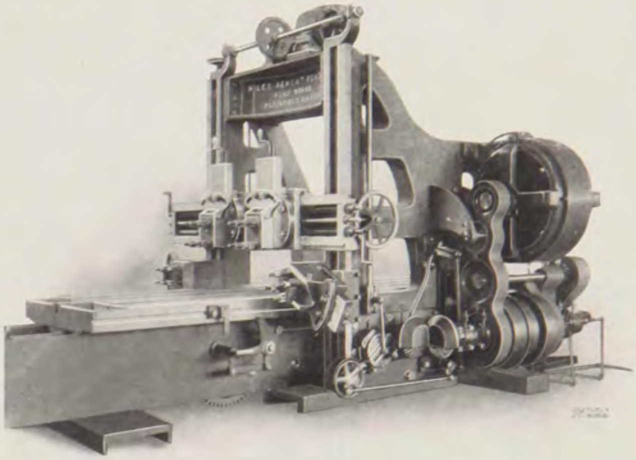


LUCAS HORIZONTAL BORING MILL DRIVEN BY ENCLOSED RL MOTOR



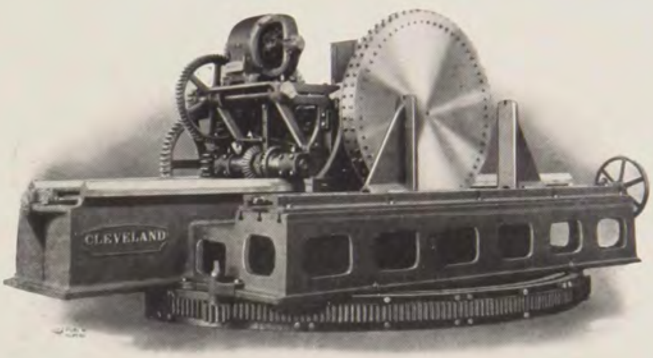
NILES BORING MILL DRIVEN BY INDUCTION MOTORS

The individual motor drive as applied to planers has many advantages, among them being the use of independent motors, one for planing and one for raising or lowering the cross-head.



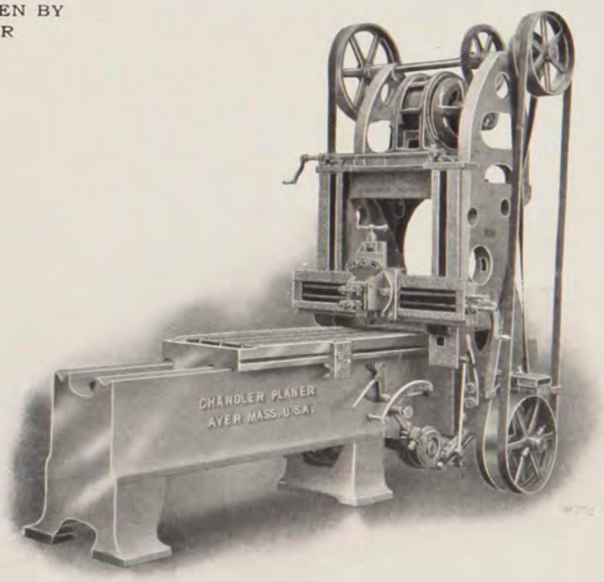
NILES-BEMENT-POND CO. PLANER DRIVEN BY CLB MOTOR WITH PNEUMATIC CLUTCHES

If only on the score of expense, lost time and annoyance incident to belt renewals, plus the depreciation, wear and general uncertainty involved where mechanical methods of power transmission are employed, the change over to electric drive is amply justified.

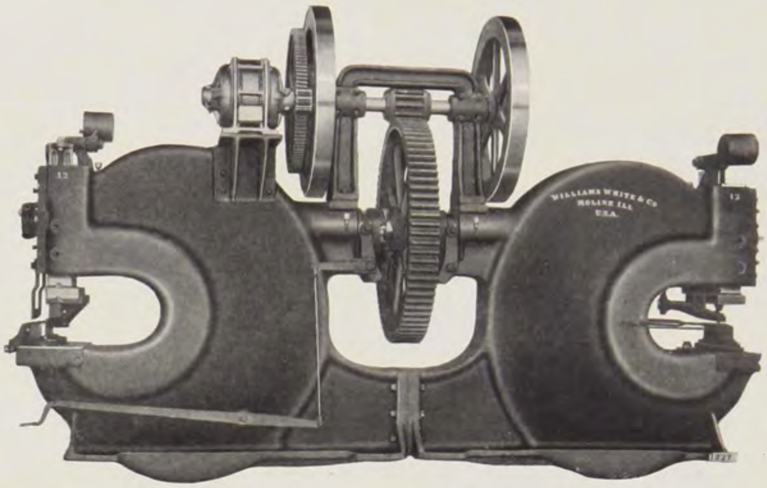


CLEVELAND ROTARY PLANER DRIVEN BY CQ-10, 15 H.P., 1000 R.P.M. MOTOR

Mechanical drives demand that machines conform to fixed shaft alignments. Individual motor drive permits the widest latitude in machine location or relocation—at once affording the best light and aisle space.



24-IN. CHANDLER PLANER WITH 7½ H.P., 1200 R.P.M INDUCTION MOTOR

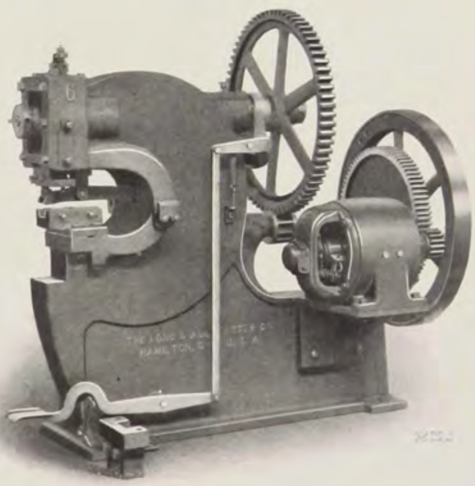


WHITE COMBINED PUNCH AND SHEAR DRIVEN BY 10 H.P., 1200 R.P.M. 60 CYCLE INDUCTION MOTOR

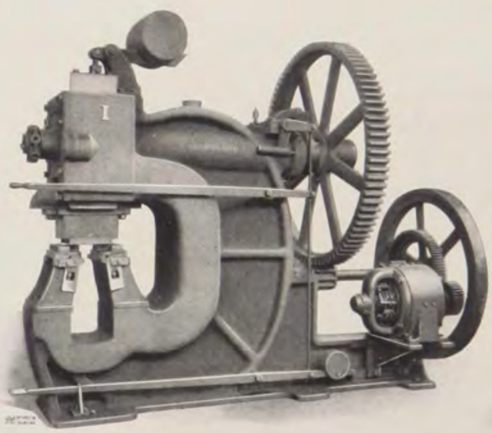
Particular attention is called to the direct application of motors to large punches and shears as shown in the illustrations on pages 16 and 17. The heavy belts and shafting (causing excessive expense for maintenance and renewals) necessary to accelerate the massive fly wheels, are entirely eliminated.

The motors may be mounted on the tools themselves, thus forming a complete, compact, efficient and positive unit.

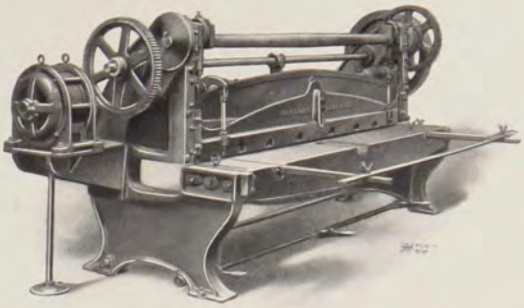
As an additional advantage of direct motor application, a number of tools of this type may be conveniently arranged for any desired sequence of operations without reference to location or size of countershafts, hangers and belts as in the case of mechanical systems of drive.



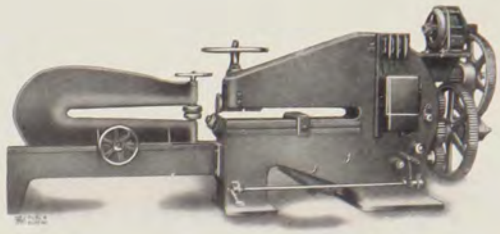
LONG & ALLSTATTER PUNCH DRIVEN BY CQ MOTOR



CLEVELAND PUNCH DRIVEN BY CQ MOTOR



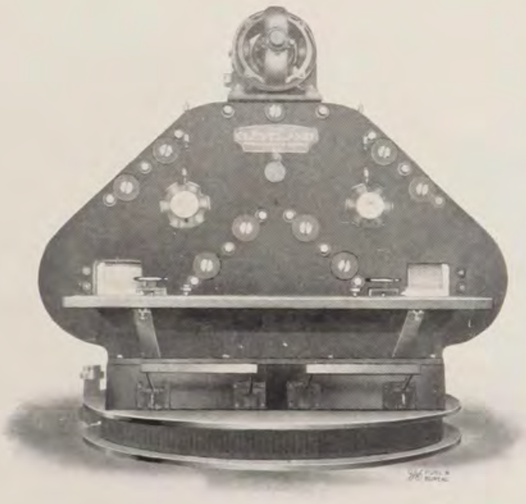
120-IN. NIAGARA SQUARING SHEAR DIRECT DRIVEN BY INDUCTION MOTOR



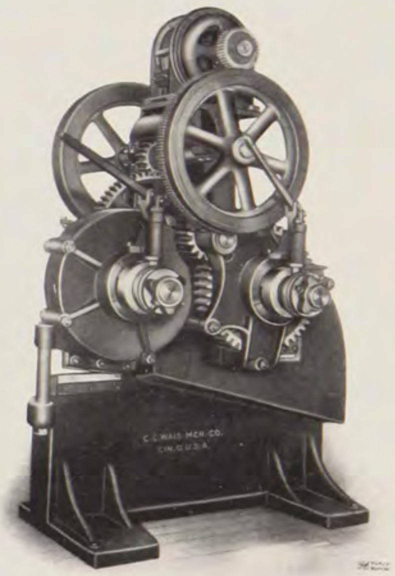
48-IN. NIAGARA CIRCULAR SHEARS DRIVEN BY 5 H.P., 1200 R.P.M. INDUCTION MOTOR

The illustration below shows one important advantage attendant upon the direct application of motors to shears. This massive shear weighing several tons is operated by a 20-H.P. constant speed motor and is capable of cutting 8 in. by 8 in. by $1\frac{1}{4}$ in. angles at a 45 deg. bevel. The large belt which would be necessary to transmit the maximum power is entirely eliminated. The high torque required in starting up the shear and when cutting, could not be provided satisfactorily and efficiently except by the direct motor drive. The appearance of the outfit is also symmetrical and pleasing.

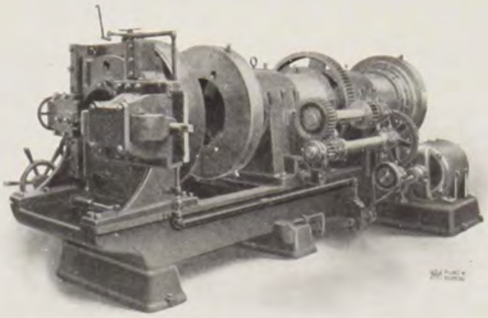
The direct connected electric motor saves much valuable floor space. Note in how many of the illustrations in this pamphlet the motor infringes upon no useful space.



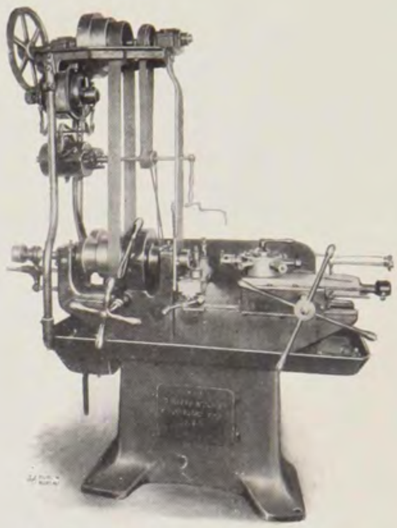
CLEVELAND ANGLE SHEAR WITH CQ. 20 H.P. MOTOR



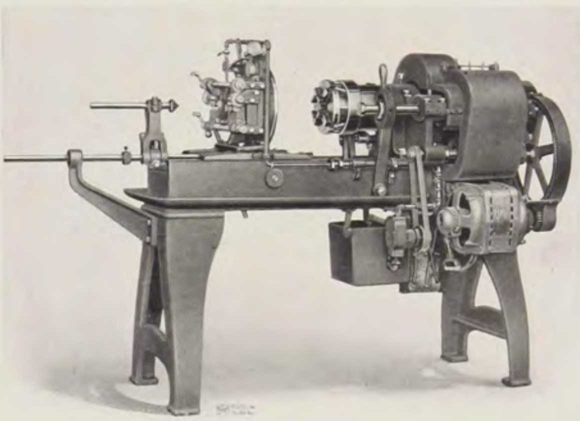
WAIS SHEAR DRIVEN BY 5 H.P., 900 R.P.M. INDUCTION MOTOR



CRANE PIPE MACHINE WITH RL MOTOR



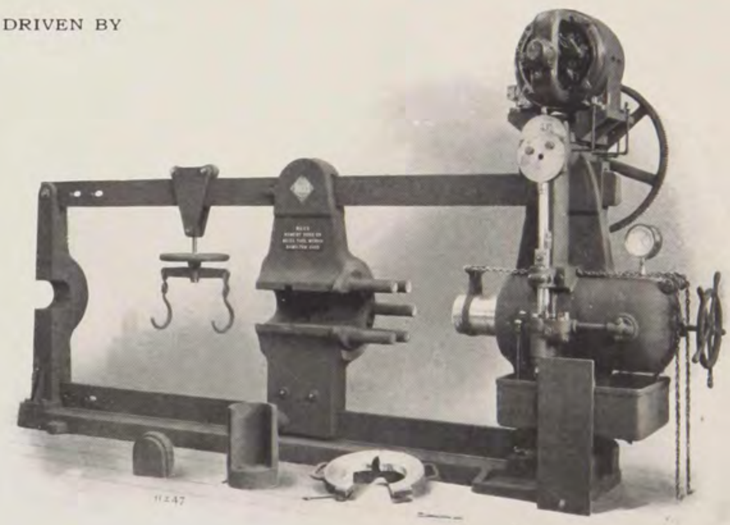
2 H.P. KT MOTOR DRIVING BARDONS & OLIVER SCREW MACHINE



APEX PIPE AND NIPPLE MACHINE DRIVEN BY INDUCTION MOTOR

Remember that electric motor drive commands at the will of the operator practically unlimited power and that no matter how little or how much energy is required, the source is always ready and the switch convenient.

GOULD'S HYDRAULIC PUMP DRIVEN BY INDUCTION MOTOR

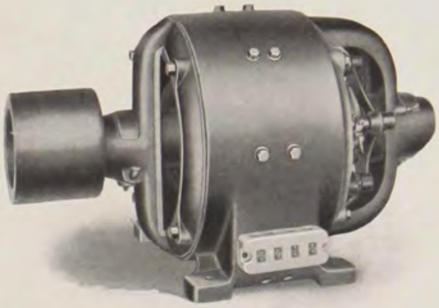


NILES-BEMENT-POND CO. WHEEL PRESS DRIVEN BY CQ MOTOR

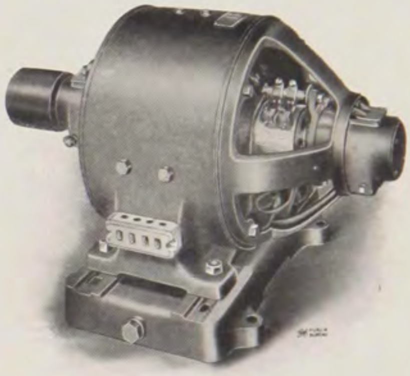
CONTINUOUS CURRENT MOTORS

General Electric Company Continuous Current Motors are made in six types:

Constant Speed	CQ 1/4 to 2 h.p. CVC 2 to 20 h.p. DLC 20 h.p. and above.
Adjustable Speed	RL 1/2 to 10 h.p. CQC 5 to 20 h.p. RLC 20 h.p. and above.

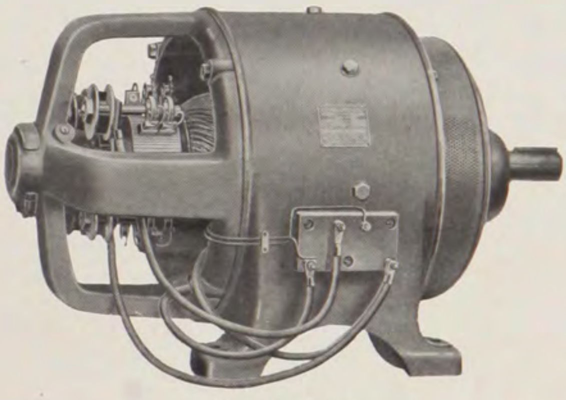


CQC MOTOR FOR ADJUSTABLE SPEED WORK



CVC MOTOR FOR CONSTANT SPEED WORK

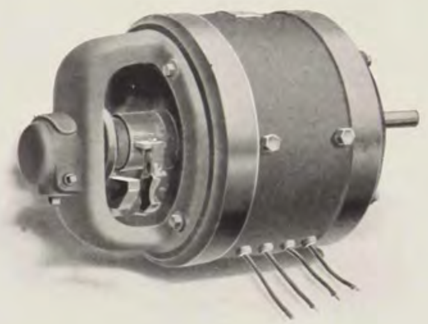
The motors above tabulated are all of rugged and symmetrical construction, with low center of gravity. All parts are made with special tools and are carefully gauged and inspected; hence, strict interchangeability between motors of corresponding size and type is assured. Every detail of construction, mechanical and electrical, is given the most careful consideration both as regards initial design and the subsequent manufacturing processes.



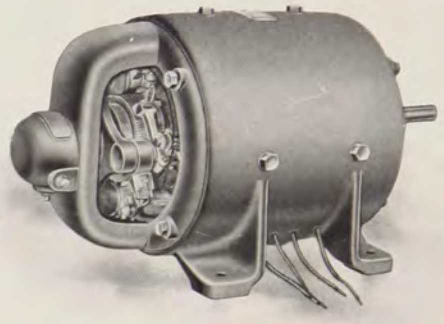
RLC MOTOR

The material used throughout is the best that can be procured. The shafts are especially large and rigid with ample bearing surfaces supplied with oil from wells of generous capacity. The bearing heads are of such construction as to fully protect the windings and commutator while affording ready access for the care or inspection of these parts. Motors may be furnished if required with semi or totally enclosing covers, provided the horse-power rating be modified to allow for such operation.

The Type RL adjustable speed motor is especially adapted to machine tool drive. The small diameter and comparatively short length produce a compact unit well adapted to use where economy of floor space and head room are of importance. The bearing brackets may be rotated to allow for mounting on a vertical surface or on the under side of a horizontal surface.

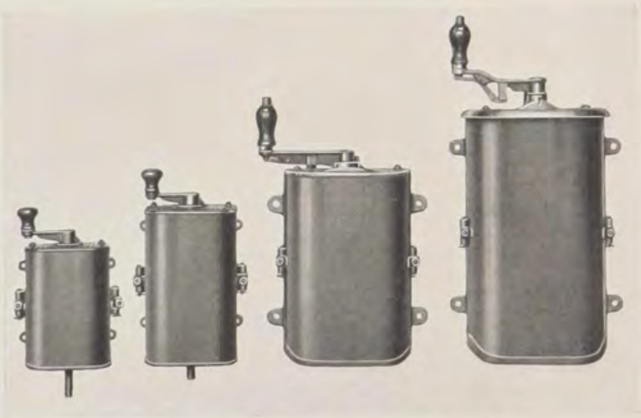


RL FORM C MOTOR



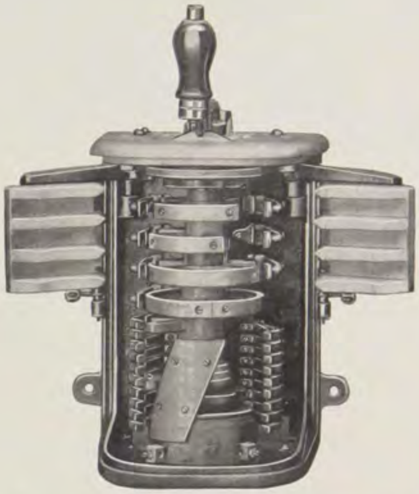
RL FORM B MOTOR

CONTINUOUS CURRENT CONTROLLERS AND RHEOSTATS

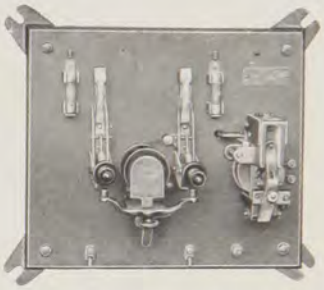


DRUM CONTROLLERS FOR ADJUSTABLE SPEED DC MOTORS

Type CR-253 drum controllers are designed to meet the severe service required in the control of both constant and adjustable speed motors as applied to individual drive, when frequent starting and stopping is necessary or where the location of the controller is such as to require protection. By the use of mechanical attachments, such as chain and sprockets, gears, etc., drum controllers may be located in the most convenient position for operating, thus avoiding the necessity of leaving the work in order to start or stop the machine. The Type CR controllers are arranged for reverse operation, but in case it is desirable to operate the motor in only one direction, a small pin which is screwed in the top of the cap plate may be used as a stop to make the controller non-reversible. Drum type controllers are used on motors up to 35 h.p., 230 volts. For motors of larger rating it is not considered practicable to use direct acting controllers and contactor panels with a small master controller are therefore recommended. Controllers for adjustable speed motors are so arranged that when turned to the off position the field current is reduced so that no damage will be done to the motor field if left continuously upon the line.



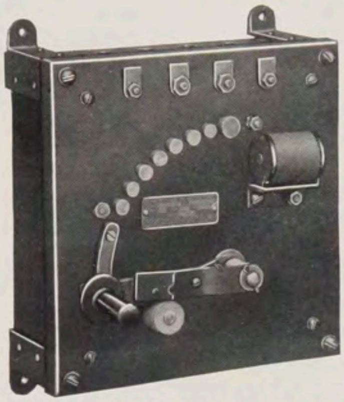
CR-253 (R118) DRUM TYPE CONTROLLER



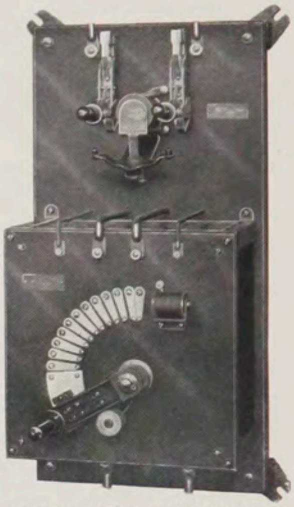
CR-251 PANEL WITH OVERLOAD CIRCUIT BREAKER AND NO-VOLTAGE RELEASE FOR USE WITH CR-253 DRUM TYPE CONTROLLER

The R-134-A controller has been developed especially for governing motors used for raising and lowering cross rails on planers and boring mills, and for operating lathe carriages, etc. A spring return to the "off" position prevents the operator from leaving his machine while the auxiliary motor is in operation. These controllers are supplied either for hand or rope operation. For use with a direct current series motor or with an alternating current squirrel-cage type of motor, the controller is arranged to throw the machine directly across the mains.

The CR-251 panel is a very desirable combination for use in connection with all CR-253 drum controllers since it provides overload and no-voltage protection and eliminates the use of separate cutout fuses and switch.



CR-107 STARTING RHEOSTAT WITH NO-VOLTAGE RELEASE



CR-135 PANEL EQUIPPED WITH CR-107 STARTING RHEOSTAT AND CIRCUIT BREAKER

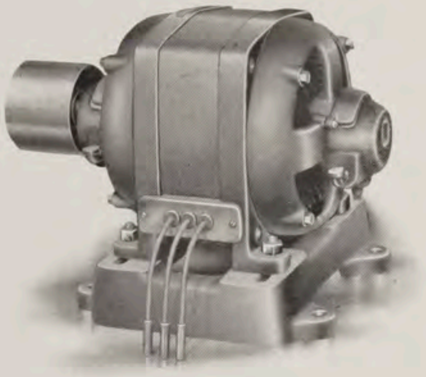
Type CR-107 rheostats are designed for the starting duty of continuous current constant speed motors.

The CR-135 equipment is often desirable, in that rheostat and circuit breaker are combined on a single panel, at once simplifying the wiring and making a neater installation. These controllers are designed for starting duty with group drives and similiar applications where starting service is infrequent.

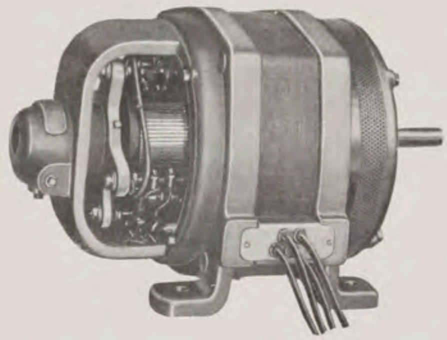
ALTERNATING CURRENT MOTORS

The General Electric Company build the following Alternating Current Motors, which may be applied to drive metal working machinery:

Constant Speed	Riveted Frame ¼ to 10 h.p. Skeleton Frame 10 h.p. and above Type RI (single-phase) 1 to 15 h.p.
Variable Speed	Multispeed Motors Form M Collector Ring Type—External Resistance Type RI (single-phase) 50% reduction from synchronous speed.

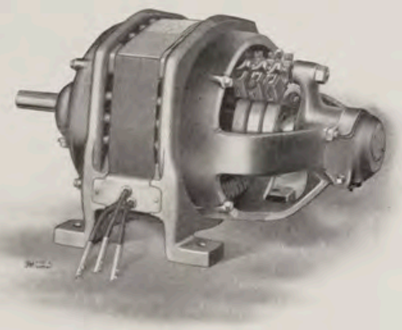


POLYPHASE INDUCTION MOTOR
RIVETED FRAME

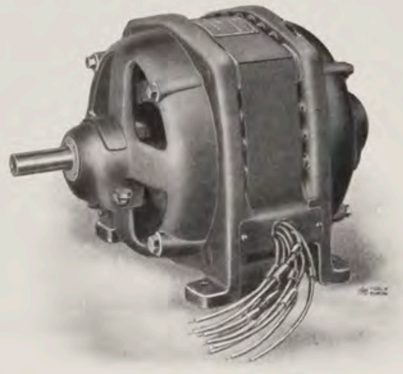


TYPE RI SINGLE-PHASE MOTOR CONSTANT OR VARIABLE SPEED

All General Electric Co. Induction Motors are of particularly rugged construction and are built with equal attention to detail as found in the continuous current types. The bearing brackets effectively protect the windings; shafts are rigid and of large diameter; oil wells are of ample capacity with provision against dust and dirt, etc., etc.



FORM M VARIABLE SPEED INDUCTION MOTOR

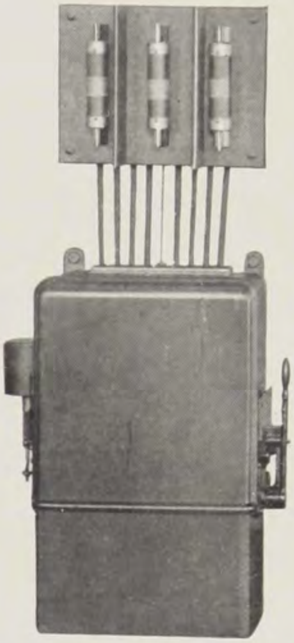


MULTISPEED INDUCTION MOTOR

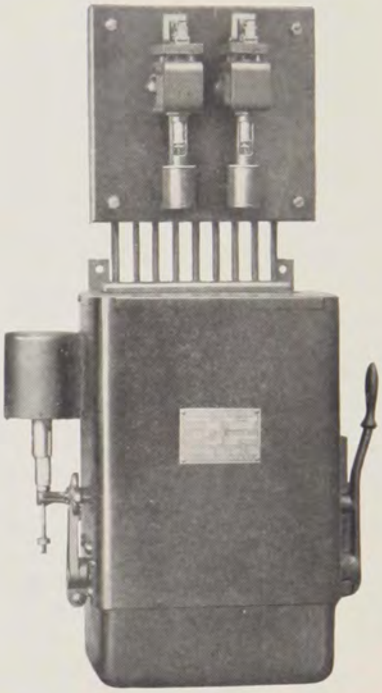
While alternating current induction motors are inherently constant speed machines, a variation in speed within certain limits can be secured by inserting resistance in series with the rotor (Form M motors) provided that the torque against which the motor works is fairly constant.

Note.—In some machine tools, such as boring mills, lathes, etc., the torque varies widely, consequently the Type M or the Type RI motors should not ordinarily be used.

For service involving wide variation in torque conditions, the multispeed motor has been developed in small sizes. This type of motor permits two fixed speeds, such as 600 and 1200, or 900 and 1800 r.p.m., or four speeds, viz., 600, 900, 1200 and 1800 r.p.m. As the multi-speed motor operates at fixed speed, regardless of load, the type is consequently suitable for use with lathes, boring mills and similar apparatus.



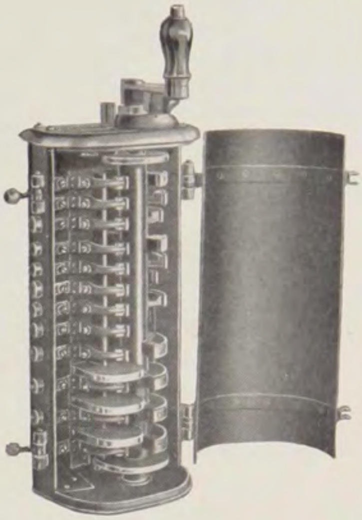
STARTING COMPENSATOR NR, FORM A-2
WITH NO-VOLTAGE RELEASE
AND FUSE BLOCK



STARTING COMPENSATOR NR, FORM A-3
WITH OVERLOAD RELAYS AND
NO-VOLTAGE RELEASE

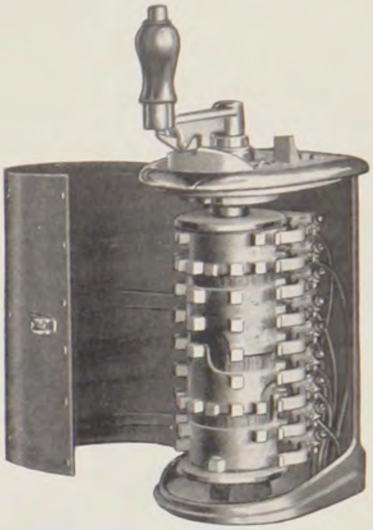
ALTERNATING CURRENT CONTROLLERS

For starting constant speed, polyphase motors above 5 h.p. a starting compensator is provided to reduce the current demand on the line. Below $7\frac{1}{2}$ h.p., polyphase motors are usually thrown directly on the line.



T-1 FORM H CONTROLLERS FOR USE WITH FORM M INDUCTION MOTORS

The illustration shows the type of controller employed with all standard Type M variable speed polyphase motors having a capacity not exceeding 40 h.p., and provided that the current required in the primary or secondary of the motor does not exceed 100 amperes per phase.



T-46-A CONTROLLERS FOR USE WITH MULTISPEED INDUCTION MOTORS

The Type T-46-A controllers shown are used in connection with all multispeed, polyphase induction motors of the constant h.p. type, up to and including 7½ h.p., 110 and 220 volts.

These controllers are designed to carry a maximum current not exceeding 50 amperes per phase.

GENERAL ELECTRIC COMPANY

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London Office, 83 Cannon St., London, E. C., England

General Electric Company
Schenectady, N.Y.
SUPPLY DEPARTMENT

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RUNNING LIGHT TELLTALE BOARDS

Government and insurance regulations require that all vessels display certain running lights from sunset to sunrise for safety in navigation. For use on vessels using electricity for light, the General Electric Company has designed a telltale board, approved and listed by the Underwriter's Laboratories, which affords a very accurate and reliable means of indicating whether or not the running lanterns are properly illuminated. This board is usually located in the pilot house, and so arranged that both an audible and visible warning is given upon the failure of any of the lamps. Running lights are usually equipped with a spare lamp in order to avoid the inconvenience of replacing lamps during rough weather. The board is so arranged that by use of the single-pole double-throw switch, the second lamp may be thrown into the circuit. The accompanying illustrations show one of these boards arranged for operating four lanterns. The first, or right hand section, is used for the incoming supply wires, warning lamp and the buzzer, and the remaining four sections for the control of the various lanterns located on different parts of the vessel. The number of lanterns controlled may be increased by adding one or more sections to the left-hand side of the board; the wiring being simply a duplication.

FOUR-LIGHT TELLTALE BOARD

The operation of the board may be easily understood by referring to the diagram of connections. The positive supply wire is attached to a terminal at the top of the board from which the current passes down to the middle point of the single-pole double-throw switch at the bottom of the board. When this switch is closed in one direction

* *Supersedes No. 4322.*

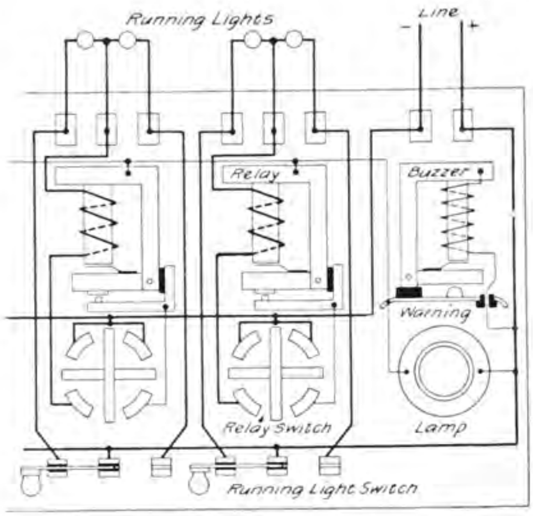
the current is sent through one of the lamps, and when thrown to the opposite pole it is sent through the other lamp in the same lantern. In order to complete the circuit, the current then passes by a common return wire through the winding of the relay magnet to one of the connections of the double-pole indicating snap switch, and through this switch to the negative supply terminal.

The relay magnet carries an insulated contact arm and is actuated by the lamp current. Mounted on the armature of this magnet is a light semaphore painted in two distinctive colors, red and white. When the lantern is properly illuminated, the white sector of the semaphore is normally in view through the opening in the relay magnet cover, but upon failure of a lamp the armature drops down, showing the red section in the cover slot of the relay controlling the lantern which is out of service. When the double-throw knife switch is thrown, restoring current to the lantern through the spare lamp and magnet coil, the semaphore again shows white.

The dropping of any of the relay magnet armatures also makes the necessary contact for operating the buzzer and warning lamp, which are mounted on the right of the board. This is effected by completing the circuit between the negative side of the warning lamp and buzzer (which are together tied to the frame of each magnet) and the negative line terminal which is connected to one pole of the snap switch.

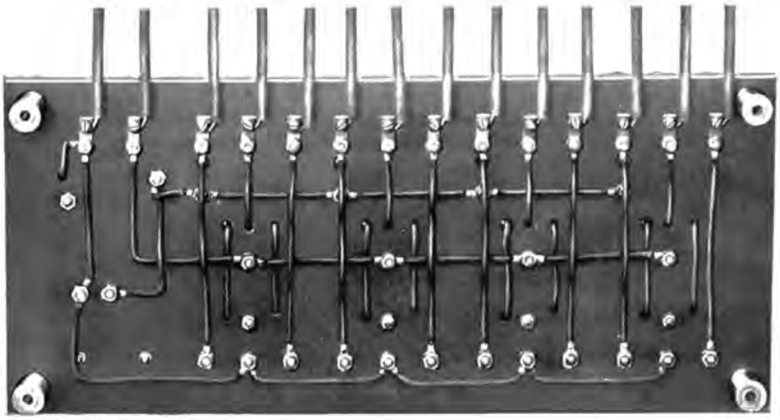
The restoration of the relay magnet current by switching in the spare lamp again restores normal conditions by opening the contact on the lower side of the armature and thus interrupting the warning signals.

The board may be tested at any time by closing the snap switch and opening the knife switch of the circuit to be tested. If the apparatus is in working order the buzzer will sound and the warning lamp will light up. While this board is designed to control a spare lamp in each signal lantern it may be used with equal facility with lanterns using but one lamp, since with the spare circuit open the warning signal will operate if the running light switch is not thrown to the right contact.



CONNECTION DIAGRAM

TELLTALE BOARD WITH RELAY AND BUZZER COVERS REMOVED



BACK OF FOUR-LIGHT BOARD SHOWING WIRING

This entire equipment is mounted on a ¾ in. natural black finished slate base and all of the exposed metal parts on the front of the board are heavily nickel-plated. Hard black fiber is used for insulating purposes, which enables the apparatus to stand a severe high potential test.

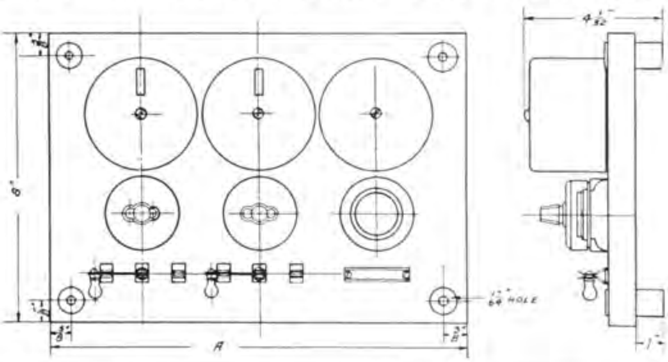
These running light telltale boards are designed for operation on circuits of 110 volts to 125 volts, but can be adapted to use on circuits of higher or lower potential upon special order.

When so ordered the General Electric Company is prepared to furnish small nickel-plated name plates suitable for labelling each of the lantern circuits. These plates, which are mounted on the magnet cover, may be supplied with the following labels from stock, but any other name can be furnished on special order.

Mainmast	Bow	Towing
Headlight	Starboard	Range
Foremast	Masthead	Stern
Peak	Port	Upper
Lantern	Anchor	High

On account of the danger of breakage in transportation, no warning lamps are supplied with these telltale boards, the socket being designed to receive lamps with standard Edison bases.

TABLE OF RUNNING LIGHT TELLTALE BOARDS



Cat. No.	Number Lights	Dimensions A	Dimensions B	Approx. Wt. Net	Approx. Wt. Ship.	List Price	Cat. No.	Number Lights	Dimensions A	Dimensions B	Approx. Wt. Net	Approx. Wt. Ship.	List Price
112666	1	8¼	8	9½	27	$36.00	112669	4	18	8	20	35	$70.00
112667	2	11½	8	13	30	48.00	112670	5	21¼	8	23½	40	80.00
112668	3	14¾	8	16½	32	60.00	112671	6	24½	8	27	45	90.00

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General Electric Company
Schenectady, N.Y.

RAILWAY DEPARTMENT

February, 1911

Bulletin No. 4817

G.E. 214 RAILWAY MOTOR

The G.E. 214 75 h.p. railway motor represents the latest construction in this class of apparatus.

The Form C frame is box type, while the Form B frame is split, and both have the following features in common:

1. Commutating poles.
2. Oil lubrication.
3. Superior method of supporting field coils.

FORM C MAGNET FRAME

The frame is of cast steel in one piece with a smooth and approximately octagonal exterior. Bored openings are provided at each end of the frame. Through the larger one, the pole pieces and field coils can be easily inserted or removed. The frame heads carrying the armature shaft bearings are supported in the recessed ends of the magnet frame and are held in place by cap bolts

GE-214C MOTOR, AXLE SIDE

4. Improved method of fastening the commutator cover.
5. Mica insulated brush-holders.
6. Removable armature shaft.

Since the introduction of commutating pole railway motors by the General Electric Company, their advantages have become generally recognized. These motors have greatly increased commutating capacity and are of such rugged construction as to effect a marked improvement in reliability and reduction in the maintenance account.

securely locked against turning. The heads have two tapped holes diametrically opposite into which bolts are screwed to force the frame heads off.

The axle bearing caps are bolted to the frame on planed, tongued surfaces inclined at a slight angle from the vertical, thereby relieving the strain on the axle cap bolts and permitting the motor to be more easily mounted on the truck.

The main exciting pole pieces are laminated and bolted to the frame at angles of 45 degrees to the horizontal. The commutating pole pieces are bolted to the frame at points midway between the exciting poles.

Bails are provided at convenient points for handling the motor.

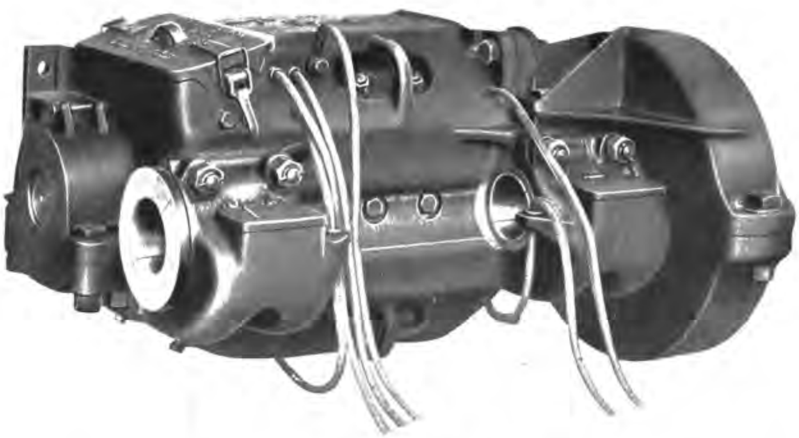
A large opening is provided over the commutator and is inclined at a slight angle to facilitate inspection. The malleable iron cover for this opening rests on a gasket and has a flat steel spring riveted to each end.

In addition to this opening are others, all having malleable iron covers fitted with gaskets so located as to best provide for the proper inspection of the interior of the motor.

The armature and field leads are brought through rubber bushed holes on either the axle or suspension side as desired.

FORM B MAGNET FRAME

The frame is of cast steel split horizontally



GE-214B MOTOR, AXLE SIDE

The springs project a little beyond the cover which is fastened down by pushing the spring at one end through a staple on the front side of the motor, after which the cover at the back of the motor is forced down and clamped in position by a link attached to a cam locking device. The link is placed over the end of the spring on the cover and the handle of the locking device pushed down until the link passes a critical center where it is held in place by the force of the spring. This method of fastening the cover holds it firmly in place under spring tension. No part of the locking device projects above the top of the cover and consequently is not easily broken or knocked off. Reference to the illustration on pages 1 and 2 will make the construction clear.

with a suspension on the top half, and has a smooth and approximately octagonal exterior. The bottom half is arranged to drop down to facilitate inspection of the interior of the motor from a pit.

The armature bearing housings are of the solid head type giving the good qualities of oil lubrication obtained in the standard box frame motors. Each housing is secured to the upper frame by four bolts. By removing these bolts and the lower half of the gear case, the armature can be lowered into a pit. The upper and lower magnet frames are provided with machined surfaces which surround the bearing housings and prevent the armature from dropping onto the lower pole pieces in case the housing bolts become loosened.

The axle bearing caps are tongued and bolted to vertical planed surfaces on the top half of the frame.

With regard to the position and method of holding the pole pieces, the provision for inspecting the interior of the motor and the fastening of covers, etc., this frame is similar to the Form C.

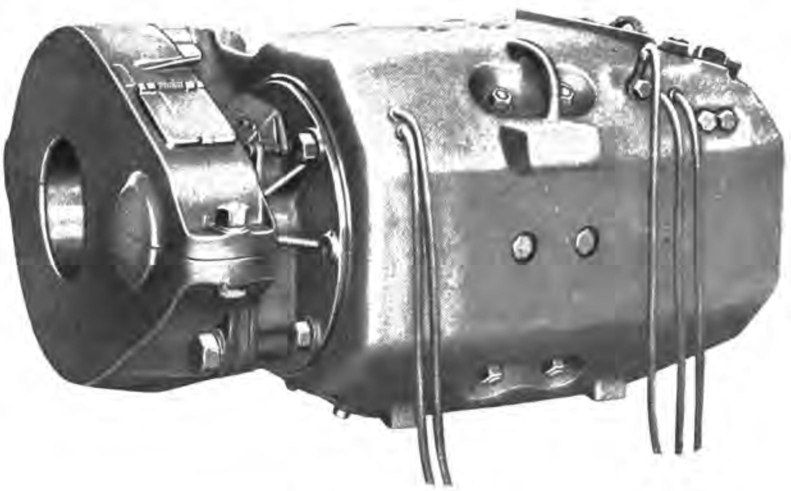
BEARINGS

The armature shaft linings of the G.E. 214 motor are bronze sleeves finished all over and lined with babbitt metal securely anchored in place. The babbitt furnishes an ideal bearing surface and is of such thickness that should the babbitt be melted out by overheating, the shaft will be supported by the bronze sleeves before the armature strikes the pole pieces.

In both axle and armature bearings, the oily waste used for lubrication is packed in large oil wells and bears on the shaft through openings in the low pressure side of the bearing linings. Waste oil from the armature shaft bearings is prevented from entering the interior of the motor by deflectors which throw it into grooves from which it is conducted away.

This form of bearing is fully equal in simplicity and reliability to the standard car journal bearing. The method of lubrication and treatment is practically the same and the boxes are reached through large hand holes protected by swing covers with felt gaskets resting on finished seats. The covers are held in place by strong springs.

While the oil pockets are liberal, the amount of oil required for lubrication is exceedingly small, thus largely reducing the attention required.



GE-214C MOTOR, SUSPENSION SIDE

Inspection and maintenance is further reduced by the liberal size of the bearings. The armature shaft bearing is 3⅜ inches in diameter and 7 inches long at the commutator end, and 3¾ inches in diameter and 9¼ inches long at the pinion end. The linings on each end are in one piece. Axle bearing linings are 10¾ inches long and made of malleable iron and babbitt metal for axle diameters up to and including 5½ inches.

FIELD COILS

All field coils are wound with flat copper strip after which they receive a wrapping of cotton tape and are filled with an insulating compound by the vacuum process. They are then thoroughly insulated with several wrappings of specially prepared tape, and as a final protection, chiefly from mechanical injury, are taped with a heavy cotton webbing and filled with japan.

The coils are wound compact and solid, and are pressed to uniform size. They fit tightly over the pole pieces.

spaced with air ducts which provide good ventilation.

The armature coils are wound on forms with insulation between the adjacent coils in the unit or polycoil which is pressed to shape in a steam mold. The coils are then covered with insulation material of high quality, and as a final protection, principally from mechanical injury, are taped and filled with an insulating compound. The windings are specially well protected from dust, oil or mechanical injury. The pinion end core head extends under the end wind-

GE-214B MOTOR. SUSPENSION SIDE

The exciting coils rest on pressed steel supports and are held in position by means of spring flanges of tempered steel which clamp the coil securely between the support and the pole piece projections. This construction eliminates the necessity of using canvas field coil pads and ensures the coils being held firmly in position without danger of abrasion.

The commutating coils are similarly secured.

ARMATURE

The armature which is 15 inches in diameter, is built up of soft iron laminations inter-

ings with a flange reaching up past the ends of the coils. The windings at both ends are covered with a strong canvas dressing securely bound in place. Binding bands are not allowed to project above the armature core, and the ends of the band wires are secured by means independent of the solder.

The shaft may be removed from the armature without disturbing the armature winding or the connections to the commutator. The latter is mounted upon an extended hub on the front core head. To remove the shaft, bolts are inserted through the rear core head and screwed into tapped holes in the

CHANGE NOTICE

To Accompany Bulletin No. 4685

BELT-DRIVEN ALTERNATORS

Page 9, table at the bottom of the page—the first four machines should be rated 312 kw. at 1.0 power-factor instead of 250 kw. The face of the driving pulleys should be 38 in. instead of 32 in.

ERRATA

To accompany Bulletin No. 4793

STEADY vs. UNSTEADY VOLTAGE

Page 3, first column, first line: "4" should be changed to "2".

front head. These bolts securely hold the structure together while the shaft is being replaced. This construction eliminates the use of a solid spider, which materially restricts ventilation and otherwise decreases the service capacity of the motor.

COMMUTATOR

The commutator segments are made of hard drawn copper bars insulated throughout with the best grade of mica. The cone micas are built up and pressed hard and compact in steam molds. The mica between the segments is made of a softer quality to make it wear down evenly with the copper.

Great care is taken in the construction of the commutator. The cone surfaces are carefully machined and cleaned from burrs and sharp edges to prevent short circuits between the segments, and creepage distances are made long to prevent grounding.

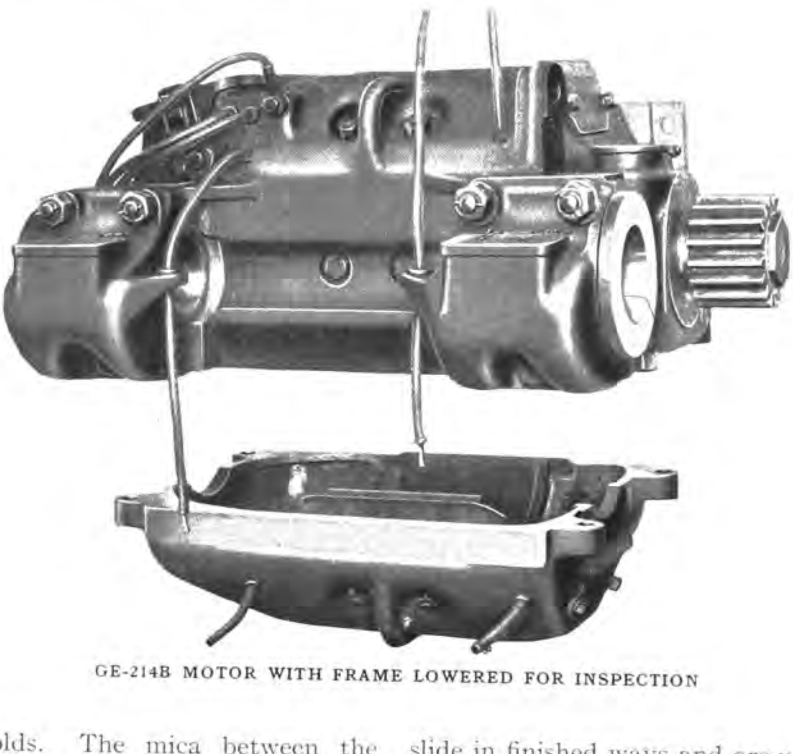
The shells and caps are made of cast steel in strong sections in order to prevent breakage and keep the shape of the commutator true. Before tightening the commutator nut, the segments are clamped tight by the cap which is pressed home in a hydraulic press.

The liberal wearing depth of the segments and the excellent commutation of the motor insures a long life to the commutator.

BRUSH-HOLDERS

The brush-holders are made of cast bronze, and two brushes are used per holder. The brushes, which are 2 by ½ inches in section, slide in finished ways and are pressed against the commutator by independent fingers, which give a practically uniform pressure throughout the working range of the brushes. The arrangement of the springs actuating the fingers is such that there is but slight pressure on the pins on which the fingers pivot. This prevents the tendency of the fingers to stick on the pins and reduces the wear to a minimum.

The brush-holders are clamped to supports which are bolted to the magnet frame through



GE-214B MOTOR WITH FRAME LOWERED FOR INSPECTION mica insulated studs. The brush-holders slide in finished ways on the supports to provide adjustment for the wear of the commutator. The cable leads are connected to the supports so that the brush-holders can be removed without in any way disturbing the connections.

VENTILATION

Particular attention has been given to ventilation. The field windings are well distributed, giving a large exposed area for radiation. The armature acts like a strong centrifugal blower, keeping the air in the motor well agitated. The ventilation is secured without sacrificing in any way the proper protection of the armature windings, a strong point in the construction of the motors.

GEAR, PINION AND GEAR CASE

The gears are made of a superior grade of cast steel and the pinions from a special stock of forged steel which is heat treated after cutting. The gears have a five-inch face and the teeth are accurately cut to a 2.5 pitch and will be furnished solid or split as required.

The maximum reduction gearing recommended for use with either Form C or B frames is $\frac{60}{17}$.

The gear case is made of malleable iron and is suspended from the magnet frame at three points to prevent vibration. Strengthening ribs radiate from the supporting points to prevent the case from cracking. The case is bolted to the motor frame in such a way as to minimize lateral vibration and the contact surfaces between the case and frame are made large to prevent undue wear.

ADVANTAGES

Attention is called to the following special qualities possessed by this motor which will commend it to all practical users of railway motors:

1. Very substantial mechanical construction with improved brush-holders and field coil supports.
2. Practically sparkless commutation even on heavy overloads.
3. Flashing at commutator largely reduced if not practically eliminated.
4. Less wear on commutator.
5. Cleaner and more reliable motor because of the reduced carbon and copper dust from brushes and commutator.
6. Marked reduction in heating of commutator.
7. Increased life of brushes.
8. Lower magnetic densities and smaller core loss.
9. Increased efficiency and free running capacity, because of lower core and commutator losses.
10. Lighter field coils to handle.

PARTS OF GE-214C MOTOR

11. Improved shape of speed curve, giving greater economy during acceleration.

12. Increased service reliability due to the elimination of commutator troubles and of delays consequent thereto.

13. Greater service reliability owing to the elimination of troubles in the car equipment due to the flashing of motors.

RATING

The G.E. 214 motor is rated at 75 h.p. which is based on a temperature rise by thermometer of not more than 75 degrees C. above the surrounding air after one hour's run at 600 volts and rated load, the temperature of the surrounding air not exceeding 25 degrees C. The capacity for continuous operation is high owing to its good electrical efficiency and ventilation. It has a liberal margin of safety at 600 volts as good commutation is a special characteristic of this type of motor.

This method of rating has been in use for a number of years, and while not necessarily giving an exact measure of the capacity of a motor to perform all classes of service, is convenient and well understood, and conveys a sufficiently close idea of the relative size of motors for general use.

A test is made on the motors at rated load, and all motors are also thoroughly tested for commutation, bearings, brush-holders, etc.

The predetermination of the capacity of a motor to perform a given service is a problem, the solution of which necessitates a complete knowledge of the mechanical, electrical, and thermal characteristics of the motor. Knowing these characteristics, it is possible to calculate the losses in a motor performing any specified service. The only way of determining how hot a motor will run is by reference to actual tests of the motor under the same or similar service conditions. The heating of a given motor in service manifestly depends entirely on the character of the service, and consequently no reliable estimate can be made of the necessary capacity or characteristics of the motor for successful operation, without a complete knowledge of the operating conditions. The weight of the car or train, schedule speed, location, number and durations of stops, profile and plan of road, and voltage, are necessary for a complete and careful analysis of the problem.

PARTS OF GE-214B MOTOR

In order to obtain full information on these questions, the General Electric Company besides carefully testing each type of motor for efficiency, I^2R, core and friction losses, speed and commutation, etc., at various voltages and amperes, also makes exhaustive test to determine the capacity of motors for heat dissipation under operating conditions. For this purpose motors are put into actual service on the company's experimental track (more than two miles in length) and are run day after day under a wide range of known service conditions, careful temperature measurements being taken until sufficient data are obtained to show what temperature different parts of the motor will reach, not only with various total losses but also with different distributions of these losses.

From the data obtained in the above tests, which cover all the characteristics of a given type of motor, the company's engineers possess all the information required to determine with practical certainty the adaptability of the motor to handle any specified service, and the problem has become not a matter of guess work, but of calculation.

As the power required to operate an equipment affects not only the heating of the motors but also the total amount and cost for operating the road, careful calculations are made to determine the most suitable characteristics of a motor for a given service and the most economical gear ratio to use. The possibilities of saving power by careful design and proper selection of the gear ratio are much greater than ordinarily appreciated.

A table which is based on tests, such as have been described above, will be found on page 11 showing schedule speeds for various gear ratios with varying number of stops per mile and different weights per motor. This table has been prepared to enable customers to determine quickly and with considerable accuracy the capacity of the G.E. 214 motor to handle cars or trains under ordinary conditions, and it will also be found useful for laying out operating schedules.

As the reputation of the General Electric Company's motors and the interests of its customers are affected by the proper selection of motors for any given service, the company desires to aid and co-operate with its customers in selecting motors best adapted to their service. For this purpose, customers are furnished with blank service data sheets to fill out as so to show the character of the service which it is desired to operate. The company's great experience enables it to render valuable assistance in this class of work, and long experience has shown that co-operation is mutually beneficial.

The blank form on page 18 will be gladly furnished to prospective customers.

Speed torque and efficiency curves for the G.E. 214 motor, with various gear ratios corresponding to the gear ratios given in the table, will be found on pages 12 to 16.

These curves are convenient for general reference.

The diagrams of the motor on pages 16 and 17, which show the external dimensions and axle preparation, will enable truck builders and car manufacturers to adapt their trucks and cars for the proper reception of the motor.

The table on page 11 giving the estimated schedule speeds in miles per hour for the G.E. 214 motor is calculated on the basis of a 600 volt line pressure at the motors.

The duration of each stop has been taken as ten seconds.

The maximum temperature rise of the motors above the surrounding air has been taken as not more than 65 degrees C. with the motors closed, this temperature being based on the operation of motors under average normal conditions. Though the temperature rise will not usually exceed the estimate of 65 degrees C., it should be noted that this temperature rise cannot be guaranteed, as motor temperatures depend on the manner in which motormen handle the equipments.

For convenience in knowing what schedules can be made in the city by high speed interurban equipments, schedules have been given which in some cases it will be found physically possible to exceed, but which should not be exceeded for any length of time.

If it is of importance to make better schedules than those given for the high speed equipments in city service, full information should be furnished the General Electric Company for complete analysis.

When applying the tables to service requiring two or more different schedules, such as a city service with many stops per mile combined with a suburban or interurban service with but few stops per mile, the schedules for each class of service should be taken separately and a resulting schedule for the combined service obtained.

The schedule speeds given in the table are based on the operation of motors under favorable conditions, and are at least 10 per cent below the theoretical speeds, in order to allow for the normal delays due to curves, grades, slow-downs, etc.; in other words, it is assumed that the delays due to these causes will equal six minutes in every hour. If this allowance is considered insufficient, due to special local conditions, the schedule should be reduced 1.85 per cent for each additional minute of delay. The improper handling of the cars or excessive track or car friction may also reduce the schedule, and this will also be the case if, in addition to the regular stops, there are an unusual number of slow-downs, curves or grades. If curves and grades are numerous or excessive, or the conditions are special or abnormal and an extensive analysis is necessary, complete information should be furnished to the General Electric Company before deciding on the motor equipment to be used. The schedule speeds given in the table should be decreased by the percentage given below for any voltages below 600. For each 1 per cent reduction in the voltage, there will be approximately the following reduction in the schedule:

1 stop per mile	0.5%
3 stops per mile	0.2%
7 stops per mile	0.1%

When the voltage is greater than 600, the schedule may be increased by approximately the same per cent as it is decreased for a reduction of voltage. It should, however, be borne in mind that there will be an increase in temperature at the higher voltages and schedules. Nevertheless, as there will be somewhat less heating of the motors at a lower voltage and schedule, it is permissible to increase the schedule on parts of the line by increasing the voltage, providing there is a corresponding decrease in the voltage on the other portions.

As the number of stops per mile increases, the schedules that can be made with the same car weights, but with different speed gears, become more nearly equal.

When the same schedule is made with different speed gears, the heating of the motors is less with the low speed than with the high speed gear.

Under ordinary service conditions the watt hours per ton mile for a given schedule are less with a low than with a high speed gear. Therefore, in order to operate with the lowest power consumption and also with the minimum heating of the motors, the lowest speed gear, that is, the highest gear ratio which will make the required schedule, is generally best suited for a given service.

The tractive effort is taken at 19 to 29 lb. per ton, depending on the speed and weight of the car. An examination of the motor curves will show the tractive effort assumed for the various speeds.

In determining "tons per motor" the total weight of the car or train, including the load, motors, controllers, rheostats, etc., divided by the number of motors, should be taken.

In ordinary service the average and not the maximum load should be taken. The average passenger load may be represented by the seating capacity and the average weight per passenger can be assumed to be 140 pounds. If the motors operate with maximum load for a large part of the time, the maximum and not the average load should be taken.

The tables do not apply when the motors are used for electric braking, as the heating of the motors is increased thereby.

APPROXIMATE WEIGHT IN POUNDS OF FORM C MOTOR

Motor complete with gear and gear case	3806
Two-motor equipment complete with two controllers	9282
Two-motor equipment complete with Sprague-General Electric Type M control	9902
Four-motor equipment complete with two controllers	17414
Four-motor equipment complete with Sprague-General Electric Type M control	18009

APPROXIMATE WEIGHT IN POUNDS OF FORM B

Motor complete with gear and gear case	3916
Two-motor equipment complete with two controllers	9502
Two-motor equipment complete with Sprague-General Electric Type M control	10122
Four-motor equipment complete with two controllers	17854
Four-motor equipment complete with Sprague-General Electric Type M control	18449

GEAR RATIOS, CHARACTERISTIC CURVES, ETC.

The gear ratio with characteristic letters and numerals corresponding with three turn armatures and 56 turn exciting fields are as follows:

Pinion	Gear	Gear Ratio	Classification	Characteristic No.
17	60	3.53	G.E. 214-C-1	178
19	58	3.05	G.E. 214-C-2	179
21	56	2.66	G.E. 214-C-3	180
23	54	2.35	G.E. 214-C-4	181
17	60	3.53	G.E. 214-B-1	178
19	58	3.05	G.E. 214-B-2	179
21	56	2.66	G.E. 214-B-3	180
23	54	2.35	G.E. 214-B-4	181

SCHEDULE SPEED—GE-214 MOTORS

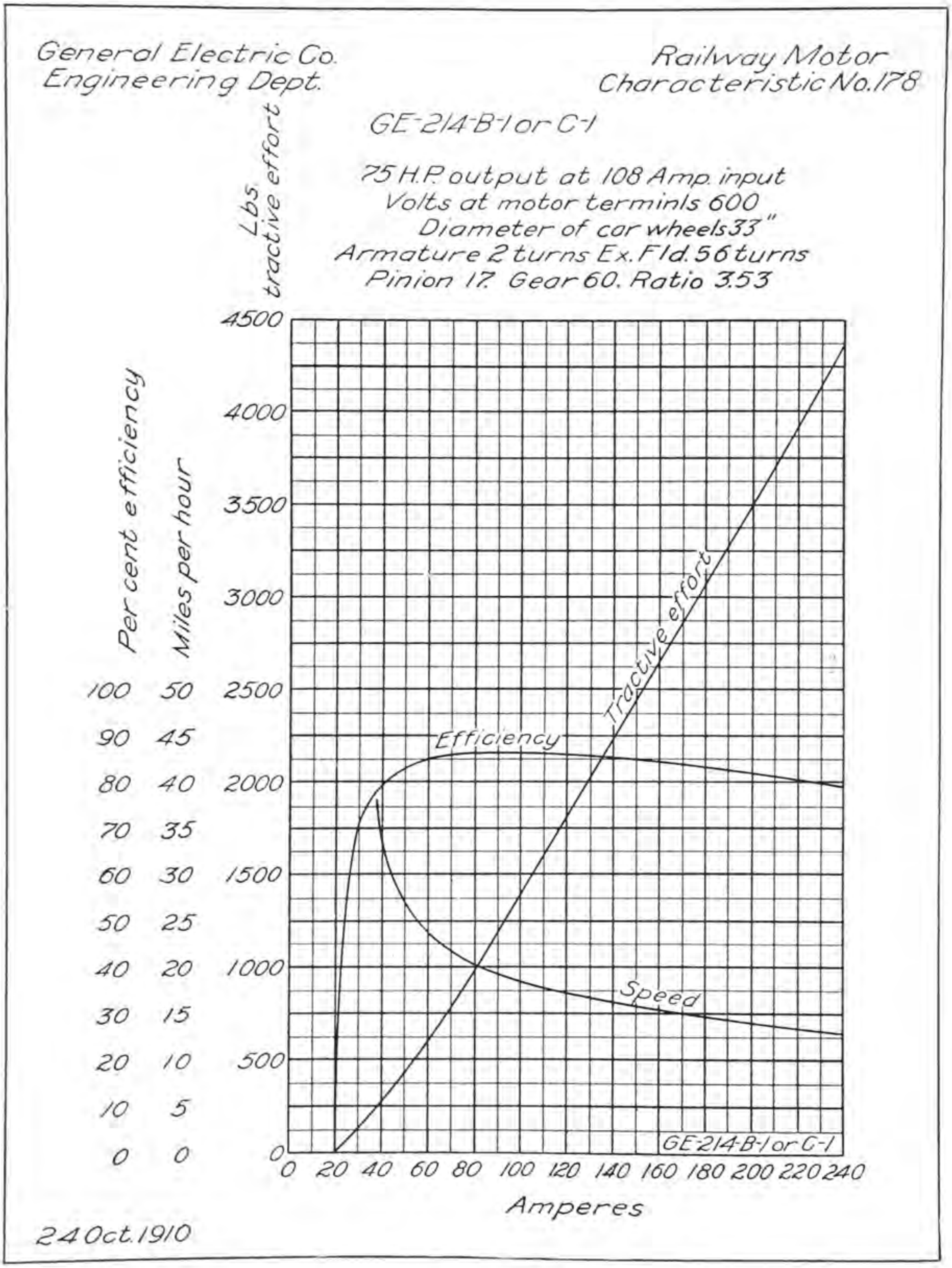
ARM. 2 TURNS. EXC. FIELDS, 56 TURNS. 600 VOLTS, 33 IN. HEELS

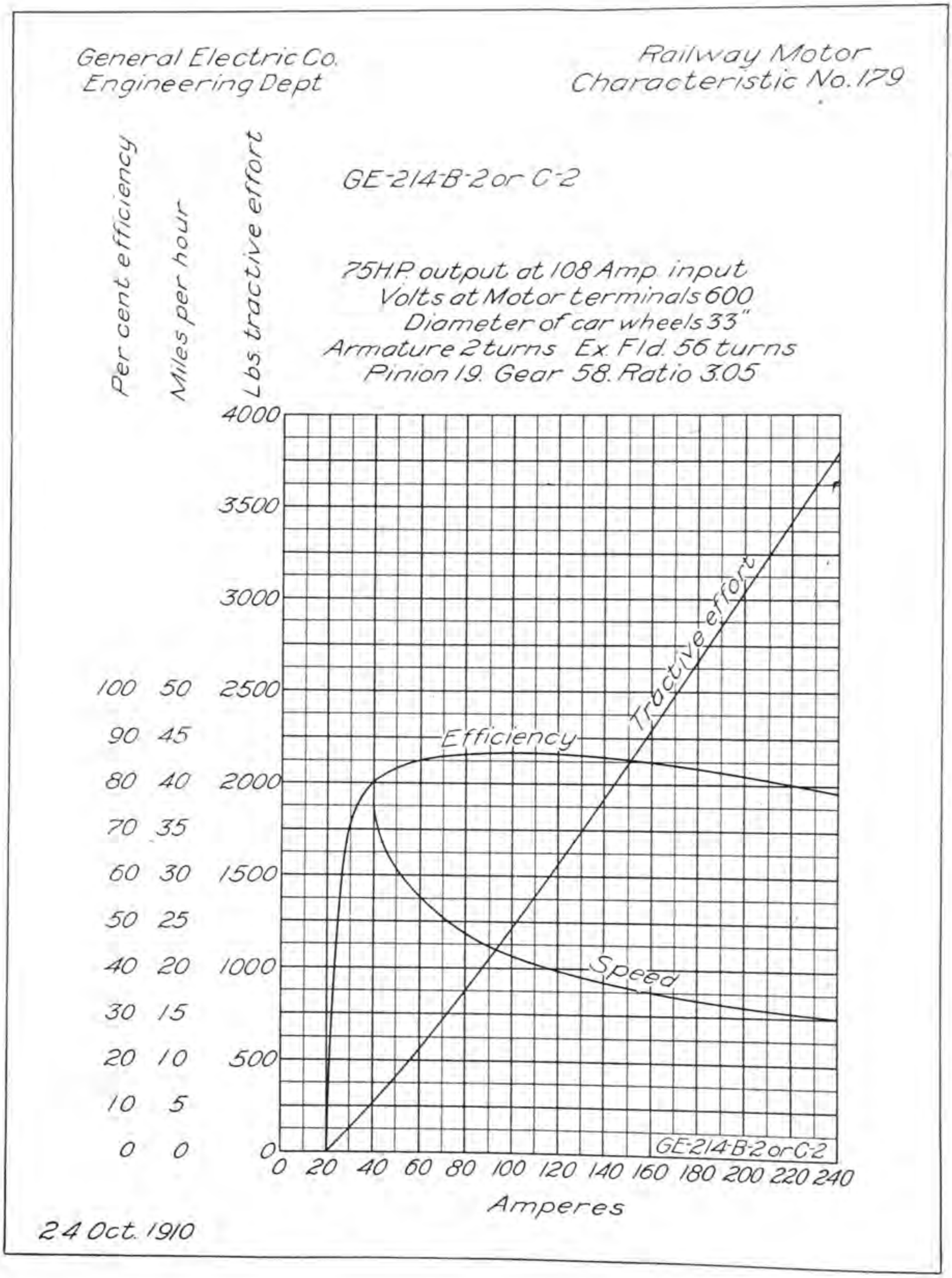
READ BULLETIN CAREFULLY BEFORE APPLYING TABLE

Stops per Mile	Gear Ratio	TONS PER MOTOR 6	7	8	9	10	11	12	13	14	15
¼	3.53	31.7	31	30.2	29.5	28.8	28.1	27.4	26.6	26	25.3
¼	3.05	33.5	32.9	32.4	31.8	31.3	30.8	30.2	29.7	29.2	28.7
¼	2.66	35.2	34.8	34.3	33.8	33.3	32.8	32.3	31.8		
¼	2.35	37.3	36.7	36.1	35.5	35	34.4				
½	3.53	28.6	28	27.5	26.9	26.4	25.2	25.2	24.6	24	23.5
½	3.05	29.8	29.3	28.8	28.4	27.8	27.4	26.9	26.4	26	
½	2.66	31.2	30.6	30.2	29.7	29.2	28.7				
½	2.35	32.4	31.8	31.2							
1	3.53	23.6	23.2	22.8	22.4	22.1	21.8	21.4	21	20.7	
1	3.05	24.4	24	23.6	23.2	22.8	22.4				
1	2.66	24.9	24.6	24.2	23.8						
1	2.35	26	25.3	24.7							
2	3.53	18.4	18.2	18	17.8	17.6	17.4	17.2			
2	3.05	18.5	18.3	18.2	18						
2	2.66	19.2	18.8	18.6							
2	2.35	19.3	18.9								
3	3.53	15.4	15.4	15.3	15.2	15.1					
3	3.05	15.8	15.6	15.4	15.2						
3	2.66	16	15.7								
3	2.35	16.2									
4	3.53	13.4	13.3	13.2	13.1	13					
4	3.05	13.6	13.5	13.3	13.1						
4	2.66	13.7	13.6								
4	2.35	13.8									
5	3.53	12	12	11.9	11.8	11.8					
5	3.05	12.2	12.1	12	11.8						
5	2.66	12.3	12.2								
5	2.35	12.4									
6	3.53	10.6	10.5	10.5	10.4	10.4					
6	3.05	10.7	10.6	10.6	10.5						
6	2.66	10.8	10.7								
6	2.35	10.9									
Max. Speed Quadruple Equip.	3.53	40	39	38	37	36	35	34	33	32	31
	3.05	42	41.5	41	40	39.5	39	38	37.5	37	36.5
	2.66	45	44.5	43.5	43.5	43	42.5	42	41.5	41	40.5
	2.35	49	48	47.5	46.5	46	45	44.5	44	43	42.5

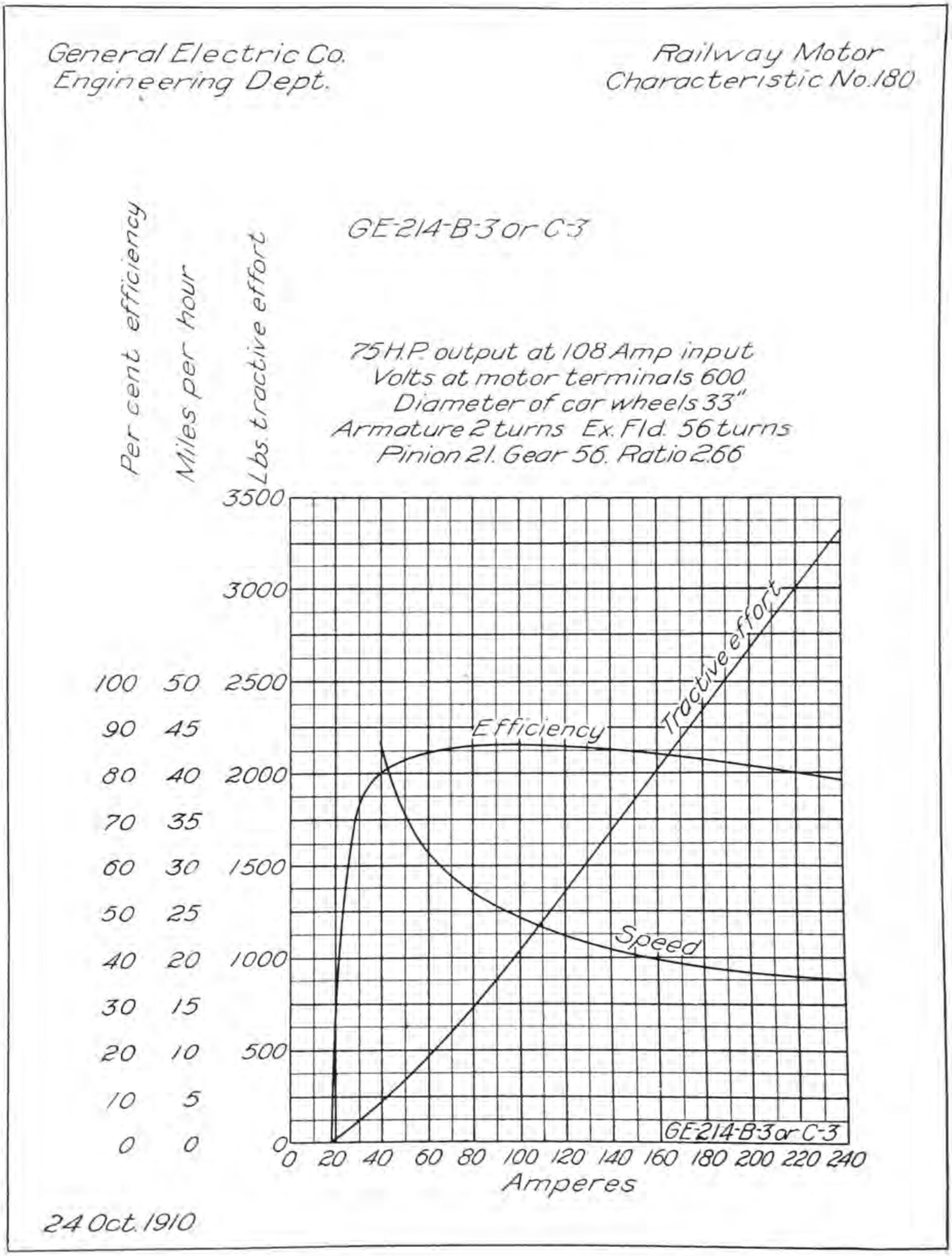
Maximum speed of two motor equipment approximately 90 per cent of above.

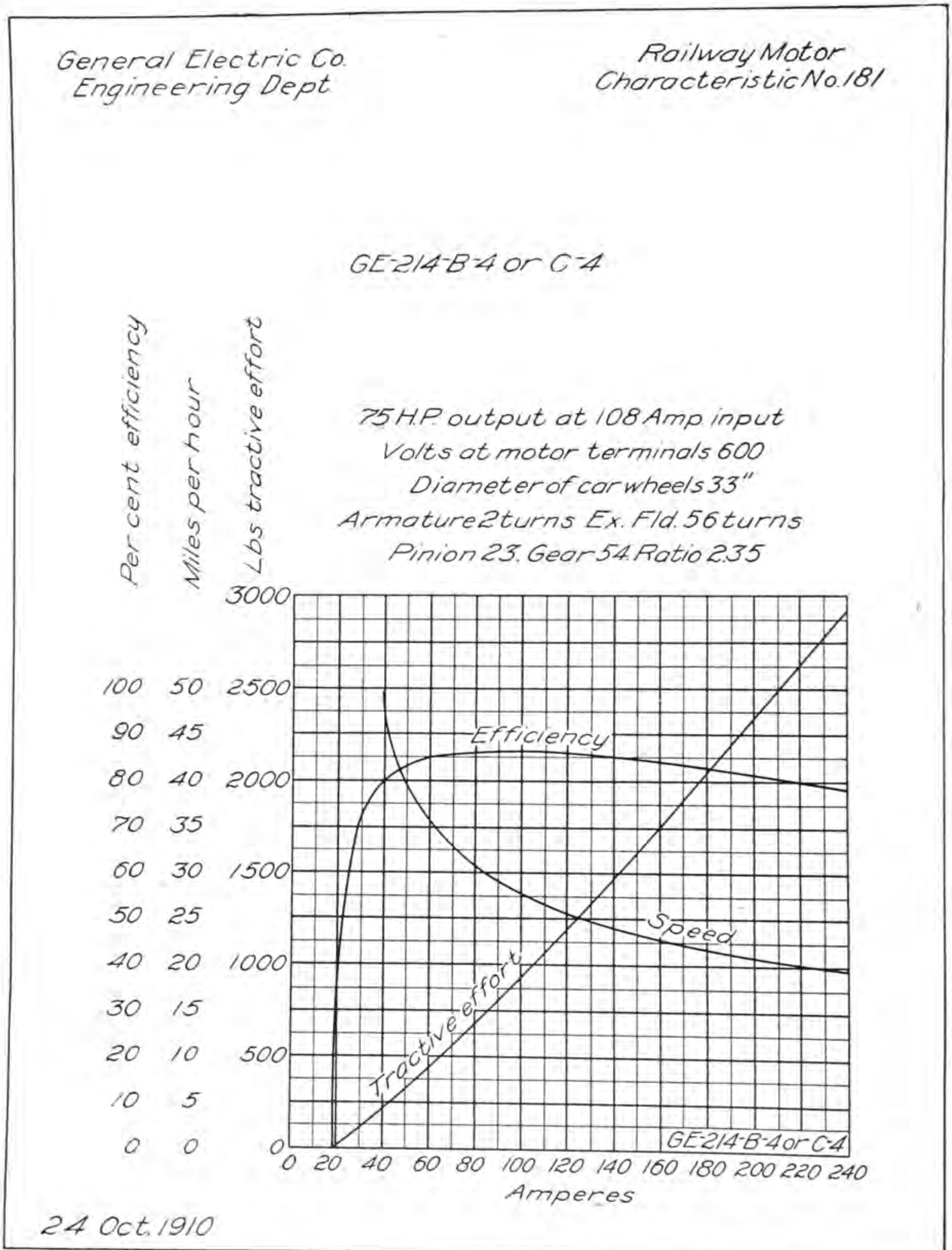
4817-12 G.E. 214 Railway Motor



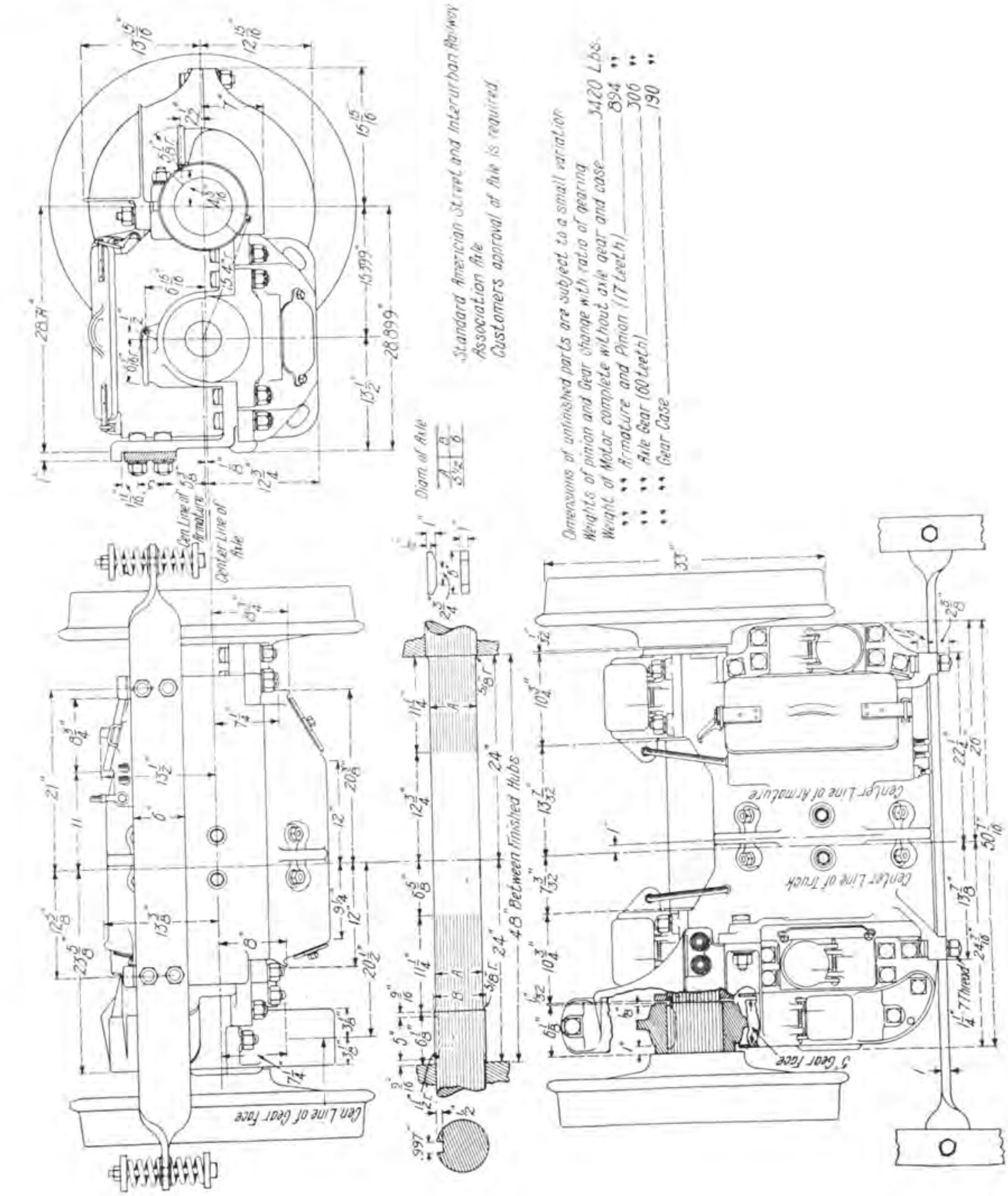

General Electric Co.
Engineering Dept.
Railway Motor
Characteristic No. 179
GE-214-B-2 or C-2
75 H.P. output at 108 Amp. input
Volts at Motor terminals 600
Diameter of car wheels 33"
Armature 2 turns Ex. Fld. 56 turns
Pinion 19. Gear 58. Ratio 3.05
Per cent efficiency
Miles per hour
Lbs. tractive effort
4000
3500
3000
100 50 2500
90 45
80 40 2000
70 35
60 30 1500
50 25
40 20 1000
30 15
20 10 500
10 5
0 0 0
0 20 40 60 80 100 120 140 160 180 200 220 240
Amperes
Tractive effort
Efficiency
Speed
GE-214-B-2 or C-2
24 Oct. 1910

4817-14 G.E. 214 Railway Motor




General Electric Co.
Engineering Dept.
Railway Motor
Characteristic No. 181
GE-214-B-4 or C-4
Per cent efficiency
Miles per hour
Lbs tractive effort
75 H.P. output at 108 Amp. input
Volts at motor terminals 600
Diameter of car wheels 33"
Armature 2 turns Ex. Fld. 56 turns
Pinion 23, Gear 54 Ratio 2.35
3000
100 50 2500
90 45
80 40 2000
70 35
60 30 1500
50 25
40 20 1000
30 15
20 10 500
10 5
0 0 0
Efficiency
Speed
Tractive effort
GE-214-B-4 or C-4
0 20 40 60 80 100 120 140 160 180 200 220 240
Amperes
24 Oct. 1910

4817-16 G.E. 214 Railway Motor

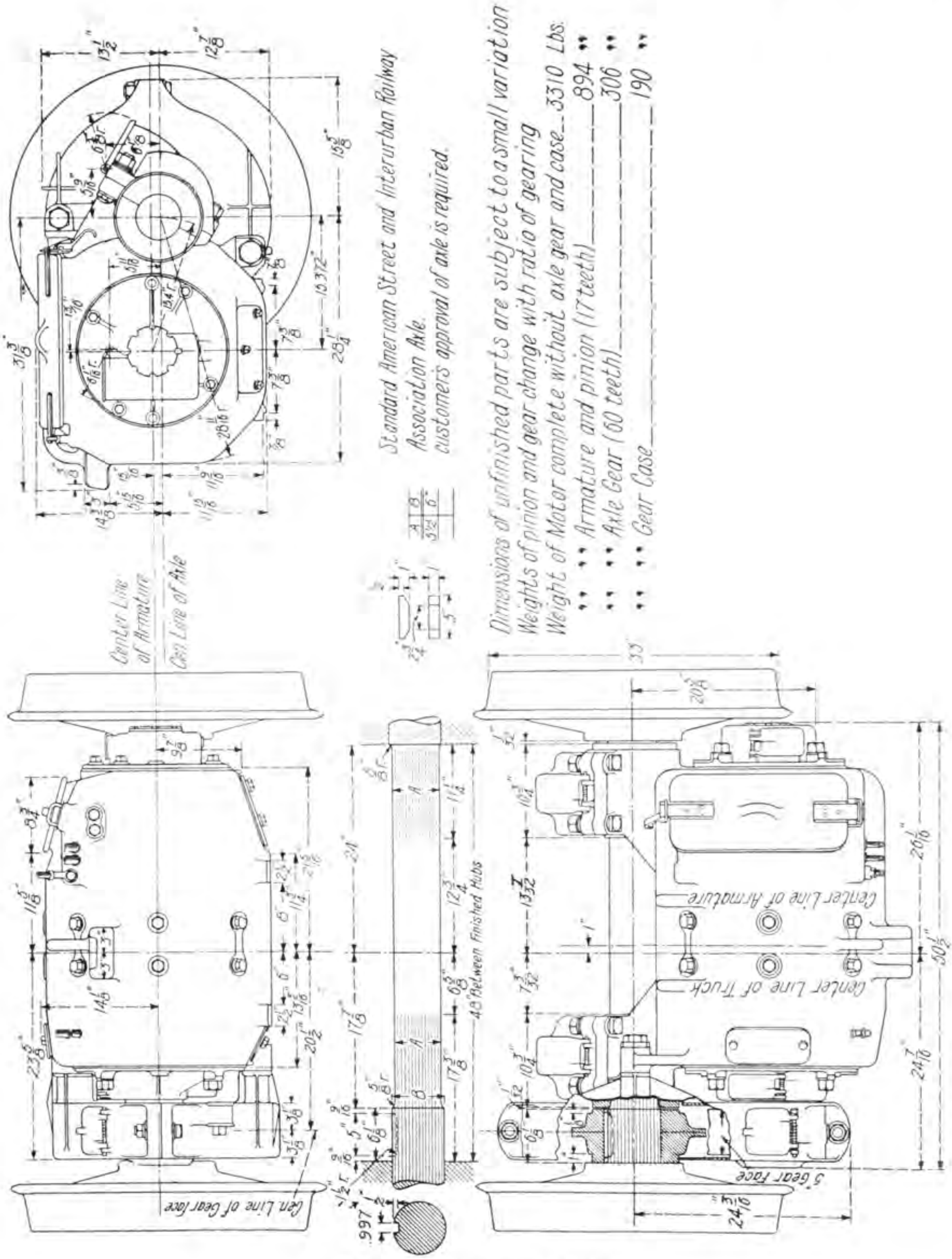


DIMENSION DIAGRAM

GE-214B RAILWAY MOTOR

1st Dec., 1910

No. 14496



DIMENSION DIAGRAM

GE-214C RAILWAY MOTOR

1st Dec., 1910

No. 14497

4817–18 G.E. 214 Railway Motor

GENERAL ELECTRIC COMPANY SERVICE DATA SHEET FOR RAILWAY EQUIPMENTS

on the..Railway.

MOTOR CARS: (OPEN OR CLOSED).................... No. of motors per car.........................

Weight of empty cars and trucks not including electrical equipment....................tons (2000 lbs.)

Length of car overall,..............Length of car body,..............Seating capacity,.....................

Capacity with standing load,.....................If open car give number of benches,....................

Have cars single or double trucks?.... ....Diameter of car wheel is.............. .... inches.

TRAIL CARS: (OPEN OR CLOSED).......................

Weight of empty cars and trucks............tons (2000 lbs.) Length of car over all,................

Length of car body,............Seating capacity,............Capacity with standing load,............

No. of trail cars handled by motor car,....................Hours during which trail cars are operated,...

LINE POTENTIAL: Maximum voltage is .... .Minimum voltage is............. ..Average voltage is.......................

TIME: (excluding layovers) required to make round trip............ ... ..minutes. Length round trip........................miles.

Distance **round trip** in city service.......................miles. Suburban.......................miles. Interurban........................miles.

STOPS: Average number on **round trip** in city service is...................Suburban is.................... Interurban is....................

(It is assumed that the average duration of stops will be 10 seconds each.)

LAYOVERS: (If any) number and duration...

....

....

GRADES: Underscore grades which cars both ascend and descend in round trip.

Length in Ft.	%	Length in Ft.	%	Length in Ft.	%	Length in Ft.	%	Length in Ft.	%

REMARKS (Pertaining to character of service not covered above, particularly with reference to curves and slowdowns.)

Dated .... ..19. ... .. Signed ....

By.......................................

GENERAL ELECTRIC COMPANY

PRINCIPAL OFFICES, SCHENECTADY, N. Y.

SALES OFFICES

(Address nearest office)

BOSTON, MASS.	84 State Street
NEW YORK, N. Y.	30 Church Street
Syracuse, N. Y.	Post-Standard Building
Buffalo, N. Y.	Ellicott Square Building
New Haven, Conn.	Malley Building
PHILADELPHIA, PA.	Witherspoon Building
Baltimore, Md.	Electrical Building
Charlotte, N. C.	Trust Building
Charleston, W. Va.	Charleston National Bank Building
Erie, Pa.	632 State Street
Pittsburg, Pa.	Park Building
Richmond, Va.	Mutual Building
ATLANTA, GA.	Empire Building
Birmingham, Ala.	Brown-Marx Building
Macon, Ga.	Grand Building
New Orleans, La.	Maison-Blanche Building
CINCINNATI, OHIO	Provident Bank Building
Columbus, Ohio	Columbus Savings & Trust Building
Cleveland, Ohio	Citizens Building
Chattanooga, Tenn.	James Building
Memphis, Tenn.	Randolph Building
Nashville, Tenn.	Stahlman Building
Indianapolis, Ind.	Traction Terminal Building
CHICAGO, ILL.	Monadnock Building
Detroit, Mich.	Majestic Building (Office of Soliciting Agent)
St. Louis, Mo.	Wainwright Building
Kansas City, Mo.	Dwight Building
Butte, Montana	Electric Building
Minneapolis, Minn.	410-412 Third Ave., North
DENVER, COLO.	First National Bank Building
Salt Lake City, Utah	Newhouse Building
SAN FRANCISCO, CAL.	Nevada Bank Building
Los Angeles, Cal.	124 West Fourth Street
Portland, Ore.	Electric Building
Seattle, Wash.	Colman Building
Spokane, Wash.	Paulsen Building

For TEXAS and OKLAHOMA Buisness refer to
General Electric Company of Texas,

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General Electric Company
Schenectady, N.Y.
SUPPLY DEPARTMENT

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COUPLINGS

The various types of couplings manufactured by the General Electric Company and

Fig. 1
LEATHER LINK FLEXIBLE COUPLING

described in this bulletin have been found by experience to fulfill all requirements and are especially adapted for coupling electrical apparatus together, or to other machines. They are as follows: leather link flexible couplings, laced belt flexible couplings, mill type flexible couplings, rubber buffer flexible couplings and flange couplings. All the couplings will run equally well in either direction. The rubber or leather connections in all forms of flexible couplings efficiently insulate the two halves from one another, a point which is often of great importance in this class of work.

The leather used in these couplings is not the ordinary leather belting. It is treated to a special tanning process by which means not only is the hide rendered more flexible but the strength is also greatly increased.

The leather insulated couplings are not recommended for use when exposed to flying dust and grit, which soon score and cut the belt leather and render the coupling inoperative. As oil and dampness also affect the leather, such couplings should not be used under these conditions. If a flexible coupling is needed in the above cases, the Mill Type should be used.

The rubber buffer couplings are no longer standard and are furnished only on demand. The reason is that uniform quality of rubber cannot always be obtained for the buffers.

The long hub couplings are usually recommended, unless the two connected machines are close together, in which case short hub couplings should be used. For shaft sizes, speeds, weights, prices and general dimensions of the different types see pages 3 to 9.

Fig. 2
DISASSEMBLED VIEW OF LEATHER LINK FLEXIBLE COUPLING

Leather Link Flexible Couplings

The leather link flexible coupling consists of two iron castings which are connected

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together through leather links securely fastened by bolts as shown in the illustration. (Figs. 1 and 2.) In small sizes, these links are replaced by a single leather disc which connects both halves by means of bolts alternately fastened to opposite halves. The

Fig. 3
LACED BELT FLEXIBLE COUPLING

torque stresses are transmitted through these discs or links to the bolts which fasten them to the castings as shown in the cross sectional view given on page 3.

In order to allow sufficient play for the heads of the bolts, alternate holes are bored to a large diameter, the bolts accurately fitting the other holes in the castings. By

Fig. 4
DISASSEMBLED VIEW OF LACED BELT FLEXIBLE COUPLING

this means flexibility is obtained and a small amount of end or side play is permissible between the shafts of the two machines to which each half coupling is securely keyed.

This coupling is less expensive in the small sizes than the lace belt coupling described below and is therefore recommended for shafts up to two inches in diameter. For shafts between 2 in. and 3½ in. in diameter either this type or the leather laced type may be used.

Leather Laced Flexible Couplings

For shafts above 3½ inches in diameter the leather laced flexible coupling is recommended on account of its structural advantages. It consists of two steel rings,

Fig. 5
FLANGE COUPLING

an outer and an inner with cast iron hubs bolted to them. Slots are formed in these rings through which an endless leather belt is interwoven as shown in the illustration. (Figs. 3 and 4.) This construction not only gives great flexibility but due to the two rings being concentric, it is not subjected to

Fig. 6
DISASSEMBLED VIEW OF FLANGE COUPLING

bending strains and therefore is specially adapted for transmitting a high torque commensurate with the strength of the belt and the size of the coupling employed.

As the outer ring of the coupling is only connected to the shaft of the machine through the coupling hub which is keyed to the shaft, machines using this form of coupling can be readily disconnected without unlacing or interfering with the coupling belt. To do this, it is only necessary to remove the bolts, holding the outer ring to the hub. This partial disassembling also aids in the replacing of a worn out belt without removing the coupling from the machine.

Mill Type Flexible Couplings

Where conditions are too severe for the belt or rubber of the other flexible couplings, that is, where there is much grit or hot vapor present and where noise is not objectionable, the mill type flexible coupling should be used. This coupling is intended for heavy drives using shafts of 2 in. diameter and above. Best results are obtained from this coupling when it is used on a constant load, as the noise under these conditions is at a minimum. This coupling is shown in Fig. 12.

Rubber Buffer Couplings

The rubber buffer flexible couplings shown in Figs. 10 and 11 are made up of two cast iron spiders, the small interlocking arms of which are separated by cylinders of soft rubber. This construction affords great flexibility as well as insulating qualities. The rubber cylinders are held in place by projecting plates screwed to the arms of one of the spiders. This coupling is made with 3, 4, 6, 7 and 8 arm spiders. For dimensions, weights, etc., see page 6.

Flange Coupling

The flange couplings shown in Figs. 5 and 6 consists of two steel castings rigidly bolted together. All surfaces are machined, bolt holes reamed and the two adjacent surfaces, besides being carefully machined, are provided with a male and female fit to insure their alignment. Owing to its simplicity, this form is recommended in all cases where the two machines are fastened to a common iron bed plate and exact alignment is therefore possible.

Owing to the large flanges of these couplings, they tend to overcome bending stresses especially when the couplings carry part of the load which occurs when three bearing sets are used.

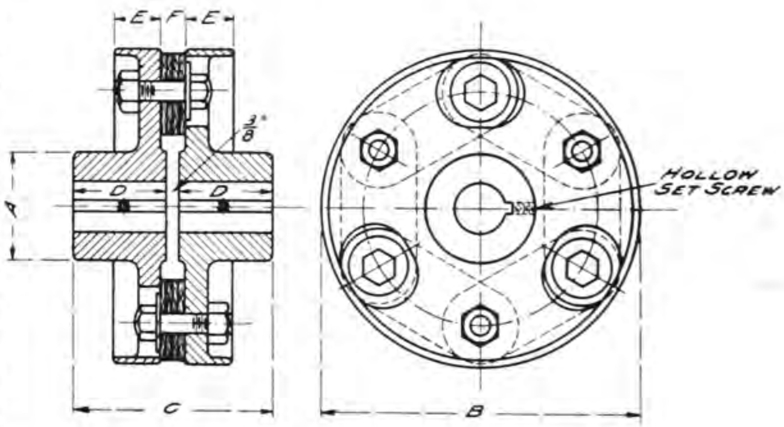

Fig. 7
LEATHER LINK FLEXIBLE COUPLING (LONG HUB)

Bore (Max.)	Dimensions in Inches						Rating per Revolution with 400 Lb. per Sq. In. Tensile Stress in Belt		Max. R.P.M.	Weight with Max. Bore in Lb.	List Price
	A	B	C	D	E	F	Kw.	H.P.			
3/4	1 3/8	3 3/8	2 7/8	1 1/4	11/16	3/8	.0012	.0016	1800	2 3/4	$13.50
1	2	5	4	1 13/16	7/8	3/8	.0032	.0043	1800	7 1/4	16.50
1 1/2	2 3/4	6 3/4	6	2 13/16	1 1/16	3/8	.0076	.0102	1800	15	20.00
2	3 1/2	8 1/4	8	3 13/16	1 1/8	3/4	.0149	.0200	1800	27	31.00
2 1/2	4 1/8	9 1/2	10	4 13/16	1 7/16	3/4	.0258	.0346	1800	43	36.50
3	5	11 1/8	12	5 13/16	1 5/8	3/4	.0410	.0550	1800	75	45.00
3 1/2	6	12 1/2	12	5 13/16	1 15/16	1 1/8	.0612	.0821	1800	103	56.00

NOTE.—For shaft diameters not given take next size above.

4818–4 Couplings

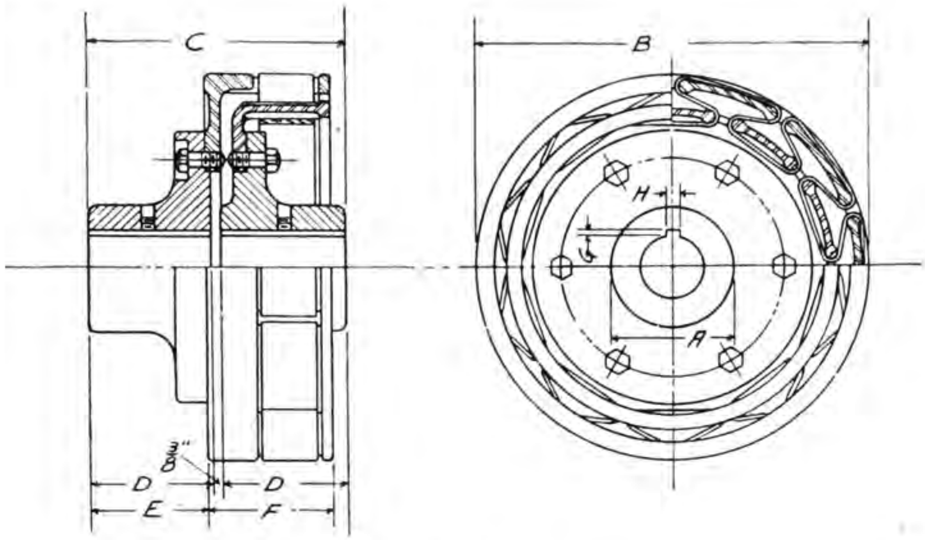

Fig. 8
DIMENSIONS OF LACED BELT FLEXIBLE COUPLING (LONG HUB)

Bore	DIMENSIONS IN INCHES								RATING PER REVOLUTION WITH 400 LB. PER SQ. IN. TENSILE STRESS IN BELT		Max. R.P.M.	Complete Weight in Lb.	List Price
	A	B	C	D	E	F	G	H	Kw.	H.P.			
2½	5	15½	10	$4\frac{13}{16}$	$4\frac{11}{16}$	4¾	¼	½	.1196	.1604	1200	160	$100.00
3	6	18½	12	$5\frac{13}{16}$	$5\frac{11}{16}$	$5\frac{1}{16}$	⅜	¾	.2066	.2770	900	263	140.00
3½	6	18½	12	$5\frac{13}{16}$	$5\frac{11}{16}$	$5\frac{1}{16}$	⅜	¾	.2066	.2770	900	256	140.00
4	8	24½	14	$6\frac{13}{16}$	$6\frac{11}{16}$	6¼	½	1	.4901	.6570	750	494	200.00
4½	8	24½	14	$6\frac{13}{16}$	$6\frac{11}{16}$	6¼	½	1	.4901	.6570	750	482	200.00
5	10	30½	16	$7\frac{13}{16}$	$7\frac{11}{16}$	7¼	⅝	1¼	.9573	1.2832	600	883	250.00
5½	10	30½	16	$7\frac{13}{16}$	$7\frac{11}{16}$	7¼	⅝	1¼	.9573	1.2832	600	868	250.00
6	12	37	18	$8\frac{13}{16}$	$8\frac{11}{16}$	7⅝	¾	1½	1.6540	2.2176	450	1329	375.00
6½	12	37	18	$8\frac{13}{16}$	$8\frac{11}{16}$	7⅝	¾	1½	1.6540	2.2176	450	1307	375.00
7	14	43	20	$9\frac{13}{16}$	$9\frac{11}{16}$	8⅜	¾	1½	2.6270	3.5215	350	2076	500.00
7½	14	43	20	$9\frac{13}{16}$	$9\frac{11}{16}$	8⅜	¾	1½	2.6270	3.5215	350	2046	500.00
8	16	49	24	$11\frac{13}{16}$	$11\frac{11}{16}$	9⅛	¾	1¾	3.9214	5.2566	300	2767	600.00
8½	16	49	24	$11\frac{13}{16}$	$11\frac{11}{16}$	9⅛	¾	1¾	3.9214	5.2566	300	2727	600.00
9	18	55	28	$13\frac{13}{16}$	$13\frac{11}{16}$	$9\frac{11}{16}$	⅞	2	5.5833	7.4844	250	3917	775.00
9½	18	55	28	$13\frac{13}{16}$	$13\frac{11}{16}$	$9\frac{11}{16}$	⅞	2	5.5833	7.4844	250	3865	775.00
10	20	61	32	$15\frac{13}{16}$	$15\frac{11}{16}$	$10\frac{5}{16}$	⅞	2	7.6591	10.2669	200	5120	1000.00

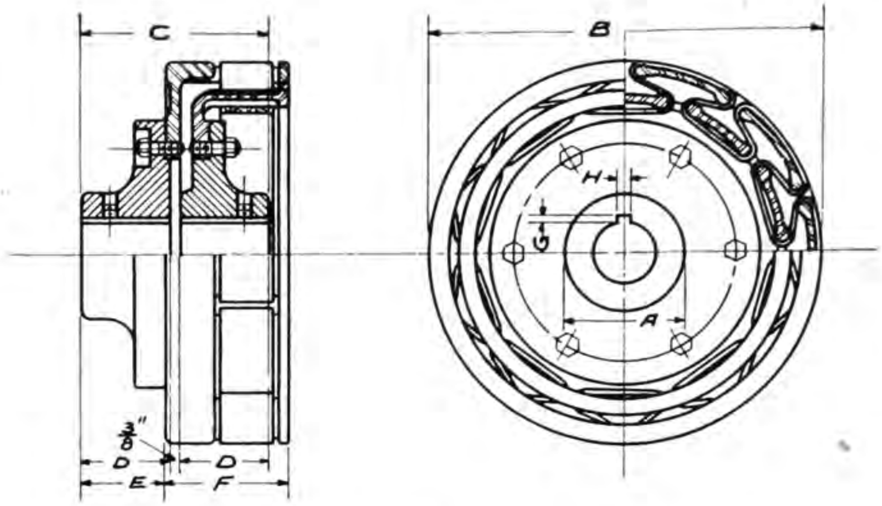

Fig. 9
DIMENSIONS OF LACED BELT FLEXIBLE COUPLING (SHORT HUB)

Bore	DIMENSIONS IN INCHES								RATING PER REVOLUTION WITH 400 LB. PER SQ. IN. TENSILE STRESS IN BELT		Max. R.P.M.	Complete Weight in Lb.	List Price
	A	B	C	D	E	F	G	H	Kw.	H.P			
3	6	15½	6	2 13/16	2 11/16	4¾	⅜	¾	.1196	.1604	1200	144	$120.00
3½	6	18½	6	2 13/16	2 11/16	5 1/16	⅜	¾	.2066	.2770	900	205	130.00
4	8	18½	8	3 13/16	3 11/16	5 1/16	½	1	.2066	.2770	900	236	155.00
4½	8	24½	8	3 13/16	3 11/16	6¼	½	1	.4901	.6570	750	427	185.00
5	10	24½	10	4 13/16	4 11/16	6¼	⅝	1¼	.4901	.6570	750	483	210.00
5½	10	30½	10	4 13/16	4 11/16	7¼	⅝	1¼	.9573	1.2832	600	768	240.00
6	12	30½	12	5 13/16	5 11/16	7¼	¾	1½	.9573	1.2832	600	954	300.00
6½	12	37	12	5 13/16	5 11/16	7⅝	¾	1½	1.6540	2.2176	450	1173	325.00
7	14	37	14	6 13/16	6 11/16	7⅝	¾	1½	1.6540	1.2176	450	1302	375.00
7½	14	43	14	6 13/16	6 11/16	8⅜	¾	1½	2.6270	3.5215	350	1814	425.00
8	16	43	16	7 13/16	7 11/16	8⅜	¾	1¾	2.6270	3.5215	350	1984	475.00
8½	16	43	16	7 13/16	7 11/16	8⅜	¾	1¾	2.6270	3.5215	350	1961	475.00
9	18	49	18	8 13/16	8 11/16	9⅛	⅞	2	3.9214	5.2566	300	2661	575.00
9½	18	49	18	8 13/16	8 11/16	9⅛	⅞	2	3.9214	5.2566	300	2628	575.00
10	20	49	20	9 13/16	9 11/16	9⅛	⅞	2	3.9214	5.2566	300	2928	650.00
10½	20	49	20	9 13/16	9 11/16	9⅛	⅞	2	3.9214	5.2566	300	2884	650.00
11	22	55	22	10 13/16	10 11/16	9 11/16	1	2½	5.5833	7.4844	250	3958	775.00
11½	22	55	22	10 13/16	10 11/16	9 11/16	1	2½	5.5833	7.4844	250	3910	775.00
12	24	55	24	11 13/16	11 11/16	9 11/16	1	2½	5.5833	7.4844	250	4357	875.00
12½	24	55	24	11 13/16	11 11/16	9 11/16	1	2½	5.5833	7.4844	250	4295	875.00
13	26	61	26	12 13/16	12 11/16	10 5/16	1	2½	7.6591	10.2669	200	5540	1000.00
13½	26	61	26	12 13/16	12 11/16	10 5/16	1	2½	7.6591	10.2669	200	5465	1000.00
14	28	61	28	13 13/16	13 11/16	10 5/16	1	2½	7.6591	10.2669	200	6091	1200.00
14½	28	61	28	13 13/16	13 11/16	10 5/16	1	2½	7.6591	10.2669	200	6010	1200.00

Fig. 10
ASSEMBLED VIEW

Fig. 11
DISASSEMBLED VIEW

RUBBER BUFFER FLEXIBLE COUPLINGS

No. of Arms.	Outside Diam.	H.P. per R.P.M.	Kw. per R.P.M.	Hub. Diam.	Bore (Max.)	Length of Hub	Overall Length	Weight	Speed (Max.)	List Price
4	10	.025	.0186	2⅝	1⅝	3	6½	40	1900	$50.00
4	12	.035	.026	5	3 7/16	4	8½	60	1500	60.00
3	16	.12	.0895	7½	4½	5¾	12	160	1500	110.00
4	20	.225	.168	9	5½	7 13/16	16¼	380	1000	165.00
4	28	.3	.223	9	5½	8	16⅝	600	950	175.00
6	28	.46	.342	12	6½	8 13/16	18	650	750	225.00
8	32	.9	.67	12	8	8½	18	1000	510	325.00
8	36	1.23	.99	14	7	11½	24	2000	740	650.00
6	40	1.5	1.12	14	7	8½	17	2100	560	450.00
7	40	2	1.49	14	8	9½	20	1800	500	500.00
7	50¼	2.5	1.56	16	9	10	21	4000	450	900.00

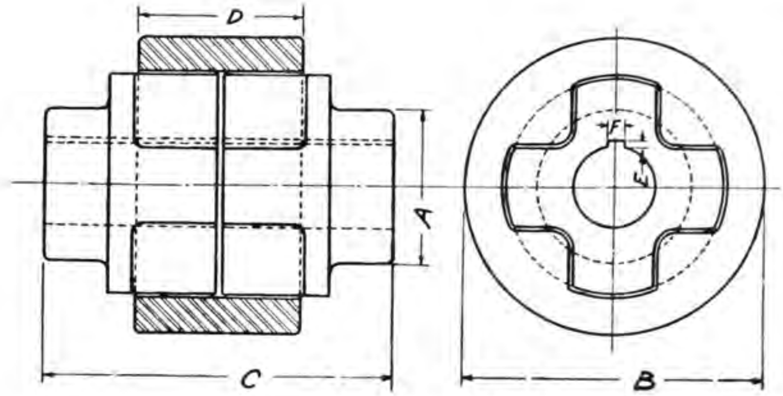

Fig. 12
MILL TYPE FLEXIBLE COUPLING

Bore	DIMENSIONS IN INCHES						RATING PER REVOLUTION WITH 3300 LB. PER SQ. IN. TORSIONAL STRESS IN SHAFT		Max. R.P.M.	Complete Weight in Lb.	Net Price
	A	B	C	D	E	F	Kw.	H.P.			
2	3¾	7½	9	4	¼	½	.0612	.0821	1200	125	$ 16.00
2½	4⅝	9	10½	5	¼	½	.1196	.1604	1200	170	18.50
3	5½	10½	12½	6	⅜	¾	.2066	.2770	900	210	25.00
3½	6¼	12¼	14½	7	⅜	¾	.3282	.4400	750	305	32.00
4	7¼	13¾	16½	8	½	1	.4901	.6570	750	400	37.00
4½	8	15⅜	18½	9	½	1	.6978	.9355	600	570	50.00
5	8¾	17	20½	10	⅝	1¼	.9573	1.2832	600	740	53.00
6	10½	20¼	24½	12	¾	1½	1.6540	2.2176	450	1295	80.00
8	13¾	26½	32	16	¾	1¾	3.9214	5.2566	300	3000	155.00
10	17	33	40	20	⅞	2	7.6591	10.2669	200	5830	275.00

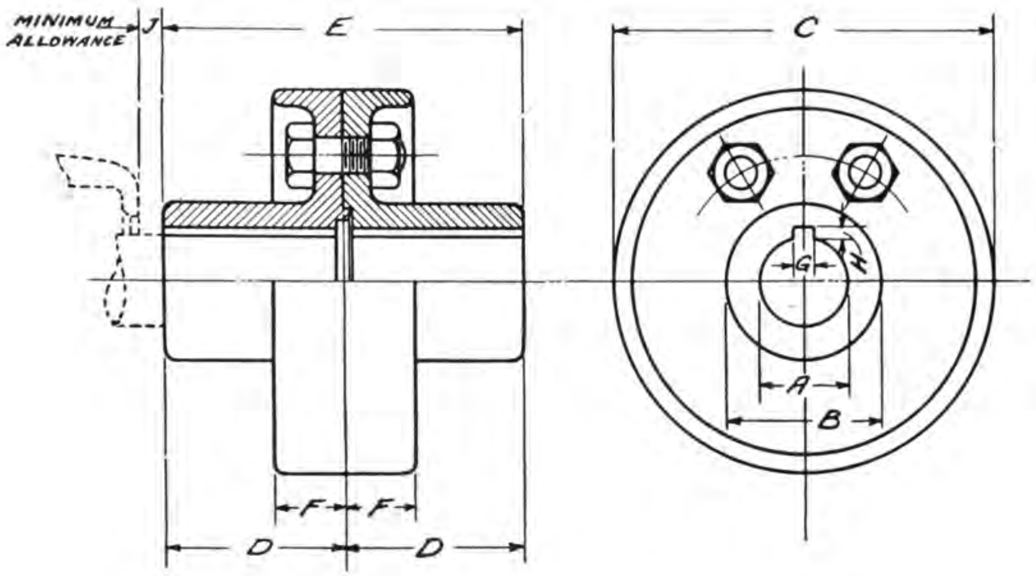

Fig. 13
FLANGE COUPLING (LONG HUB)

Bore	DIMENSIONS IN INCHES								RATING PER REVOLUTION WITH 3300 LB. PER SQ. IN. TORSIONAL STRESS IN SHAFT		Weight of Complete Coupling in Lb.	List Price
A	B	C	D	E	F	G	H	J	Kw.	H.P.		
1	2	5 1/2	2	4	1	1/4	1/8	1/2	.0076	.0102	10	$19.00
1 1/4	2 1/4	5 5/8	3	6	1 1/16	1/4	1/8	1/2	.0149	.0200	13	20.00
1 1/2	2 3/4	6 7/8	3	6	1 1/4	3/8	3/16	1/2	.0258	.0346	20	28.00
1 3/4	3	7 3/8	4	8	1 5/16	3/8	3/16	1/2	.0410	.0550	27	31.00
2	3 1/2	8 1/2	4	8	1 9/16	1/2	1/4	1/2	.0612	.0821	40	35.00
2 1/2	4 1/8	9 1/4	5	10	1 5/8	1/2	1/4	1/2	.1196	.1604	53	40.00
3	5	10 1/4	6	12	1 11/16	3/4	3/8	1/2	.2066	.2770	79	45.00
3 1/2	6	12 1/2	6	12	2	3/4	3/8	3/4	.3282	.4400	127	60.00
4	6 3/4	13	7	14	2 1/16	1	1/2	3/4	.4901	.6570	160	65.00
4 1/2	7 1/2	14	7	14	2 3/16	1	1/2	3/4	.6978	.9355	199	80.00
5	8 3/8	15 7/8	8	16	2 1/2	1 1/4	5/8	3/4	.3573	1.2832	281	110.00
5 1/2	9	16 7/8	8	16	2 5/8	1 1/4	5/8	3/4	1.2741	1.7081	320	115.00
6	9 7/8	17 5/8	9	18	2 3/4	1 1/2	3/4	3/4	1.6540	2.2176	411	145.00
6 1/2	10 1/2	19	9	18	2 3/4	1 1/2	3/4	1	2.1033	2.8195	464	180.00
7	11 3/8	20 1/4	10	20	3 1/8	1 1/2	3/4	1	2.6270	3.5215	593	210.00
7 1/2	12	21 1/4	10	20	3 1/4	1 1/2	3/4	1	3.2312	4.3314	661	225.00
8	12 3/4	22 1/2	12	24	3 1/4	1 3/4	3/4	1	3.9214	5.2566	840	265.00
8 1/2	13 3/4	23 3/4	12	24	3 1/2	1 3/4	3/4	1	4.7036	6.3051	965	300.00
9	14 3/4	25 1/2	14	28	3 11/16	2	7/8	1	5.5833	7.4844	1313	360.00
10	16	27	16	32	4	2	7/8	1	7.6591	10.2669	1652	425.00
11	17 1/2	28 3/4	16	32	4 3/16	2 1/2	1	1	10.1943	13.6653	1958	485.00
12	19	31 1/2	18	36	4 5/8	2 1/2	1	1	13.2349	17.7412	2580	585.00
13	20 1/2	33	18	36	4 13/16	2 1/2	1	1	16.8270	22.5563	2973	650.00
14	22	35 1/2	20	40	5	2 1/2	1	1	21.0166	28.1725	3775	775.00
15	23 3/4	37 1/2	20	40	5 1/2	2 1/2	1	1	25.8495	34.6509	4323	885.00
16	25 1/4	39 1/2	24	48	5 7/8	3 1/4	1 1/4	1	31.3717	42.0533	5729	1100.00

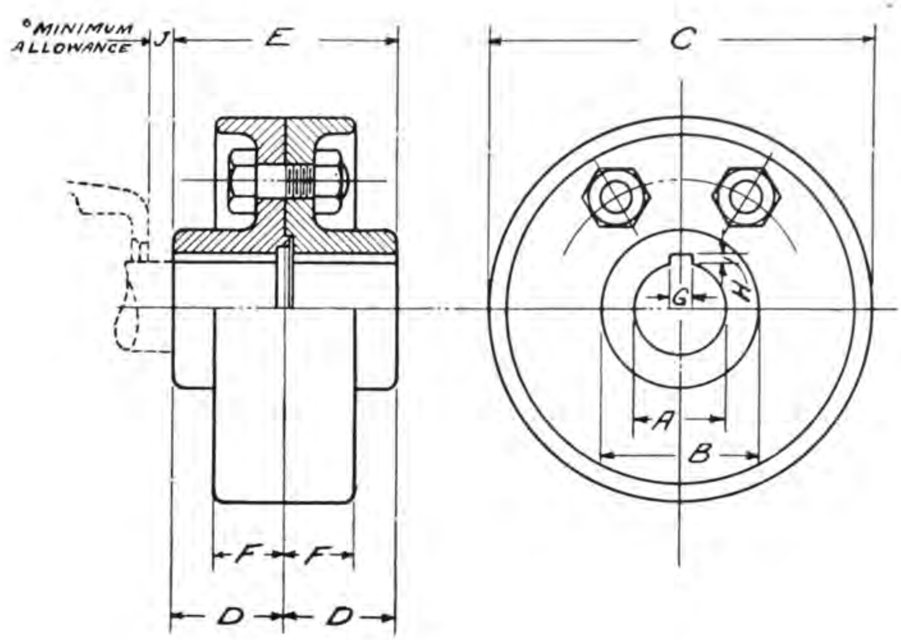

Fig. 14
FLANGE COUPLING (SHORT HUB)

Bore	DIMENSIONS IN INCHES								RATING PER REVOLUTION WITH 3300 LB. PER SQ. IN. TORSIONAL STRESS IN SHAFT		Weight of Complete Coupling in Lb.	List Price
A	B	C	D	E	F	G	H	J	Kw.	H.P.		
1	2	5 1/2	1 1/2	3	1	1/4	1/8	1/2	.0076	.0102	9	$19.00
1 1/4	2 1/4	5 5/8	1 1/2	3	1 1/16	1/4	1/8	1/2	.0149	.0200	10	20.00
1 1/2	2 3/4	6 7/8	2	4	1 1/4	3/8	3/16	1/2	.0258	.0346	18	23.00
1 3/4	3	7 3/8	2	4	1 5/16	3/8	3/16	1/2	.0410	.0550	22	25.00
2	3 1/2	8 1/2	2 1/2	5	1 9/16	1/2	1/4	1/2	.0612	.0821	34	32.00
2 1/2	4 1/8	9 1/4	2 1/2	5	1 5/8	1/2	1/4	1/2	.1196	.1604	41	36.50
3	5	10 1/4	3	6	1 11/16	3/4	3/8	1/2	.2066	.2770	57	42.50
3 1/2	6	12 1/2	3	6	2	3/4	3/8	3/4	.3282	.4400	95	51.00
4	6 3/4	13	4	8	2 1/16	1	1/2	3/4	.4901	.6570	121	60.00
4 1/2	7 1/2	14	4	8	2 3/16	1	1/2	3/4	.6978	.9355	148	67.00
5	8 3/8	15 7/8	5	10	2 1/2	1 1/4	5/8	3/4	.9573	1.2832	221	85.00
5 1/2	9	16 7/8	5	10	2 5/8	1 1/4	5/8	3/4	1.2741	1.7081	253	95.00
6	9 7/8	17 5/8	6	12	2 3/4	1 1/2	3/4	3/4	1.6540	2.2176	330	130.00
6 1/2	10 1/2	19	6	12	2 3/4	1 1/2	3/4	1	2.1033	2.8195	373	140.00
7	11 3/8	20 1/4	7	14	3 1/8	1 1/2	3/4	1	2.6270	3.5215	487	170.00
7 1/2	12	21 1/4	7	14	3 1/4	1 1/2	3/4	1	3.2312	4.3314	544	200.00
8	12 3/4	22 1/2	8	16	3 1/4	1 3/4	3/4	1	3.9214	5.2566	669	230.00
8 1/2	13 3/4	23 3/4	8	16	3 1/2	1 3/4	3/4	1	4.7036	6.3051	759	250.00
9	14 3/4	25 1/2	9	18	3 13/16	2	7/8	1	5.5833	7.4844	1011	300.00
10	16	27	10	20	4	2	7/8	1	7.6591	10.2669	1236	350.00
11	17 1/2	28 3/4	11	22	4 3/16	2 1/2	1	1	10.1943	13.6653	1548	400.00
12	19	31 1/2	12	24	4 5/8	2 1/2	1	1	13.2349	17.7412	2004	500.00
13	20 1/2	33	13	26	4 13/16	2 1/2	1	1	16.8270	22.5563	2417	550.00
14	22	35 1/2	14	28	5	2 1/2	1	1	21.0166	28.1725	3009	650.00
15	23 3/4	37 1/2	15	30	5 1/2	2 1/2	1	1	25.8495	34.6509	3672	750.00
16	25 1/4	39 1/2	16	32	5 7/8	3 1/4	1 1/4	1	31.3717	42.0533	4377	900.00

GENERAL ELECTRIC COMPANY

PRINCIPAL OFFICES, SCHENECTADY, N. Y.

SALES OFFICES

(Address nearest office)

BOSTON, MASS.	84 State Street
NEW YORK, N. Y.	30 Church Street
Rochester, N. Y.	Granite Building
Syracuse, N. Y.	Post-Standard Building
Buffalo, N. Y.	Ellicott Square Building
New Haven, Conn.	Malley Building
PHILADELPHIA, PA.	Witherspoon Building
Baltimore, Md.	Electrical Building
Charlotte, N. C.	Trust Building
Charleston, W. Va.	Charleston National Bank Building
Erie, Pa.	Marine National Bank Building
Pittsburg, Pa.	Oliver Building
Richmond, Va.	Mutual Building
ATLANTA, GA.	Empire Building
Birmingham, Ala.	Brown-Marx Building
Macon, Ga.	Grand Building
New Orleans, La.	Maison-Blanche Building
CINCINNATI, OHIO	Provident Bank Building
Columbus, Ohio	Columbus Savings & Trust Building
Cleveland, Ohio	Citizens Building
Chattanooga, Tenn.	James Building
Memphis, Tenn.	Randolph Building
Nashville, Tenn.	Stahlman Building
Indianapolis, Ind.	Traction Terminal Building
CHICAGO, ILL.	Monadnock Building
Detroit, Mich.	Majestic Building (Office of Soliciting Agent)
St. Louis, Mo.	Wainwright Building
Kansas City, Mo.	Dwight Building
Butte, Montana	Electric Building
Minneapolis, Minn.	410 Third Ave., North
DENVER, COLO.	First National Bank Building
Boise, Idaho	Idaho Building
Salt Lake City, Utah	Newhouse Building
SAN FRANCISCO CAL.	Nevada Bank Building
Los Angeles, Cal.	124 West Fourth Street
Portland, Ore.	Electric Building
Seattle, Wash.	Colman Building
Spokane, Wash.	Paulsen Building

For TEXAS and OKLAHOMA Business refer to
General Electric Company of Texas,

Dallas, Tex.	Lamar & Caruth Sts.
El Paso, Tex.	Chamber of Commerce Building
Houston, Tex.	Chronicle Building
Oklahoma City, Okla.	Insurance Building

FOREIGN SALES OFFICES

Schenectady, N. Y., Foreign Dept.
New York, N. Y., 30 Church St.
London, E. C., England, 83 Cannon St.

For all CANADIAN Business refer to
Canadian General Electric Co., Ltd., Toronto, Ont.

Apr 1911

4819

ALTERNATING CURRENT SWITCHBOARD PANELS

With Oil Switches on Panel

THREE-PHASE THREE-WIRE

480 AND 600 VOLTS, 25 TO 60 CYCLES

90 INCHES HIGH

General Electric Company

April, 1911 *Schenectady, N. Y.* ***Bulletin No. 4819***

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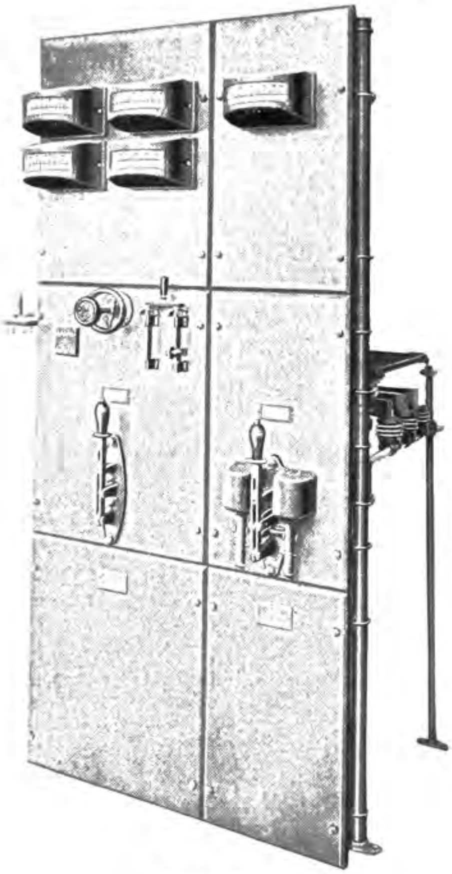
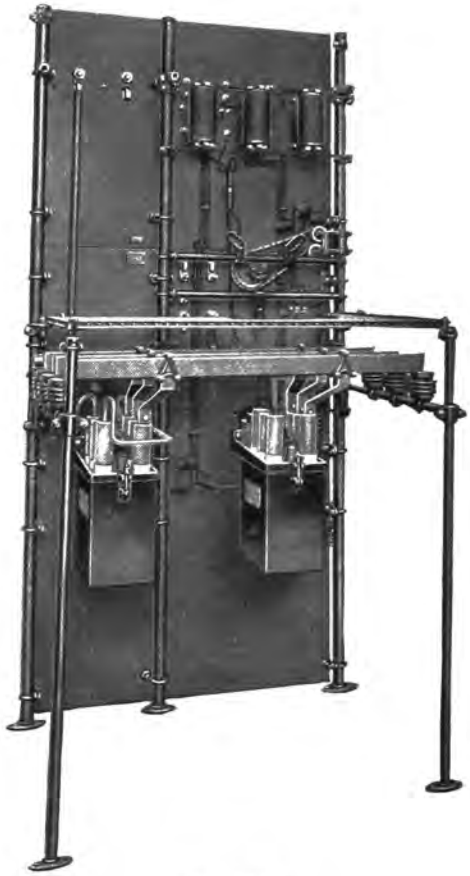


Front View



Rear View

Combination Generator and Exciter Panel and Feeder Panel

This bulletin contains a number of references to other publications. Information regarding the matters thus referred to may be obtained from any local office of the General Electric Company.

GENERAL INFORMATION

These panels are designed for general use in central stations and isolated plants, and are extensively used in mills and factories. They are designed for use with one set of busbars to which all generators and feeders are connected by means of single-throw oil switches, suitable provision being made for the parallel operation of generators.

Instruments, meters, and oil switch trip coils having primary (series) current windings are used whenever the ampere capacity of the circuit is within the limits of such primary apparatus and providing the use of the latter will reduce the number of current transformers required or eliminate the necessity of relays. The equipment is thereby cheapened as far as possible, at the same time securing a thoroughly satisfactory equipment for low voltage service. All apparatus excepting TA regulators has primary potential windings. There is no objection to using in the same switchboard some panels with primary devices and other panels with secondary devices.

The instruments, meters, oil switches, etc., furnished with these panels are of the General Electric Company's highest grade, and sufficient information regarding them is given under the "Equipment" of the panels to enable the reader to refer to the various bulletins which contain detailed description.

VOLTAGE

All panels may be used for either 480 or 600 volt circuits. Since instruments and meters having potential windings require different resistances for the two voltages, it is essential that the voltage of the circuit to be controlled be given with the order. Unless otherwise ordered panels will be furnished for 600 volts.

FREQUENCY

All panels may with slight modifications be used on any frequency from 25 to 60 cycles, but the frequency must be given with the order. Unless otherwise ordered panels will be furnished for 60 cycles.

MATERIAL OF PANELS

All sections are oiled natural black slate 1½ in. thick, with ⅜ in. bevel. Blue Vermont Marble, Black Enameled Slate, or panels 2 in. thick may be substituted at increased prices which may be obtained from any office of the General Electric Company.

FRAMEWORK

A complete supporting framework of 1¼ in. pipe with necessary fittings is included with each panel, excepting the pipe for tie rods.

SILL

A wooden sill for supporting the switchboard 2 in. from the floor is recommended for all installations. (See Switchboard Arrangements.) This sill is not furnished by the General Electric Company.

BUSES

Suitable insulating supports for alternating current and exciter buses are furnished with these panels. A shield of interwoven drawn wire with metal frame is provided above the alternating current buses on all panels where it is not necessary to cut through the shield for connection bars, etc. Buses will be located as shown on the Switchboard Arrangements.

Owing to the varying amounts of busbar copper which may be required for a given panel, it is impossible to include with these panels a *fixed* amount which would not be too great for some cases and too small for others. *All panels are, therefore, listed without copper for buses* and the latter must be ordered by Cat. No. from the busbar tables on another page.

CONNECTIONS

Each panel is furnished complete with bare connections from oil switches to buses, necessary small wiring on back of panel, primary leads (not exceeding 15 ft. in length) for potential transformers, and multi-conductor cable (not exceeding 25 ft. in length) for secondary connections from both the current and potential transformers to the terminal blocks on the panel.

It will be noted from the diagrams of connections for the various panels that each panel is so wired on the back that secondary leads from current transformers may be brought to the panel either from above or from below, and that suitable terminal blocks are provided for attaching these leads to the panel. The terminal blocks have suitable terminals and links for the insertion of calibrating instruments while the panel is in service.

The Switchboard Arrangements on the pages in rear of this bulletin show the main connections and supports for same which are to be furnished by the purchaser. When generator panels with governor control switches are ordered, the purchaser must furnish the necessary control leads from the panel to the governor.

INSTRUMENT EQUIPMENTS

Alternative instrument equipments are provided for both generator and feeder panels in order that suitable combinations may be available for any of the usual load conditions.

For Generator Panels the following are recommended:

(a) For ordinary balanced power loads	*One* A.C. Ammeter, *One* A.C. Voltmeter, *One* D.C. Field Ammeter, for units 500 kw. and above, *One* A.C. Indicating Wattmeter.
(b) For unbalanced loads	*One* A.C. Ammeter, *One* Ammeter Switch, *One* A.C. Voltmeter, *One* D.C. Field Ammeter, *One* A.C. Indicating Wattmeter.

INSTRUMENT EQUIPMENTS (Cont'd)

With combination (b) an eight point receptacle is furnished on the middle section to allow voltage readings on all three phases.

Indicating wattmeters are important as it is not possible to determine by any other means the division of load between two generators operating in parallel. The ammeters do not differentiate between the idle current and the line current from the machines.

Field ammeters are useful, but not absolutely necessary when the panel is equipped with an indicating wattmeter. They serve as a check on the generator in case of trouble and are invaluable at times of testing for trouble.

For **Feeder Panels** it is customary to use:

One ammeter and ammeter switch for three-phase lighting.

One ammeter for three-phase power. If indicating wattmeters are not used on the generator panels, it will generally be advisable to use them on three-phase power feeders instead of ammeters.

METER EQUIPMENTS

Watthour meters are listed for both generator and feeder panels. Except where it is necessary to meter certain feeders, *generator watthour meters are recommended* in preference to feeder watthour meters as the former operate at better load factors and are not subject to changes in capacity

*OIL SWITCH EQUIPMENT

All panels are equipped with single-throw oil switches mounted on the panel pipe supports 5 inches behind the panel. Panels with switches greater than 500 amp. capacity are not listed; when the same are required the matter should be referred to the General Office of the Company for recommendations.

RELAYS

Relays are not required on any of these panels excepting when an indicating wattmeter or a watthour meter and an automatic oil switch are operated from the same current transformers. However, *time limit relays* are listed for all panels having automatic switches, both for the purpose of securing *greater oil switch rupturing capacity* when required, and for use on circuits subject to heavy *momentary overloads*.

RATINGS OF GENERATOR PANELS

The ampere ratings given for generator panels are the maximum currents which they are designed to carry for one or two hours, the corresponding kilowatt ratings being the normal capacity of the largest machines with which the panels may be used. The kilowatt ratings given are based on *unity power factor* and overloads of 25 per cent. for one or two hours and 65 per cent. momentarily. For overloads of 50 per cent. for one or two hours and 100 per cent. momentarily multiply the normal kw. rating of the generator by 1.2 and select a panel having a kw. rating at least equal to product thus obtained.

RATINGS OF INDUCTION MOTOR PANELS

The apparent efficiency of an induction motor of given horse-power and voltage varies somewhat with the speed for which the motor is designed, so that panels having a given ampere rating cannot be given a corresponding horse-power rating which will be correct for all speeds. Panels listed herein which are intended for controlling induction motors are, therefore, rated in amperes only, the ratings given being the maximum current (other than momentary) which they are designed to carry. The ampere capacity of the panel required for a given motor may be determined by the following formula:

For motors with 25 per cent. overload guarantee:

$$\text{Ampere Capacity of Panel} = \frac{\text{H.P.} \times .746 \times 1000 \times 1.25}{1.73 \times \text{volts} \times \text{efficiency} \times \text{power factor}} = \frac{\text{H.P.} \times 539}{\text{volts} \times \text{efficiency} \times \text{power factor}}$$

RATINGS OF FEEDER PANELS

The ampere ratings given for feeder panels are the maximum currents (normal or overload other than momentary) which they are designed to carry. *Panels of larger capacity than necessary* should not as a rule be chosen in order to provide for a possible future increase of load, since the consequent low load factor of the current transformers has an injurious effect on the accuracy of the instruments and meters; furthermore the overload feature on the oil switches is rendered inoperative except on short circuits and extremely heavy overloads due to the very high ratio of the current transformers as compared with the normal load of the circuit to be controlled.

RUPTURING CAPACITY OF OIL SWITCHES

The switches used on these panels are capable of opening heavy overloads or short circuits on any system where the aggregate full load capacity of all the generators connected to the bus does not exceed the kilowatt ratings given below.

If power is received from an outside source having a capacity in excess of the following limits, the incoming lines must be equipped with automatic

* The K-5 oil switch which has been specified under the equipment of panels listed herein is a new switch recently developed and will shortly supersede the K-3. However, the full line of K-5 switches is not in production at the present time and the General Electric Company reserves the privilege of substituting, without notice, K-3 switches on orders which are received for any of these panels before the K-5 switch specified is in production.

RUPTURING CAPACITY OF OIL SWITCHES (Cont'd)

switches capable of rupturing the power behind them and the automatic devices must be so set as to limit the bus capacity to the rupturing capacity of the switches connected to the bus.

It will be noted that the rupturing capacity of automatic switches is materially increased by the use of time limit relays.

RUPTURING CAPACITY IN KILOWATTS
480 AND 600 VOLTS

Switch Ampere Rating	Non-Automatic	Automatic Instantaneous	Automatic with Time Limit Relay Set for a Minimum of 1½ Seconds Delay
200	5900	2400	5900
300-500	6300	2500	6300

INFORMATION WHICH SHOULD ACCOMPANY ORDERS

Delay in shipment and dissatisfaction on the part of the purchaser will often be avoided if the order is accompanied by as much of the following information as pertains to the panel or panels ordered.

GENERAL

1. **Order of Panels**—Preferably in the form of a rough sketch including *existing*, *blank* and *new panels*, and also showing any open spaces. See Fig. 1, Page 40 for recommended arrangement.
2. **If Existing Panels are to be Matched** give serial numbers of same if of General Electric manufacture, otherwise give brief description preferably in form of sketch showing location of apparatus and bolts on front of panels, location and size of busbars, location of oil switches, etc.
3. **Ultimate Total Capacity of Station**—If power is received from an outside source, do conditions exist such as outlined under "Rupturing Capacity of Oil Switches?"
4. **Available Space** behind and above switchboard, also height of basement, if any.

GENERATOR PANELS

1. **Rating of Generators** including voltage, normal load, one or two hour overload, frequency, power factor and maximum excitation.
2. **Location of Rheostats**—All of these panels are designed for chain operated generator field rheostats. Which of the rheostat locations shown on pages in rear of this bulletin is desired?
3. **Main Cables**—Are they to be brought to oil switches from above or from below?

FEEDER PANELS

1. **Main Cables**—Are they to be brought to oil switches from above or from below?
2. **Voltage** of circuit to be controlled.
3. **Normal Ampere Load of Circuits** to be controlled. —See "Rating of Feeder Panels" on a preceding page.

INDUCTION MOTOR PANELS

1. **Main Cables**—Are they to be brought to oil switches from above or from below?
2. **Rating of Motor** including voltage, normal and overload h.p. rating, power factor and efficiency.
3. **Method of Starting Motor.**

TA REGULATOR PANELS

1. Fill out and attach special Regulator Information Blank.
2. If a current transformer is used for compensating for line drop specify where same is to be connected.

THREE-PHASE GENERATOR PANELS

480 VOLTS—44 TO 330 KILOWATTS
600 VOLTS—55 TO 415 KILOWATTS

IMPORTANT—NOTE BEFORE ORDERING

1. Do not forget "Information which should accompany orders"—see page 4.
2. Always consider carefully the question of "Oil Switch Rupturing Capacity" in order to determine if panels are suitable for future as well as present requirements.
3. Note that kw. ratings are based on *unity* power factor; also that unless otherwise ordered panels will be furnished for 600 volts and 60 cycles. See VOLTAGE, FREQUENCY and RATING OF GENERATOR PANELS in General Information.
4. The generator field rheostats used with these panels must be arranged for chain and sprocket control, and the exciter field rheostats must all be suitable for mounting directly behind the panel. See Switchboard Arrangements.
5. **Exciter Panels** are listed in S 413 and should be used whenever the exciters are to be connected to a bus for use with one or more generators.
   When TA regulators are used, all exciters must be paralleled and exciter panels are therefore necessary.
6. **Rheostat Mechanism**—Use *Concentric Rheostat Mechanism* (for operating both the generator and exciter field rheostats) when generators have individual exciters and exciter panels are not required.
   Use *Chain Rheostat Mechanism* (for operating generator field rheostat only) when generators are excited from an exciter bus or other common source.
7. One **D.P.D.T. Governor Control Switch** Cat. No. 108907 should be ordered in addition to the generator panel whenever the generator is equipped with a motor operated governor.
8. **Synchronizing Equipment**—*One* of the following equipments should be ordered for the entire switchboard, if two or more generators are to be operated in parallel. Equipment B is necessary only when exciter panels are used and the same are not equipped with voltmeters.

Equipment A

One—Swinging bracket containing:
- *One*—....volt....cycle synchronism indicator.
- *Two*—Synchronizing lamp receptacles and lamps.

Two—6 point synchronizing plugs.

Equipment B

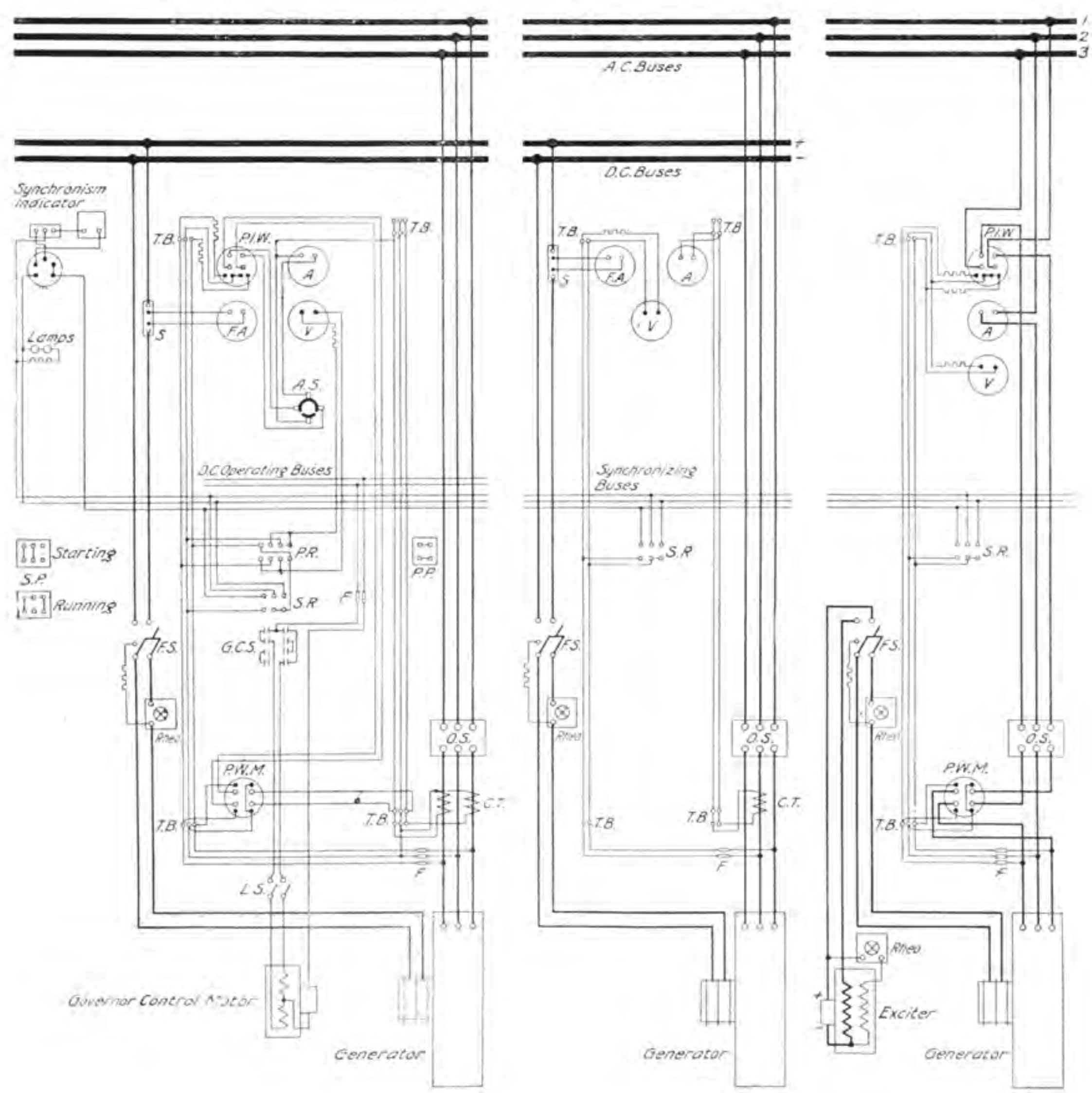
One—Swinging bracket containing:
- *One*—....volt....cycle synchronism indicator.
- *Two*—Synchronizing lamp receptacles and lamps.
- *One*—150 volt exciter voltmeter Type DH-2.

Two—6 point synchronizing plugs.

One—4 point potential plug.

		25 Cycles	40 Cycles	60 Cycles
Equipment A	480 Volts	Cat. No. 59730	Cat. No. 59731	Cat. No. 59732
	600 Volts	Cat. No. 59736	Cat. No. 59737	Cat. No. 59738
Equipment B	480 Volts	Cat. No. 113035	Cat. No. 113036	Cat. No. 113037
	600 Volts	Cat. No. 113038	Cat. No. 113039	Cat. No. 113040

DIAGRAMS OF CONNECTIONS FOR GENERATOR PANELS



KEY TO SYMBOLS

A =Ammeter (A.C.).
A.S. =Three-way ammeter switch.
C.T. =Current transformer.
F =Fuse.
F.A. =Field ammeter (D.C.).
F.S. =Field switch.
G.C.S. =Governor control switch.
L.S. =Limit switch (included with governor motor).
O.S. =Oil switch.
P.I.W. =Polyphase indicating wattmeter.
P.W.M. =Polyphase watthour meter.
P.R. =Potential receptacle.
P.P. =Potential plug.
Rheo. =Rheostat.
S =Shunt (only for 80 amp. and over).
S.R. =Synchronizing receptacle.
S.P. =Synchronizing plugs.
T.B. =Terminal board for instrument leads.
V =Voltmeter (A.C.).

GENERATOR PANELS

EQUIPMENT

(Current coils for A.C. instruments and meters are **primary** for capacities above heavy lines in tables and **secondary** for capacities below heavy lines.)

A =H.E. A.C. ammeter with ...... amp. scale.

F.A. =DH-2 D.C. field ammeter with ...... amp. scale (scale to be given with order).

V =H.E. A.C. voltmeter with 750 volt scale.

R.M. = ... rheostat mechanism (chain or concentric). See page 5.

S.R. =6 point synchronizing receptacle.

F.S. =D.P.S.T. 250 volt 200 amp. field switch with discharge clips. (Discharge resistance is not included.)

G.C.S. =Governor control switch—**not included** (when desired see page 5)

C.H. =Card holder.

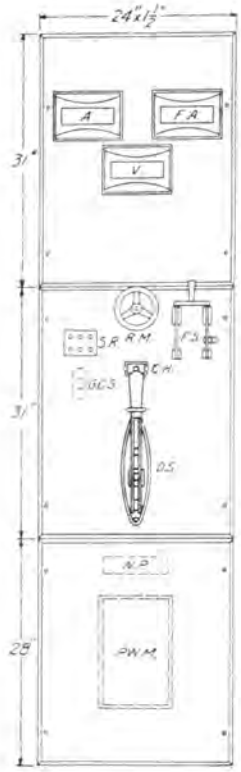
O.S. =T.P.S.T. ...... amp. non-automatic K-5 oil switch mounted on back of panel, with operating mechanism.

N.P. =Name plate (on only one panel in a complete switchboard).

P.W.M. (optional) =Polyphase watthour meter with metal cover, Type DS-4.

...... current transformers ...... amp.

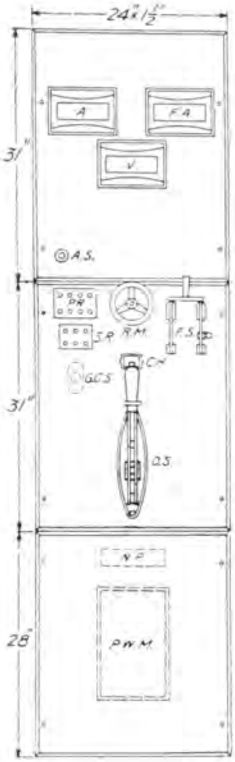
Busbars must be ordered separately; see "Busbar Copper."



Unless otherwise ordered panels will be furnished for 600 volts

KW. OF GEN.		AMPERE CAPACITY					No. of Current Transformers	CAT. NO.	
480 Volts	600 Volts	Panel	Ammeter	Watthour Meter	Oil Switch	Current Transformers		With Chain Rheostat Mech.	With Concentric Rheostat Mech.
PANELS WITHOUT WATTHOUR METER									
44	55	65	80	...	200	...	none	113300	113309
55	70	80	100	...	200	...	none	113301	113310
83	100	125	150	...	200	...	none	113302	113311
110	135	160	200	...	200	...	none	113303	113312
130	165	200	300	...	200	...	none	113304	113313
165	205	250	300	...	300	...	none	113305	113314
200	250	300	400	...	300	400	one	113306	113315
275	340	400	500	...	500	600	one	113307	113316
330	415	500	600	...	500	600	one	113308	113317
PANELS WITH WATTHOUR METER									
44	55	65	80	60	200	...	none	113318	113327
55	70	80	100	80	200	...	none	113319	113328
83	100	125	150	150	200	...	none	113320	113329
110	135	160	200	150	200	...	none	113321	113330
130	165	200	250	5	200	300	two	113322	113331
165	205	250	300	5	300	300	two	113323	113332
200	250	300	400	5	300	400	two	113324	113333
275	340	400	500	5	500	600	two	113325	113334
330	415	500	600	5	500	600	two	113326	113335

GENERATOR PANELS



EQUIPMENT

(Current coils for A.C. instruments and meters are **secondary** for all capacities.)

A =H.E. A.C. ammeter with......amp. scale.

F.A. =DH-2 D.C. field ammeter with......amp. scale (scale to be given with order).

V =H.E. A.C. voltmeter with 750 volt scale.

A.S. =Three-way ammeter switch for connecting **A** in each phase.

R.M. =......rheostat mechanism (chain or concentric). See page 5.

P.R. =8 point potential receptacle with *one* 4 point plug.

S.R. =6 point synchronizing receptacle.

F.S. =D.P.S.T. 250 volt 200 amp. field switch with discharge clips. (Discharge resistance is not included.)

G.C.S. =Governor control switch—**not included** (when desired see page 5).

C.H. =Card holder

O.S. =T.P.S.T.......amp. non-automatic K-5 oil switch mounted on back of panel, with operating mechanism.

N.P. =Name plate (on only one panel in a complete switchboard).

P.W.M. (optional) =Polyphase watthour meter with metal cover, Type DS-4.

Two current transformers......amp.

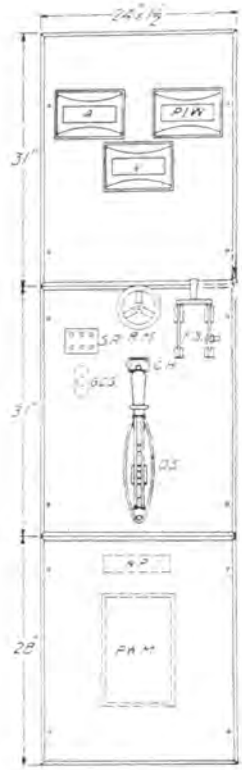
Busbars must be ordered separately; see "Busbar Copper."

Unless otherwise ordered panels will be furnished for 600 volts

KW. OF GEN.		AMPERE CAPACITY				CAT. NO.	
480 Volts	600 Volts	Panel	Ammeter	Oil Switch	Current Transformers	With Chain Rheostat Mech.	With Concentric Rheostat Mech.
			PANELS WITHOUT WATTHOUR METER				
44	55	65	80	200	80	113336	113346
55	70	80	100	200	100	113337	113347
66	83	100	120	200	150	113338	113348
83	100	125	150	200	150	113339	113349
110	133	160	200	200	200	113340	113350
130	165	200	250	200	300	113341	113351
165	205	250	300	300	300	113342	113352
200	250	300	400	300	400	113343	113353
275	340	400	500	500	600	113344	113354
330	415	500	600	500	600	113345	113355
			PANELS WITH WATTHOUR METER				
44	55	65	80	200	80	113356	113366
55	70	80	100	200	100	113357	113367
66	83	100	120	200	150	113358	113368
83	100	125	150	200	150	113359	113369
110	135	160	200	200	200	113360	113370
130	165	200	250	200	300	113361	113371
165	205	250	300	300	300	113362	113372
200	250	300	400	300	400	113363	113373
275	340	400	500	500	600	113364	113374
330	415	500	600	500	600	113365	113375

GENERATOR PANELS

EQUIPMENT



(Current coils for A.C. instruments and meters are **secondary** for all capacities.)

A =H.E. A.C. ammeter with ...... amp. scale.

P.I.W. =H.E. polyphase indicating wattmeter with ...... kw. scale.

V =H.E. A.C. voltmeter with 750 volt scale.

R.M. = ... rheostat mechanism (chain or concentric). See page 5.

S.R. =6 point synchronizing receptacle.

F.S. =D.P.S.T. 250 volt 200 amp. field switch with discharge clips. (Discharge resistance is not included.)

G.C.S. =Governor control switch—**not included** (when desired see page 5).

C.H. =Card holder.

O.S. =T.P.S.T. ...... amp. non-automatic K-5 oil switch mounted on back of panel, with operating mechanism.

N.P. =Name plate (on only one panel in a complete switchboard).

P.W.M. (optional) =Polyphase watthour meter with metal cover, Type DS-4.

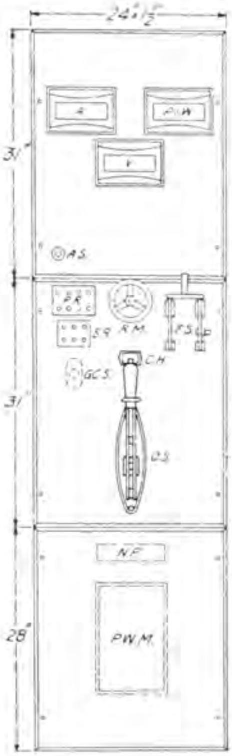
Two current transformers ...... amp.

Busbars must be ordered separately; see "Busbar Copper."

Unless otherwise ordered panels will be furnished for 600 volts

KW. OF GEN.		P.I.W. SCALE IN KW.		AMPERE CAPACITY				CAT. NO.	
480 Volts	600 Volts	480 Volts	600 Volts	Panel	Ammeter	Oil Switch	Current Transformers	With Chain Rheostat Mech.	With Concentric Rheostat Mech.
				PANELS WITHOUT WATTHOUR METER					
44	55	70	80	65	80	200	80	113376	113386
55	70	80	100	80	100	200	100	113377	113387
66	83	100	120	100	120	200	150	113378	113388
83	100	125	150	125	150	200	150	113379	113389
110	135	175	200	160	200	200	200	113380	113390
130	165	200	250	200	250	200	300	113381	113391
165	205	250	300	250	300	300	300	113382	113392
200	250	350	400	300	400	300	400	113383	113393
275	340	400	500	400	500	500	600	113384	113394
330	415	500	600	500	600	500	600	113385	113395
				PANELS WITH WATTHOUR METER					
44	55	70	80	65	80	200	80	113396	113406
55	70	80	100	80	100	200	100	113397	113407
66	83	100	120	100	120	200	150	113398	113408
83	100	125	150	125	150	200	150	113399	113409
110	135	175	200	160	200	200	200	113400	113410
130	165	200	250	200	250	200	300	113401	113411
165	205	250	300	250	300	300	300	113402	113412
200	250	350	400	300	400	300	400	113403	113413
275	340	400	500	400	500	500	600	113404	113414
330	415	500	600	500	600	500	600	113405	113415

GENERATOR PANELS



EQUIPMENT

(Current coils for A.C. instruments and meters are **secondary** for all capacities.)

A =H.E. A.C. ammeter with . . . . . . amp. scale.

P.I.W. =H.E. polyphase indicating wattmeter with . . . . . . kw. scale.

V =H.E. A.C. voltmeter with 750 volt scale.

A.S. =Three-way ammeter switch for connecting **A** in each phase.

R.M. = ... rheostat mechanism (chain or concentric). See page 5.

P.R. =8 point potential receptacle with *one* 4 point plug.

S.R. =6 point synchronizing receptacle.

F.S. =D.P.S.T. 250 volt 200 amp. field switch with discharge clips (discharge resistance is not included).

G.C.S. =Governor control switch—**not included** (when desired see page 5).

C.H. =Card holder.

O.S. =T.P.S.T. . . . . . . amp. non-automatic K-5 oil switch mounted on back of panel, with operating mechanism.

N.P. =Name plate (on only one panel in a complete switchboard)

P.W.M. (optional) =Polyphase watthour meter with metal cover, Type DS-4.

Two current transformers . . . . . . amp.

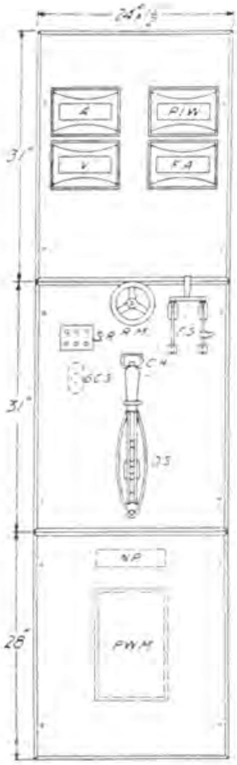
Busbars must be ordered separately; see "Busbar Copper."

Unless otherwise ordered panels will be furnished for 600 volts

KW. OF GEN.		P.I.W. SCALE IN KW.		AMPERE CAPACITY				CAT. NO.	
480 Volts	600 Volts	480 Volts	600 Volts	Panel	Ammeter	Oil Switch	Current Transformers	With Chain Rheostat Mech.	With Concentric Rheostat Mech.
				PANELS WITHOUT WATTHOUR METER					
44	55	70	80	65	80	200	80	113416	113426
55	70	80	100	80	100	200	100	113417	113427
66	83	100	120	100	120	200	150	113418	113428
83	100	125	150	125	150	200	150	113419	113429
110	135	175	200	160	200	200	200	113420	113430
130	165	200	250	200	250	200	300	113421	113431
165	205	250	300	250	300	300	300	113422	113432
200	250	350	400	300	400	300	400	113423	113433
275	340	400	500	400	500	500	600	113424	113434
330	415	500	600	500	600	500	600	113425	113435
				PANELS WITH WATTHOUR METER					
44	55	70	80	65	80	200	80	113436	113446
55	70	80	100	80	100	200	100	113437	113447
66	83	100	120	100	120	200	150	113438	113448
83	100	125	150	125	150	200	150	113439	113449
110	135	175	200	160	200	200	200	113440	113450
130	165	200	250	200	250	200	300	113441	113451
165	205	250	300	250	300	300	300	113442	113452
200	250	350	400	300	400	300	400	113443	113453
275	340	400	500	400	500	500	600	113444	113454
330	415	500	600	500	600	500	600	113445	113455

GENERATOR PANELS

EQUIPMENT



(Current coils for A.C. instruments and meters are **secondary** for all capacities.)

A = H.E. A.C. ammeter with . . . . . . amp. scale.

P.I.W. = H.E. polyphase indicating wattmeter with . . . . . . kw. scale.

V = H.E. A.C. voltmeter with 750 volt scale.

F.A. = DH-2 D.C. field ammeter with . . . . . . amp. scale (scale to be given with order).

R.M. = ... rheostat mechanism (chain or concentric). See page 5.

S.R. = 6 point synchronizing receptacle.

F.S. = D.P.S.T. 250 volt 200 amp. field switch with discharge clips. (Discharge resistance is not included.)

G.C S. = Governor control switch—**not included** (when desired see page 5).

C.H. = Card holder.

O.S. = T.P.S.T. . . . . . . amp. non-automatic K-5 oil switch mounted on back of panel, with operating mechanism.

N.P. = Name plate (on only one panel in a complete switchboard).

P.W.M. (optional) = Polyphase watthour meter with metal cover, Type DS-4.

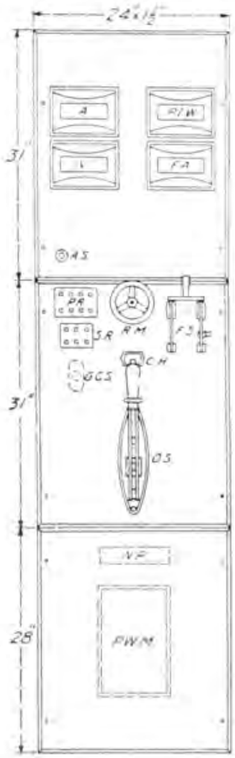
Two current transformers . . . . . . amp.

Busbars must be ordered separately; see "Busbar Copper."

Unless otherwise ordered panels will be furnished for 600 volts

KW. OF GEN.		P.I.W. SCALE IN KW.		AMPERE CAPACITY				CAT. NO.	
480 Volts	600 Volts	480 Volts	600 Volts	Panel	Ammeter	Oil Switch	Current Transformers	With Chain Rheostat Mech.	With Concentric Rheostat Mech.
PANELS WITHOUT WATTHOUR METER									
44	55	70	80	65	80	200	80	113456	113466
55	70	80	100	80	100	200	100	113457	113467
66	83	100	120	100	120	200	150	113458	113468
83	100	125	150	125	150	200	150	113459	113469
110	135	175	200	160	200	200	200	113460	113470
130	165	200	250	200	250	200	300	113461	113471
165	205	250	300	250	300	300	300	113462	113472
200	250	350	400	300	400	300	400	113463	113473
275	340	400	500	400	500	500	600	113464	113474
330	415	500	600	500	600	500	800	113465	113475
PANELS WITH WATTHOUR METER									
44	55	70	80	65	80	200	80	113476	113486
55	70	80	100	80	100	200	100	113477	113487
66	83	100	120	100	120	200	150	113478	113488
83	100	125	150	125	150	200	150	113479	113489
110	135	175	200	160	200	200	200	113480	113490
130	165	200	250	200	250	200	300	113481	113491
165	205	250	300	250	300	300	300	113482	113492
200	250	350	400	300	400	300	400	113483	113493
275	340	400	500	400	500	500	600	113484	113494
330	415	500	600	500	600	500	600	113485	113495

GENERATOR PANELS



EQUIPMENT

(Current coils for A.C. instruments and meters are **secondary** for all capacities.)

A = H.E. A.C. ammeter with......amp. scale.

P.I.W. = H.E. polyphase indicating wattmeter with......kw. scale.

V = H.E. A.C. voltmeter with 750 volt scale.

F.A. = DH-2 D.C. field ammeter with......amp. scale (scale to be given with order).

A.S. = Three-way ammeter switch for connecting **A** in each phase.

R.M. = ...rheostat mechanism (chain or concentric). See page 5.

P.R. = 8 point potential receptacle with *one* 4 point plug.

S.R. = 6 point synchronizing receptacle.

F.S. = D.P.S.T. 250 volt 200 amp. field switch with discharge clips (discharge resistance is not included).

G.C.S. = Governor control switch—**not included** (when desired see page 5).

C.H. = Card holder.

O.S. = T.P.S.T.......amp. non-automatic K-5 oil switch mounted on back of panel, with operating mechanism.

N.P. = Name plate (on only one panel in a complete switchboard).

P.W.M. (optional) = Polyphase watthour meter with metal cover, Type DS-4.

Two current transformers......amp.

Busbars must be ordered separately; see "Busbar Copper."

Unless otherwise ordered panels will be furnished for 600 volts

KW. OF GEN.		P.I.W. SCALE IN KW.		AMPERE CAPACITY				CAT. NO.	
480 Volts	600 Volts	480 Volts	600 Volts	Panel	Ammeter	Oil Switch	Current Transformers	With Chain Rheostat Mech.	With Concentric Rheostat Mech.
				PANELS WITHOUT WATTHOUR METER					
44	55	70	80	65	80	200	80	113496	113506
55	70	80	100	80	100	200	100	113497	113507
66	83	100	120	100	120	200	150	113498	113508
83	100	125	150	125	150	200	150	113499	113509
110	135	175	200	160	200	200	200	113500	113510
130	165	200	250	200	250	200	300	113501	113511
165	205	250	300	250	300	300	300	113502	113512
200	250	350	400	300	400	300	400	113503	113513
275	340	400	500	400	500	500	600	113504	113514
330	415	500	600	500	600	500	600	113505	113515
				PANELS WITH WATTHOUR METER					
44	55	70	80	65	80	200	80	113516	113526
55	70	80	100	80	100	200	100	113517	113527
66	83	100	120	100	120	200	150	113518	113528
83	100	125	150	125	150	200	150	113519	113529
110	135	175	200	160	200	200	200	113520	113530
130	165	200	250	200	250	200	300	113521	113531
165	205	250	300	250	300	300	300	113522	113532
200	250	350	400	300	400	300	400	113523	113533
275	340	400	500	400	500	500	600	113524	113534
330	415	500	600	500	600	500	600	113525	113535

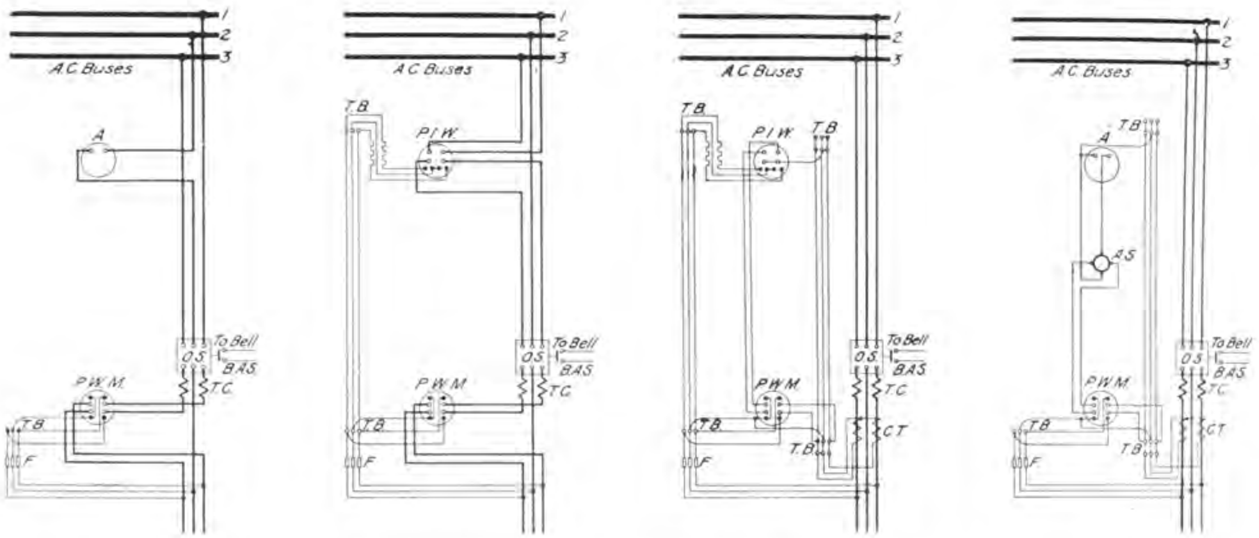
SINGLE-CIRCUIT
THREE-PHASE FEEDER PANELS

480 AND 600 VOLTS
50 to 500 AMPERES

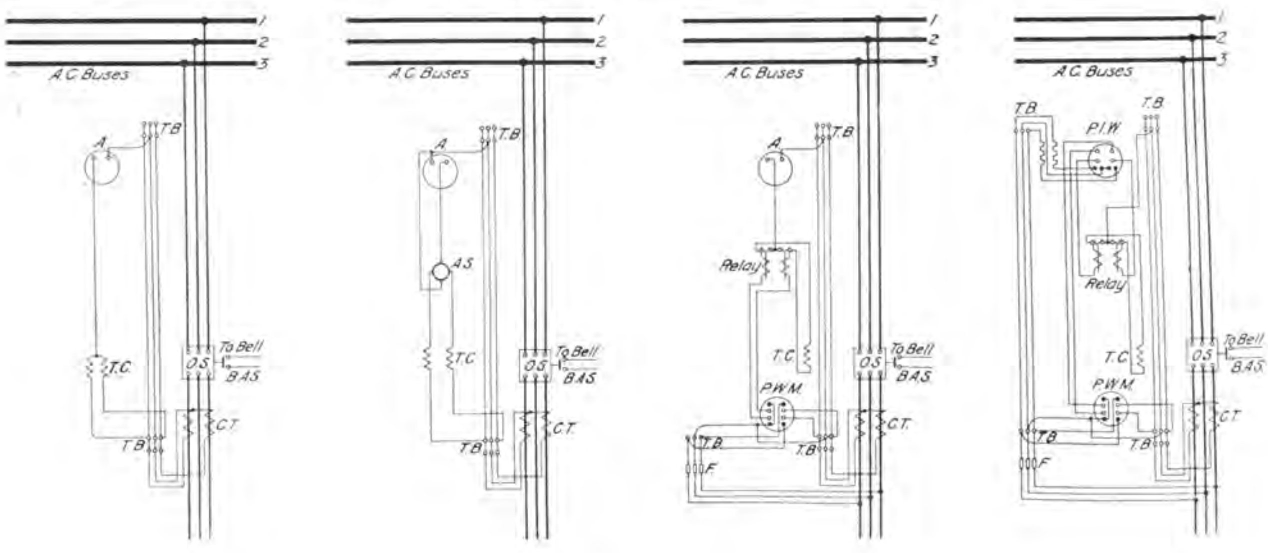
IMPORTANT—NOTE BEFORE ORDERING

1. Do not forget "Information which should accompany orders"—see page 4.
2. Avoid ordering *panels larger than necessary* for present requirements—See "Rating of Feeder Panels."
3. Always consider the question of "Oil Switch Rupturing Capacity" in order to determine if panels are suitable for future as well as present requirements.
4. Unless otherwise ordered panels will be furnished for 600 volts and 60 cycles. See VOLTAGE and FREQUENCY in General Information.
5. *Lightning Arresters* are not included with these panels.

DIAGRAMS OF CONNECTIONS FOR FEEDER PANELS



On 600 Volt Circuits Current Transformer feet should be insulated from ground



KEY TO SYMBOLS

A	=Ammeter.	**O.S.**	=Oil switch.
A.S.	=Three-way ammeter switch.	**P.I.W.**	=Polyphase indicating wattmeter.
B.A.S.	=Bell alarm switch.	**P.W.M.**	=Polyphase watthour meter.
C.T.	=Current transformer.	**T.B.**	=Terminal board.
F	=Fuse.	**T.C.**	=Trip coils for oil switch.

SINGLE-CIRCUIT FEEDER PANELS WITH INSTANTANEOUS OIL SWITCH TRIP

EQUIPMENT

(Oil switch trip coils and current coils of watthour meter are **primary** for capacities above heavy lines in tables and **secondary** for capacities below heavy lines.)

I.R. = D.P. instantaneous overload relay (for Fig. 2 only).

C.H. = Card holder.

O.S. = T.P.S.T.......amp. automatic K-5 oil switch mounted on back of panel, with bell alarm switch and operating mechanism (double coil for Fig. 1 and single coil for Fig. 2).

N.P. = Name plate (on only one panel in a complete switchboard).

P.W.M. (optional) = Polyphase watthour meter with metal cover, Type DS-4.

......current transformers......amp.

Busbars must be ordered separately; see "Busbar Copper."

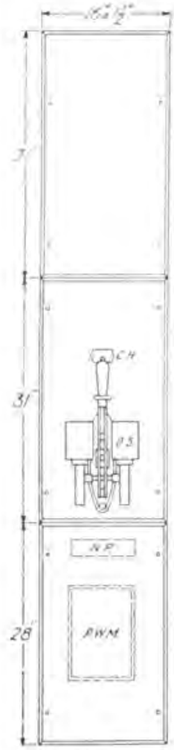


Fig. 1

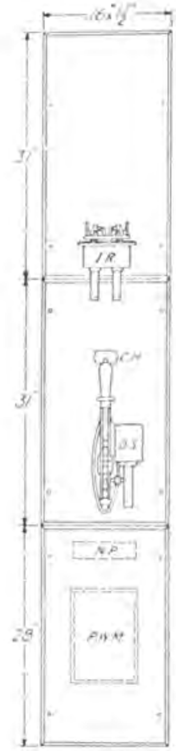
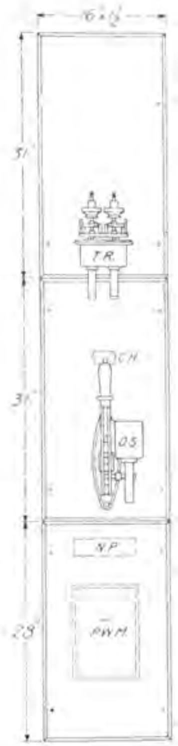


Fig. 2

Unless otherwise ordered panels will be furnished for 600 volts

Ampere Capacity				No. of Current Transformers	Fig. No.	Cat. No.
Panel	Oil Switch	Watthour Meter	Current Transformers			
PANELS WITHOUT WATTHOUR METER						
50	200	...	...	none	1	113536
65	200			none	1	113537
80	200			none	1	113538
125	200		...	none	1	113539
160	200		...	none	1	113540
200	200		...	none	1	113541
300	300		...	none	1	113542
400	500		600	two	1	113543
500	500		600	two	1	113544
PANELS WITH WATTHOUR METER						
50	200	60	...	none	1	113545
65	200	60	...	none	1	113546
80	200	80	...	none	1	113547
125	200	150	...	none	1	113548
160	200	150	...	none	1	113549
200	200	5	300	two	1	113550
250	300	5	300	two	1	113551
300	300	5	400	two	1	113552
400	500	5	600	two	2	113553
500	500	5	600	two	2	113554

SINGLE-CIRCUIT FEEDER PANELS WITH TIME LIMIT OIL SWITCH TRIP



EQUIPMENT

(Oil switch trip coil and current coils of watthour meter are **secondary** for all capacities.)

T.R. = D.P. time limit overload relay.

C.H. = Card holder.

O.S. = T.P.S.T. . . . . . amp. automatic K-5 oil switch mounted on back of panel, with bell alarm switch and operating mechanism (one secondary coil).

N.P. = Name plate (on only one panel in a complete switchboard).

P.W.M. (optional) = Polyphase watthour meter with metal cover, Type DS-4.

Two current transformers . . . . . . amp.

Busbars must be ordered separately; see "Busbar Copper"

Unless otherwise ordered panels will be furnished for 600 volts

AMPERE CAPACITY			CAT. NO.	
Panel	Oil Switch	Current Transformers	Without Watthour Meter	With Watthour Meter
50	200	60	113555	113566
65	200	80	113556	113567
80	200	100	113557	113568
100	200	150	113558	113569
125	200	150	113559	113570
160	200	200	113560	113571
200	200	300	113561	113572
250	300	300	113562	113573
300	300	400	113563	113574
400	500	600	113564	113575
500	500	600	113565	113576

SINGLE-CIRCUIT FEEDER PANELS WITH INSTANTANEOUS OIL SWITCH TRIP

EQUIPMENT

(Oil switch trip coils and current coils of ammeter and watthour meter are **primary** for capacities above heavy lines in tables and **secondary** for capacities below heavy lines.)

A = H.E. A.C. ammeter with......amp. scale.

I.R. = D.P. instantaneous overload relay (for Fig. 2 only).

C.H. = Card holder.

O.S. = T.P.S.T.......amp. automatic K-5 oil switch mounted on back of panel, with bell alarm switch and operating mechanism (double coil for Fig. 1 and single coil for Fig. 2).

N.P. = Name plate (on only one panel in a complete switchboard).

P.W.M. (optional) = Polyphase watthour meter with metal cover, Type DS-4.

......current transformers.......amp.

Busbars must be ordered separately; see "Busbar Copper."

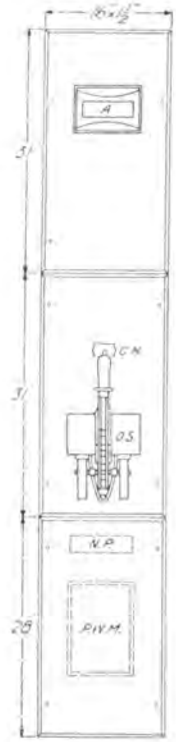


Fig. 1

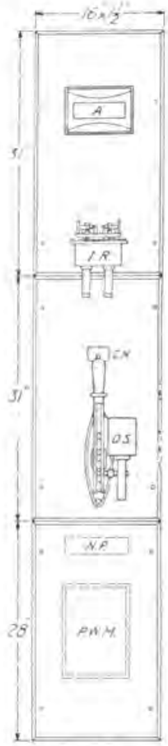
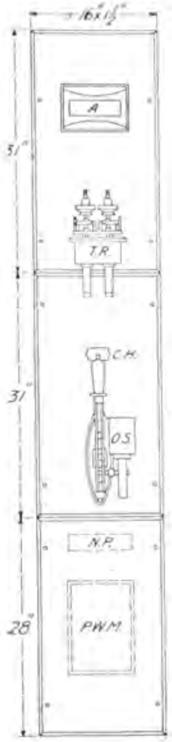


Fig. 2

Unless otherwise ordered panels will be furnished for 600 volts

AMPERE CAPACITY					No. of Current Transformers	Fig. No.	Cat. No.
Panel	Ammeter	Oil Switch	Watthour Meter	Current Transformers			
PANELS WITHOUT WATTHOUR METER							
50	60	200			none	1	113577
65	80	200			none	1	113578
80	100	200			none	1	113579
125	150	200			none	1	113580
160	200	200			none	1	113581
200	300	200			none	1	113582
250	300	300			none	1	113583
300	400	300		400	one	1	113584
400	500	500		600	two	1	113585
500	600	500		600	two	1	113586
PANELS WITH WATTHOUR METER							
50	60	200	60		none	1	113587
65	80	200	60		none	1	113588
80	100	200	80		none	1	113589
125	150	200	150		none	1	113590
160	200	200	150		none	1	113591
200	250	200	5	300	two	1	113592
250	300	300	5	300	two	1	113593
300	400	300	5	400	two	1	113594
400	500	500	5	600	two	2	113595
500	600	500		600	two	2	113596

SINGLE-CIRCUIT FEEDER PANELS WITH TIME LIMIT OIL SWITCH TRIP



EQUIPMENT

(Oil switch trip coil and current coils of ammeter and watthour meter are **secondary** for all capacities.)

A = H.E. A.C. ammeter with......amp. scale.

T.R. = D.P. time limit overload relay.

C.H. = Card holder.

O.S. = T.P.S.T.......amp. automatic K-5 oil switch mounted on back of panel, with bell alarm switch and operating mechanism (one secondary coil).

N.P. = Name plate (on only one panel in a complete switchboard).

P.W.M. (optional) = Polyphase watthour meter with metal cover. Type DS-4.

Two current transformers......amp.

Busbars must be ordered separately; see "Busbar Copper."

Unless otherwise ordered panels will be furnished for 600 volts

AMPERE CAPACITY				CAT. NO.	
Panel	Ammeter	Oil Switch	Current Transformers	Without Watthour Meter	With Watthour Meter
50	60	200	60	113597	113608
65	80	200	80	113598	113609
80	100	200	100	113599	113610
100	120	200	150	113600	113611
125	150	200	150	113601	113612
160	200	200	200	113602	113613
200	250	200	300	113603	113614
250	300	300	300	113604	113615
300	400	300	400	113605	113616
400	500	500	600	113606	113617
500	600	500	600	113607	113618

SINGLE-CIRCUIT FEEDER PANELS WITH INSTANTANEOUS OIL SWITCH TRIP

EQUIPMENT

(Current coils of ammeter and watthour meter are **secondary** for all capacities. Oil switch trip coils are **secondary** for all capacities excepting those above the heavy line in lower table which are **primary**.)

A = H.E. A.C. ammeter with ...... amp. scale.

A.S. = Three-way ammeter switch for connecting **A** in each phase.

I.R. = D.P. instantaneous overload relay (for Fig. 2 only).

C.H. = Card holder.

O.S. = T.P.S.T. ...... amp. automatic K-5 oil switch mounted on back of panel, with bell alarm switch and operating mechanism (double coil for Fig. 1 and single coil for Fig. 2).

N.P. = Name plate (on only one panel in a complete switchboard).

P.W.M. (optional) = Polyphase watthour meter with metal cover, Type DS-4.

Two current transformers ...... amp.

Busbars must be ordered separately; see "Busbar Copper."

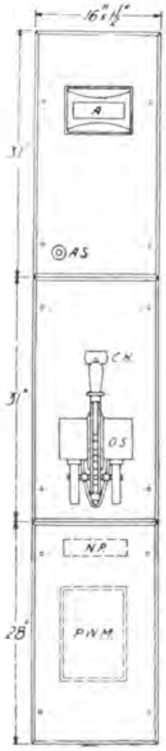


Fig. 1

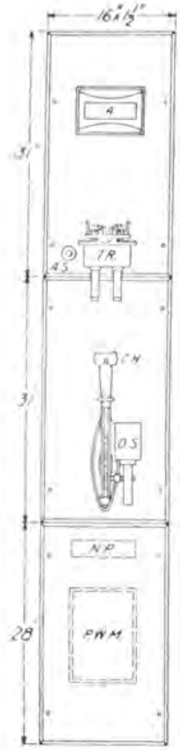
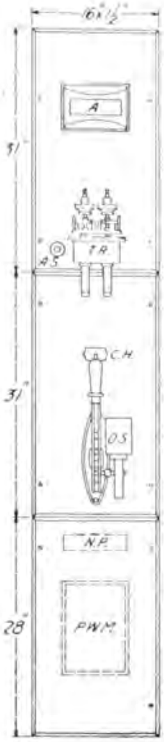


Fig. 2

Unless otherwise ordered panels will be furnished for 600 volts

Ampere Capacity: Panel	Ampere Capacity: Ammeter	Ampere Capacity: Oil Switch	Ampere Capacity: Current Transformers	Fig. No.	Cat. No.
PANELS WITHOUT WATTHOUR METER					
50	60	200	60	1	113619
65	80	200	80	1	113620
80	100	200	100	1	113621
100	120	200	150	1	113622
125	150	200	150	1	113623
160	200	200	200	1	113624
200	250	200	300	1	113625
250	300	300	300	1	113626
300	400	300	400	1	113627
400	500	500	600	1	113628
500	600	500	600	1	113629
PANELS WITH WATTHOUR METER					
50	60	200	60	1	113630
65	80	200	80	1	113631
80	100	200	100	1	113632
100	120	200	150	1	113633
125	150	200	150	1	113634
160	200	200	200	1	113635
200	250	200	300	1	113636
250	300	300	300	1	113637
300	400	300	400	1	113638
400	500	500	600	2	113639
500	600	500	600	2	113640

SINGLE-CIRCUIT FEEDER PANELS WITH TIME LIMIT OIL SWITCH TRIP



EQUIPMENT

(Oil switch trip coil and current coils of ammeter and watthour meter are **secondary** for all capacities.)

A = H.E. A.C. ammeter with ...... amp. scale.

A.S. = Three-way ammeter switch for connecting **A** in each phase.

T.R. = D.P. time limit overload relay.

C.H. = Card holder.

O.S. = T.P.S.T. ...... amp. automatic K-5 oil switch mounted on back of panel, with bell alarm switch and operating mechanism (one secondary coil).

N.P. = Name plate (on only one panel in a complete switchboard).

P.W.M. (optional) = Polyphase watthour meter with metal cover, Type DS-4.

Two current transformers ...... amp.

Busbars must be ordered separately; see "Busbar Copper."

Unless otherwise ordered panels will be furnished for 600 volts

AMPERE CAPACITY				CAT. NO.	
Panel	Ammeter	Oil Switch	Current Transformers	Without Watthour Meter	With Watthour Meter
50	60	200	60	113641	113652
65	80	200	80	113642	113653
80	100	200	100	113643	113654
100	120	200	150	113644	113655
125	150	200	150	113645	113656
160	200	200	200	113646	113657
200	250	200	300	113647	113658
250	300	300	300	113648	113659
300	400	300	400	113649	113660
400	500	500	600	113650	113661
500	600	500	600	113651	113662

SINGLE-CIRCUIT FEEDER PANELS
WITH INSTANTANEOUS OR TIME LIMIT OIL SWITCH TRIP

EQUIPMENT

(Oil switch trip coils and current coils of indicating wattmeter and watthour meter are **secondary** for all capacities excepting those above heavy lines in first table which are **primary**.)

P.I.W. = H.E. polyphase indicating wattmeter with . . . . . . kw. scale.

I.R. = D.P. instantaneous overload relay (for Fig. 2 only).

T.R. = D.P. time limit overload relay (for Fig. 3 only).

C.H. = Card holder.

O.S. = T.P.S.T. . . . . . . amp. automatic K-5 oil switch mounted on back of panel, with bell alarm switch and operating mechanism (double coi for Fig. 1 and single coil for Figs. 2 and 3).

N.P. = Name plate (on only one panel in a complete switchboard).

P.W.M (optional) = Polyphase watthour meter with metal cover, Type DS-4,

. . . . . . current transformers . . . . . . amp.

Busbars must be ordered separately; see "Busbar Copper."

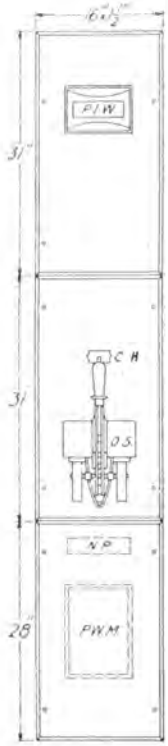


Fig. 1

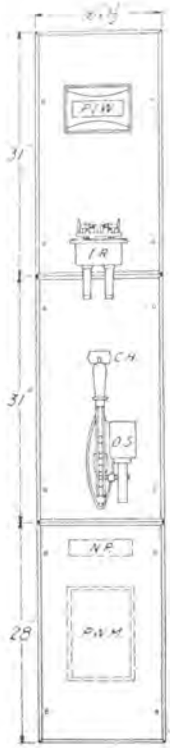


Fig. 2

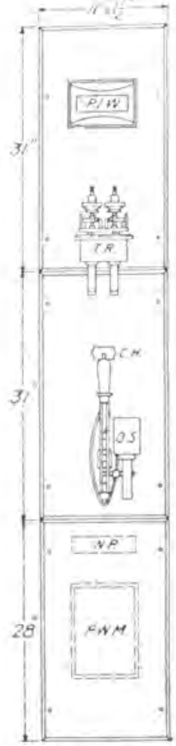


Fig. 3

Unless otherwise ordered panels will be furnished for 600 volts

AMPERE CAPACITY			P.I.W. SCALE IN KW.		CURRENT TRANSFORMERS		Fig. No.	CAT. NO.	
Panel	Oil Switch	Watthour Meter	480 Volts	600 Volts	No.	Ampere Capacity		Without Watthour Meter	With Watthour Meter
PANELS WITH INSTANTANEOUS OIL SWITCH TRIP									
50	200	60	50	60	none	. . .	1	113663	113674
60	200	60	70	80	none	. . .	1	113664	113675
80	200	5	80	100	two	100	1	113665	113676
100	200	5	100	120	two	150	1	113666	113677
125	200	5	125	150	two	150	1	113667	113678
160	200	5	175	200	two	200	1	113668	113679
200	200	5	200	250	two	300	1	113669	113680
250	300	5	250	300	two	300	1	113670	113681
300	300	5	350	400	two	400	1	113671	113682
400	500	5	400	500	two	600	2	113672	113683
500	500	5	500	600	two	600	2	113673	113684
PANELS WITH TIME LIMIT OIL SWITCH TRIP									
50	200	5	50	60	two	60	3	113685	113696
65	200	5	60	80	two	80	3	113686	113697
80	200	5	80	100	two	100	3	113687	113698
100	200	5	100	120	two	150	3	113688	113699
125	200	5	125	150	two	150	3	113689	113700
160	200	5	175	200	two	200	3	113690	113701
200	200	5	200	250	two	300	3	113691	113702
250	300	5	250	300	two	300	3	113692	113703
300	300	5	350	400	two	400	3	113693	113704
400	500	5	400	500	two	600	3	113694	113705
500	500	5	500	600	two	600	3	113695	113706

DOUBLE-CIRCUIT
THREE-PHASE FEEDER PANELS

480 AND 600 VOLTS
8 TO 200 AMPERES PER CIRCUIT

The panels listed are for controlling two circuits of equal capacity, the panel rating being the total ampere capacity of the two circuits. If so ordered, any panel will be furnished with an equipment suitable for two circuits of different capacities providing the ampere capacity of either circuit does not exceed 200 amperes.

DIAGRAM OF CONNECTIONS

See Single-Circuit Panels....Page 14

IMPORTANT—NOTE BEFORE ORDERING

1. Do not forget "Information which should accompany orders"—see page 4.
2. Avoid ordering *panels of larger capacity than necessary* for present requirements, for reasons given under "Rating of Feeder Panels."
3. Always consider carefully the question of "Oil Switch Rupturing Capacity" in order to determine if panels are suitable for future as well as present requirements.
4. Unless otherwise ordered, panels will be furnished for 600 volts and 60 cycles. See VOLTAGE and FREQUENCY in General Information.
5. Lightning Arresters are not included with these panels.

DOUBLE-CIRCUIT FEEDER PANELS

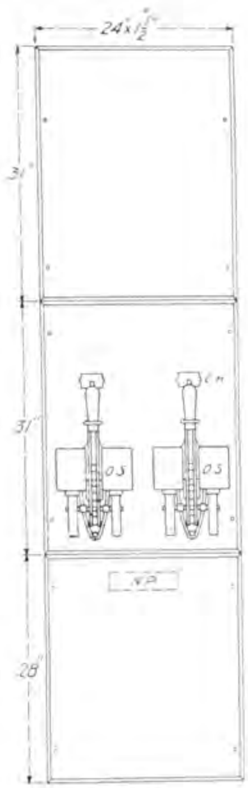


Fig. 1

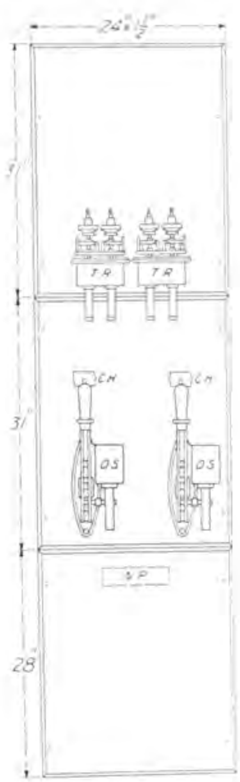


Fig. 2

EQUIPMENT

(Oil switch trip coils are **primary** for panels in Fig. 1 and **secondary** for panels in Fig. 2.)

T.R. = *Two* D.P. time limit overload relays (for Fig. 2 only).

C.H. = *Two* card holders.

O.S. = *Two* T.P.S.T. 200 amp. automatic K-5 oil switches mounted on back of panel, each with bell alarm switch and operating mechanism (double coil for Fig. 1 and single coil for Fig. 2).

N.P. = Name plate (on only one panel in a complete switchboard).

Four current transformers ______ amp. (for Fig. 2 only).

Busbars must be ordered separately; see "Busbar Copper."

AMPERE CAPACITY		CAT. NO.	
Panel	Current Transformers For Fig. 2 Only	With Instantaneous Oil Switch Trip Fig. 1	With Time Limit Oil Switch Trip Fig. 2
16	10	113707	113718
24	15	113708	113719
32	20	113709	113720
50	30	113710	113721
60	40	113711	113722
100	60	113712	113723
130	80	113713	113724
160	100	113714	113725
250	150	113715	113726
320	200	113716	113727
400	300	113717	113728

DOUBLE-CIRCUIT FEEDER PANELS

EQUIPMENT

(Oil switch trip coils and current coils of ammeters are **primary** for panels in Fig. 1 and **secondary** for panels in Fig. 2.)

A = *Two* H.E. A.C. ammeters with . . . .amp. scale.

T.R. = *Two* D.P. time limit overload relays (for Fig. 2 only).

C.H. = *Two* card holders.

O.S. = *Two* T.P.S.T. 200 amp. automatic K-5 oil switches mounted on back of panel, each with bell alarm switch and operating mechanism (double coil for Fig. 1 and single coil for Fig. 2).

N.P. = Name plate (on only one panel in a complete switchboard).

Four current transformers . . . . . .amp. (for Fig. 2 only).

Busbars must be ordered separately; see "Busbar Copper."

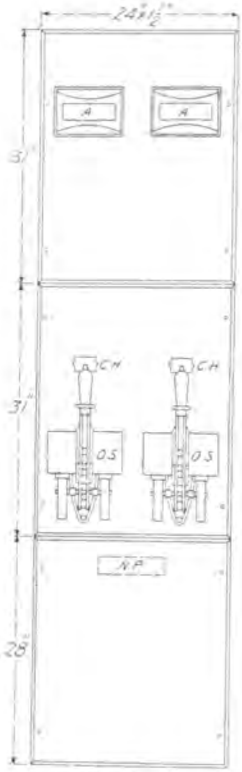


Fig. 1

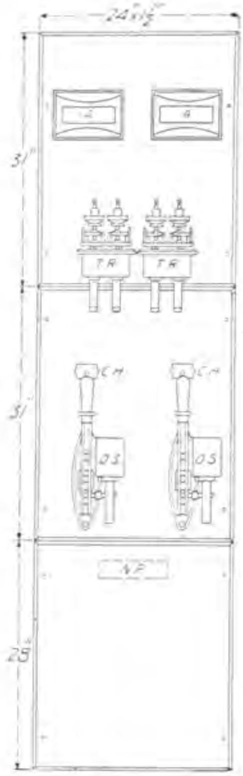


Fig. 2

AMPERE CAPACITY			CAT. NO.	
Panel	Ammeters	Current Transformers For Fig. 2 Only	With Instantaneous Oil Switch Trip Fig. 1	With Time Limit Oil Switch Trip Fig. 2
16	10	10	113729	113740
20	12	15	......	113741
24	15	15	113730	113742
32	20	20	113731	113743
40	25	30	......	113744
50	30	30	113732	113745
60	40	40	113733	113746
80	50	60	......	113747
100	60	60	113734	113748
130	80	80	113735	113749
160	100	100	113736	113750
200	120	150	......	113751
250	150	150	113737	113752
320	200	200	113738	113753
400	250	300	......	113754
400	300	...	113739	......

DOUBLE-CIRCUIT FEEDER PANELS

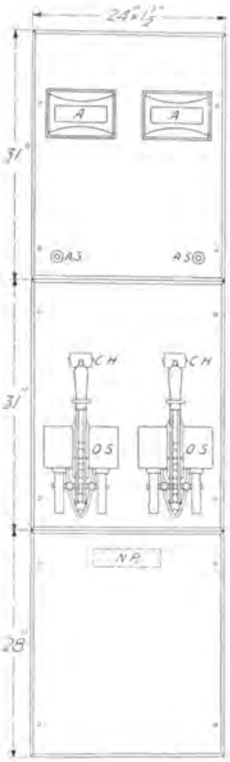


Fig. 1

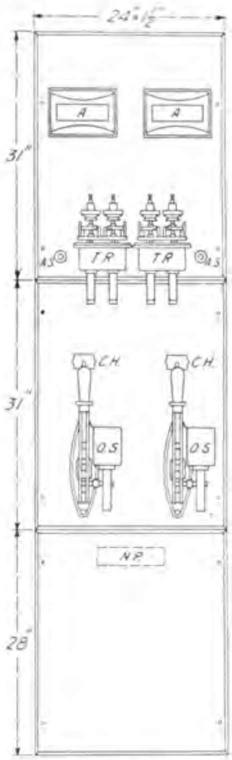


Fig. 2

EQUIPMENT

(Oil switch trip coils and current coils of ammeters are **secondary** for all panels.)

A = *Two* H.E. A.C. ammeters with......amp. scale.

A.S. = *Two* three-way ammeter switches for connecting **A** in each phase.

T.R. = *Two* D.P. time limit overload relays (for Fig. 2 only).

C.H. = *Two* card holders.

O.S. = *Two* T.P.S.T. 200 amp. automatic K-5 oil switches mounted on back of panel, each with bell alarm switch and operating mechanism (double coil for Fig. 1 and single coil for Fig. 2).

N.P. = Name plate (on only one panel in a complete switchboard).

Four current transformers......amp.

Busbars must be ordered separately; see "Busbar Copper."

AMPERE CAPACITY			CAT. NO.	
Panel	Ammeters	Current Transformers	With Instantaneous Oil Switch Trip Fig. 1	With Time Limit Oil Switch Trip Fig. 2
16	10	10	113755	113770
20	12	15	113756	113771
24	15	15	113757	113772
32	20	20	113758	113773
40	25	30	113759	113774
50	30	30	113760	113775
60	40	40	113761	113776
80	50	60	113762	113777
100	60	60	113763	113778
130	80	80	113764	113779
160	100	100	113765	113780
200	120	150	113766	113781
250	150	150	113767	113782
320	200	200	113768	113783
400	250	300	113769	113784

DOUBLE-CIRCUIT FEEDER PANELS

EQUIPMENT

(Current coils of wattmeters are **primary** for panels in Fig. 1 above the heavy line (in table), and **secondary** for all other panels. Oil switch trip coils are **primary** in Fig. 1 and **secondary** in Fig. 2.)

P.I.W. = *Two* H.E. polyphase indicating wattmeters with......kw scale.

T.R. = *Two* D.P. time limit overload relays (for Fig. 2 only).

C.H. = *Two* card holders.

O.S. = *Two* T.P.S.T. 200 amp. automatic K-5 oil switches mounted on back of panel, each with bell alarm switch and operating mechanism (double coil for Fig. 1 and single coil for Fig. 2).

N.P. = Name plate (on only one panel in a complete switchboard).

Four current transformers......amp. (not furnished for panels in Fig. 1 below 160 amp. capacity).

Busbars must be ordered separately; see "Busbar Copper."

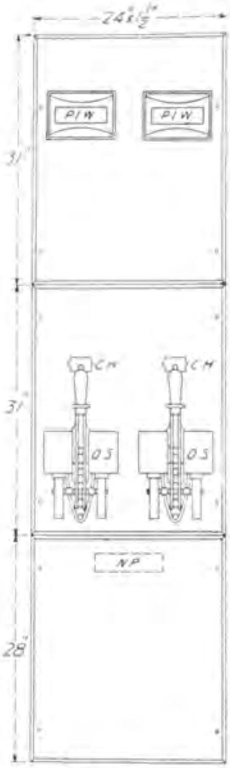


Fig. 1

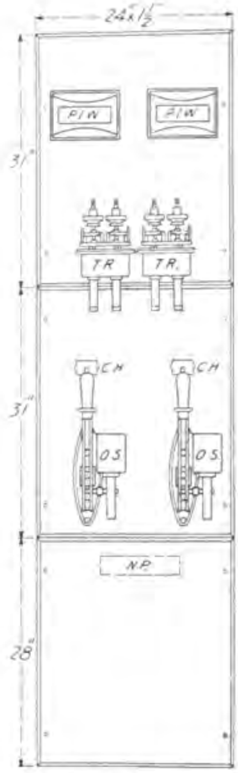


Fig. 2

Unless otherwise ordered panels will be furnished for 600 volts

AMPERE CAPACITY		P.I.W. SCALE IN KW.		CAT. NO.	
Panel	Current Transformers	480 Volts	600 Volts	With Instantaneous Oil Switch Trip Fig. 1	With Time Limit Oil Switch Trip Fig. 2
16	10	8	10	113785	113797
20	15	10	12	......	113798
24	15	12	15	113786	113799
32	20	15	20	113787	113800
40	30	20	25	......	113801
50	30	25	30	113788	113802
60	40	30	40	113789	113803
80	60	40	50	......	113804
100	60	50	60	113790	113805
130	80	60	80	113791	113806
160	100	80	100	113792	113807
200	150	100	120	113793	113808
250	150	125	150	113794	113809
320	200	175	200	113795	113810
400	300	200	250	113796	113811

TA REGULATOR PANELS AND COMBINATION TA REGULATOR AND EXCITER MOTOR PANELS

For Forms L & K Regulators

480 AND 600 VOLTS
8 TO 200 AMPERES

DIAGRAMS OF CONNECTIONS

IMPORTANT—NOTE BEFORE ORDERING

1. Do not forget "Information which should accompany orders"—see page 4.
2. Unless otherwise ordered panels will be furnished for 600 volts and 60 cycles. See VOLTAGE and FREQUENCY in General Information.
3. Regulator equipments as listed are intended for maintaining *constant bus voltage.* A current transformer is required if the regulator is to be *compounded* and suitable transformers are listed on page 39. When ordering always state where current transformer is to be connected.
4. When TA regulators are used, provision should be made for *paralleling exciters.* Separate panels for exciter control are therefore necessary.
5. See General Information for method of determining ampere capacity of panel required for a given motor. These panels cannot be used with any motors which require a controller or starting equipment mounted on the panel; for instance, those Form K motors which do not have self-contained starting compensators.

DIAGRAMS OF CONNECTIONS

These connections are representative and apply only for the conditions shown. The connections differ somewhat depending upon the number of exciters with which a regulator is used.

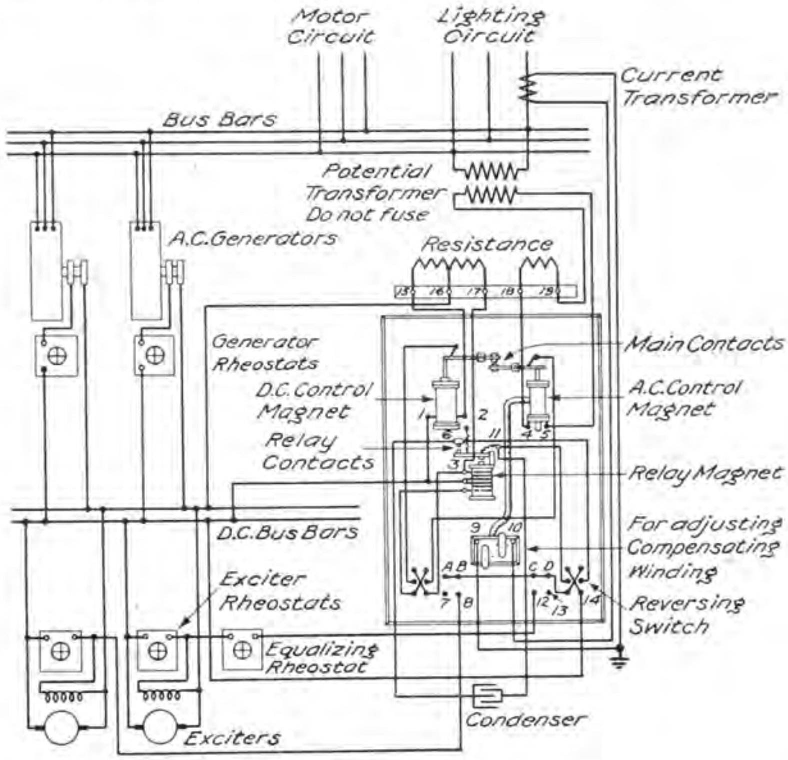


Fig. 1
Type TA Form L Regulator with Two Exciters and Several Generators

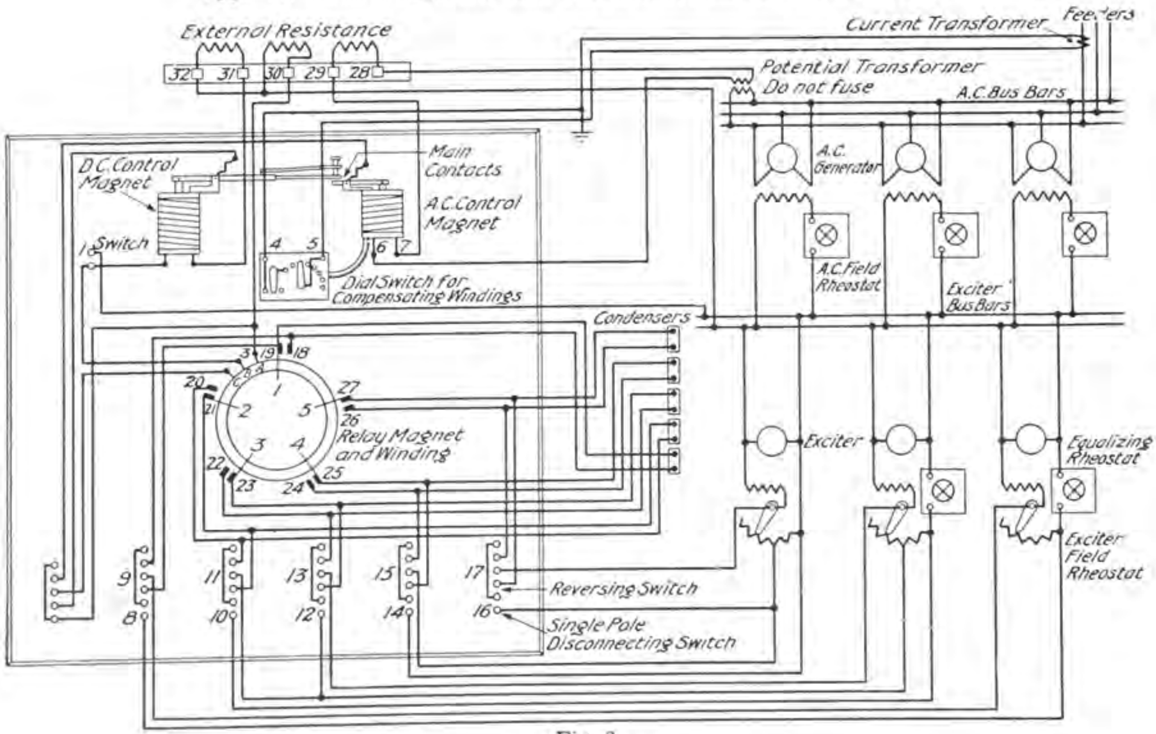


Fig. 2
Type TA Form K-5 Regulator with Three Exciters and Several Generators

TA REGULATOR PANELS

EQUIPMENT

L = Drilling and mounting only, for one TA regulator, Form L (for Fig. 1 only).

K = Drilling and mounting only, for one TA regulator, Form K (for Fig. 2 only).

N.P. = Name plate (on only one panel in a complete switchboard).

One—200 watt 440/110 (or 550/110) volts potential transformer.

R (optional) = *One, two* or *three* handwheels and mountings for equalizer rheostats.

Regulator, equalizer rheostats, condensers and compensators **are not included.**

When A.C. or exciter buses extend across panel they must be ordered separately; see "Busbar Copper."

Current transformer for regulator must be ordered separately—see page 29, paragraph 3.

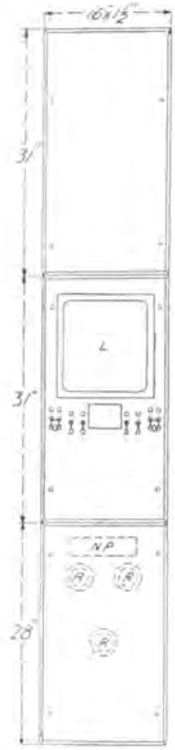


Fig. 1

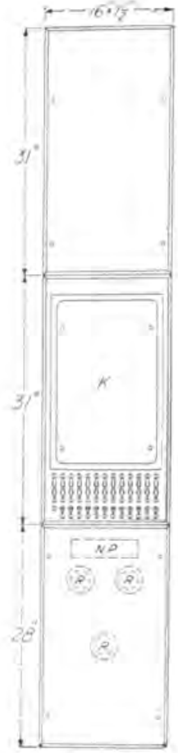


Fig. 2

Panels in Fig. 2 cannot be used for regulators larger than K-12

Unless Otherwise Ordered Panels will be Furnished for 600 Volts

Quantity of R	CAT. NO.	
	With Form L Regulator, Fig. 1	With Form K Regulator, Fig. 2
None	113812	113816
One	113813	113817
Two	113814	113818
Three	113815	113819

COMBINATION TA REGULATOR AND EXCITER MOTOR PANELS WITH INSTANTANEOUS OIL SWITCH TRIP

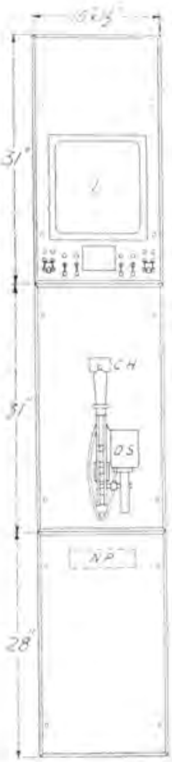


Fig. 1

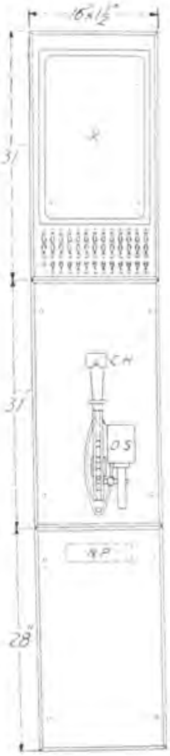


Fig. 2

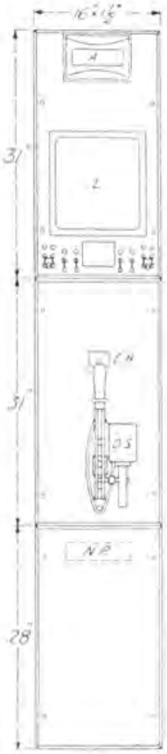


Fig. 3

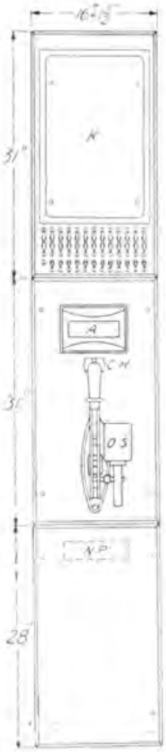


Fig. 4

EQUIPMENT

A = H.E. A.C. ammeter (primary) with......amp. scale (Figs. 3 and 4 only).

L = Drilling and mounting only for one TA regulator, Form L (Figs. 1 and 3 only).

K = Drilling and mounting only for one TA regulator, Form K (Figs. 2 and 4 only).

C.H. = Card holder.

O.S. = T.P.S.T. 200 amp. automatic K-5 oil switch, mounted on back of panel, with bell alarm switch and operating mechanism (single primary coil).

N.P. = Name plate (on only one panel in a complete switchboard).

One—200 watt 440/110 (or 550/110) volts potential transformer.

Regulator, equalizer rheostats, condensers and compensators **are not included.** Equalizer rheostats must be mounted on exciter panels.

Current transformer for regulator must be ordered separately —see page 29, paragraph 3.

Busbars must be ordered separately; see "Busbar Copper."

Panels in Figs. 2 and 4 cannot be used for regulators larger than K-12

Unless Otherwise Ordered Panels will be Furnished for 600 Volts

AMPERE CAPACITY		CAT. NO.			
Panel	Ammeter Figs. 3 and 4 Only	Fig. 1	Fig. 2	Fig. 3	Fig. 4
8	10	113820	113831	113842	113853
12	15	113821	113832	113843	113854
16	20	113822	113833	113844	113855
25	30	113823	113834	113845	113856
30	40	113824	113835	113846	113857
50	60	113825	113836	113847	113858
65	80	113826	113837	113848	113859
80	100	113827	113838	113849	113860
125	150	113828	113839	113850	113861
160	200	113829	113840	113851	113862
200	300	113830	113841	113852	113863

COMBINATION TA REGULATOR AND EXCITER MOTOR PANELS WITH TIME LIMIT OIL SWITCH TRIP

EQUIPMENT

L = Drilling and mounting only for one TA regulator, Form L.

T.R. = S.P. time limit overload relay.

A = H.E. A.C. ammeter (secondary) with......amp. scale (for Fig. 2 only).

C.H. = Card holder.

O.S. = T.P.S.T. 200 amp. automatic K-5 oil switch, mounted on back of panel, with bell alarm switch and operating mechanism (single secondary coil).

N.P. = Name plate (on only one panel in a complete switchboard).

One—200 watt 440/110 (or 550/110) volt potential transformer.

One—Current transformer......amp. (for **O.S.** and **A** only).

Regulator, equalizer rheostats, condensers and compensators **are not included**. Equalizer rheostats must be mounted on exciter panels.

Current transformer for regulator must be ordered separately—see page 29, paragraph 3.

Busbars must be ordered separately; see "Busbar Copper."

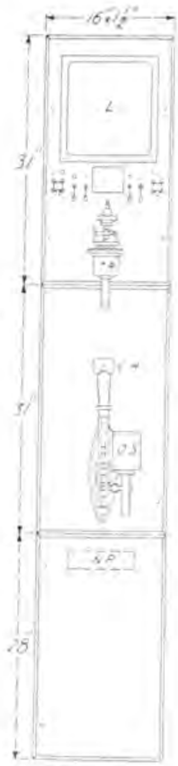


Fig. 1

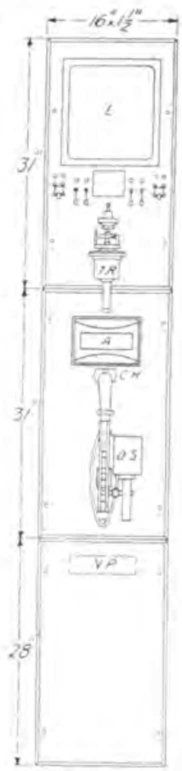


Fig. 2

Unless Otherwise Ordered Panels will be Furnished for 600 Volts

	Ampere Capacity		Cat. No.	
Panel	Ammeter Fig. 2 Only	Current Transformer	Fig. 1	Fig. 2
8	10	10	113864	113879
10	12	15	113865	113880
12	15	15	113866	113881
16	20	20	113867	113882
20	25	30	113868	113883
25	30	30	113869	113884
30	40	40	113870	113885
40	50	60	113871	113886
50	60	60	113872	113887
65	80	80	113873	113888
80	100	100	113874	113889
100	120	150	113875	113890
125	150	150	113876	113891
160	200	200	113877	113892
200	250	300	113878	113893

THREE-PHASE INDUCTION MOTOR PANELS

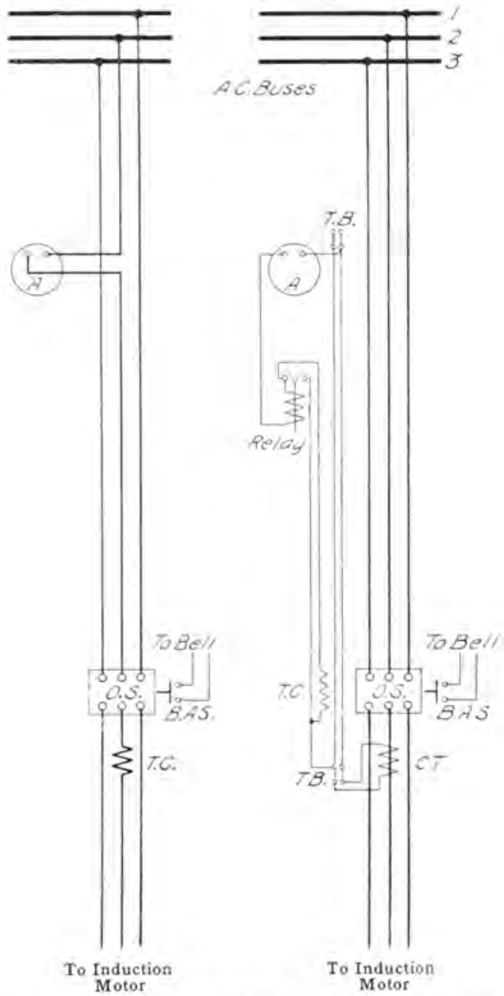
For Exciter Motor-Generator Sets

480 AND 600 VOLTS
8 TO 200 AMPERES

IMPORTANT—NOTE BEFORE ORDERING

1. Do not forget "Information which should accompany orders"—see page 4.
2. Always consider the question of "Oil Switch Rupturing Capacity" in order to determine if panels are suitable for future as well as present requirements.
3. See General Information for method of determining *ampere capacity of panel required for a given induction motor.*
4. These panels cannot be used with any motors which require a controller or starting equipment mounted on the panel; for instance, those Form K motors which do not have self-contained starting compensators.

DIAGRAMS OF CONNECTIONS
FOR THREE-PHASE INDUCTION MOTOR PANELS



On 600 volt circuits current transformer feet should be insulated from ground.

KEY TO SYMBOLS

A = Ammeter.
B.A.S. = Bell alarm switch.
C.T. = Current transformer.
O.S. = Oil switch.
T.B. = Terminal board for secondary leads.
T.C. = Trip coil on oil switch.

THREE-PHASE INDUCTION MOTOR PANELS

EQUIPMENT

(Oil switch trip coils and current coils of ammeter are **primary** for panels in Fig. 1 and **secondary** for panels in Fig. 2.)

A (optional) = H.E. A.C. ammeter with......amp. scale.

T.R. = S.P. time limit overload relay (for Fig. 2 only).

C.H. = Card holder.

O.S. = T.P.S.T. 200 amp. automatic K-5 oil switch mounted on back of panel, with bell alarm switch and operating mechanism (single coil).

N.P. = Name plate (on only one panel in a complete switchboard).

One current transformer......amp. (for Fig. 2 only).

Busbars must be ordered separately; see "Busbar Copper."

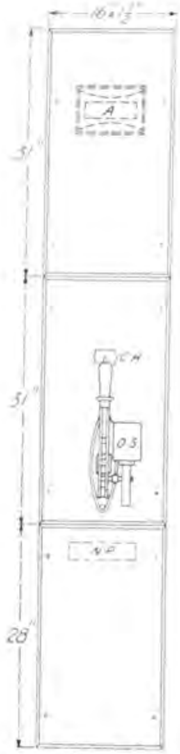


Fig. 1

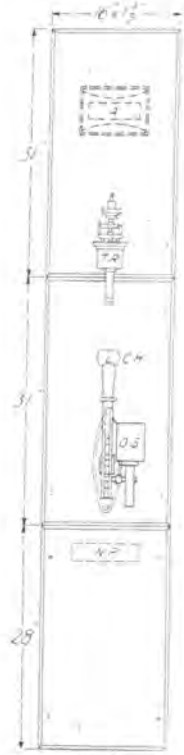


Fig. 2

Ampere Capacity			Cat. No.			
			With Instantaneous Oil Switch Trip Fig. 1		With Time Limit Oil Switch Trip Fig. 2	
Panel	Ammeter	Current Transformer Fig. 2 Only	Without Ammeter	With Ammeter	Without Ammeter	With Ammeter
8	10	10	113894	113905	113916	113931
10	12	15	......	......	113917	113932
12	15	15	113895	113906	113918	113933
16	20	20	113896	113907	113919	113934
20	25	30	......	......	113920	113935
25	30	30	113897	113908	113921	113936
30	40	40	113898	113909	113922	113937
40	50	60	......	......	113923	113938
50	60	60	113899	113910	113924	113939
65	80	80	113900	113911	113925	113940
80	100	100	113901	113912	113926	113941
100	120	150	......	......	113927	113942
125	150	150	113902	113913	113928	113943
160	200	200	113903	113914	113929	113944
200	250	300	......	......	113930	113945
200	300	...	113904	113915	......	......

CURRENT TRANSFORMERS FOR TA REGULATORS

Cat. No.	Ampere Capacity	Ratio	Cat. No.	Ampere Capacity	Ratio
41251	5	1:1	41260	150	30:1
41252	10	2:1	41261	200	40:1
41253	15	3:1	41262	300	60:1
41254	20	4:1	41263	400	80:1
41255	30	6:1	41264	600	120:1
41256	40	8:1	108053	800	160:1
41257	60	12:1	41300	1000	200:1
41258	80	16:1	41301	1500	300:1
41259	100	20:1	41302	2000	400:1

When ordering state whether the current transformer is to be connected in the busbars to regulate for total generator output or in a particular feeder circuit.

BUSBAR COPPER

Busbars must be ordered separately for each panel as per the following sample order:
Item No. 1

One three-phase generator panel Cat. No............
A.C. buses Cat. No............
Exciter buses Cat. No............

If the *total current* supplied to a bus by all panels in the board *does not exceed the minimum limits catalogued* for the different station kw. capacities, busbars may at once be chosen from the following tables since the ampere capacity of bus required for *any* panel will be within these limits. For all other cases the method described on the following page is recommended as a simple means of determining the ampere capacity of bus required.

Cat. Nos. of A.C. buses cover *one* set of three-phase buses of bare copper bar. The ultimate kw. capacity of the station must be taken into consideration in order that future additions may be made to the busbar without changing the bars already installed.

Catalogue numbers of exciter buses cover one positive and one negative bus of bare copper bar and are to be used only for panels listed herein. Exciter panels and buses are listed in S 413.

A.C. BUSES

ULTIMATE KW. CAPACITY OF STATION		Ampere Capacity of Bus Required	CAT. NOS.		
480 Volts	600 Volts		For Panel 16 In. Wide	For Panel 20 In. Wide	For Panel 24 In. Wide
1000	1250	1 to 500	110478	110481	110484
1000	1250	501 to 1000	110479	110482	110485
1000	1250	1001 to 1500	110480	110483	110486
1500	1875	1 to 750	113946	113952	113958
1500	1875	751 to 1500	113947	113953	113959
1500	1875	1501 to 2250	113948	113954	113960
2500	3100	1 to 1250	113949	113955	113961
2500	3100	1251 to 2500	113950	113956	113962
2500	3100	2501 to 3750	113951	113957	113963

EXCITER BUSES

(Do not use for exciter panels)

Ampere Capacity of Bus Required	CAT. NOS.		
	For Panel 16 In. Wide	For Panel 20 In. Wide	For Panel 24 In. Wide
1 to 500	103737	103740	103743
501 to 1000	103738	103741	103744
1001 to 1500	103739	103742	103745

A SIMPLE METHOD OF DETERMINING BUS CAPACITY

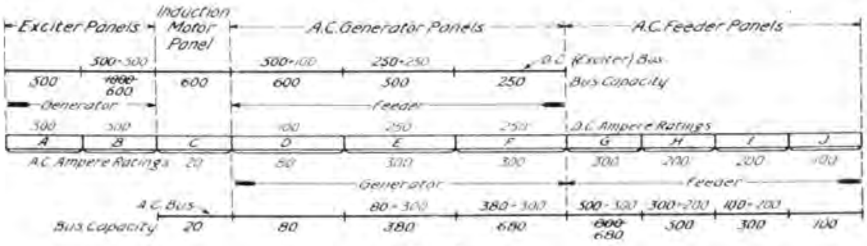


Fig. 1

Fig. 1 illustrates a simple diagrammatical method of determining the ampere capacity of bus required for any panel. The method is as follows:

1. Make a rough plan of the *entire board*, regardless of the number of panels to be ordered.

The Order of Panels shown is recommended, it being most economical of copper and best adapted to future extensions.

2. To avoid confusion keep on one side of board everything pertaining to exciter buses, and on other side everything pertaining to A.C. buses.
3. With single lines represent the exciter and A.C. buses across such panels as they actually extend and by means of arrows indicate that portion of each bus which is connected to feeders and that portion which is connected to generators. **Remember that "Generator" and "Feeder" arrows must always point toward each other,** otherwise the rules given below do not hold. Note also that the field circuits of A.C. generator panels are treated as D.C. feeders for the exciter bus.
4. On each panel mark its ampere rating, *i.e.*, the maximum current it supplies to or takes from the bus. For A.C. generator panels the D.C. rating is the excitation of the machines.
5. Apply the following rules *consecutively*, and note their application in Fig. 1. (For the sake of clearness ampere ratings are shown in light face type and bus capacities in bold face type.)
   - (a) **Always begin with the tail of the arrow and treat "Generator" and "Feeder" sections of the bus separately.**
   - (b) **Bus capacity for first panel = Ampere rating of panel.**
   - (c) **Bus capacity for each succeeding panel = Ampere rating of panel *plus* bus capacity for preceding panel.** (See sums marked above the buses in Fig. 1.)
   - (d) **For a panel not connected to a bus extending across it, use the smaller value of the bus capacities already obtained for the two adjoining panels.** (See exciter bus for panel C.)
   - (e) **The bus capacity for any feeder panel need not exceed the maximum for the generator panels** (see A.C. bus for panel G) **and vice versa** (see exciter bus for panel B). Hence the corrections made in values obtained by applying rules (b) and (c).

The arrangement of panels shown in Fig. 1 is the one which is mostly used. The above method may, however, be applied to other arrangements, one of which is shown in Fig. 2. Here the generators must feed both ways to the feeders at either end of the board so that in determining A.C. bus capacities it is necessary to first consider the generators with the feeders at one end, and then with the feeders at the other end as shown by the dotted A.C. buses. The required bus capacities are then obtained by taking the maximum values for the two cases.

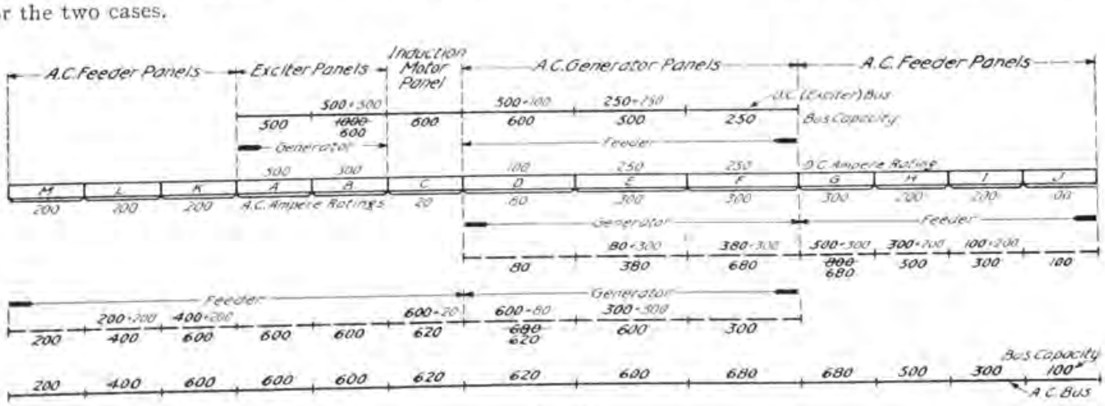
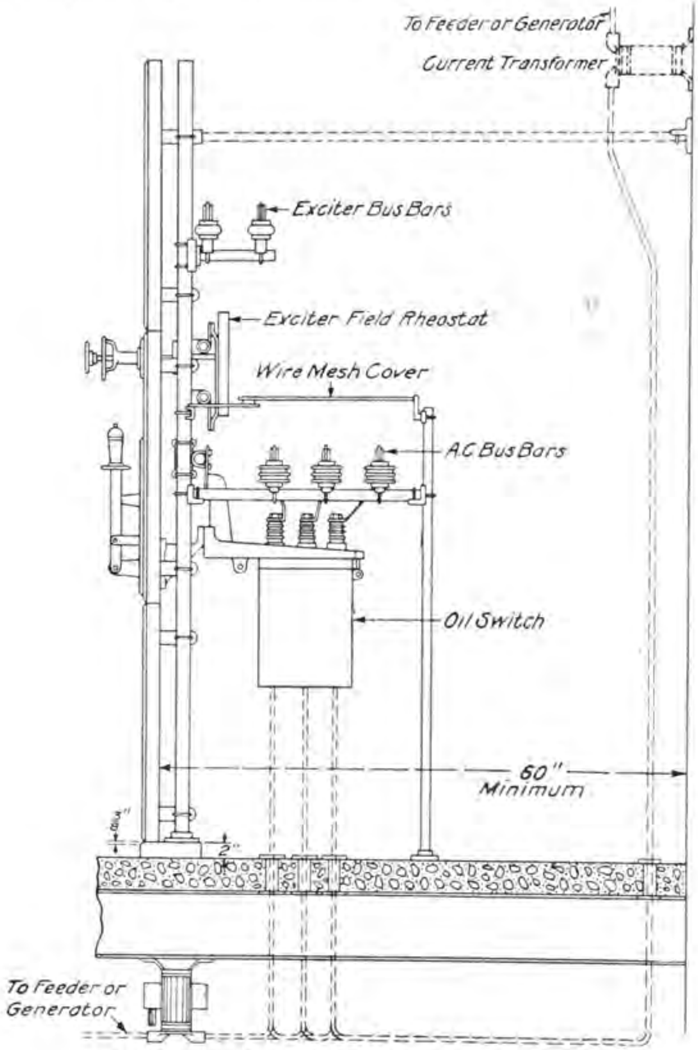


Fig. 2

480 AND 600 VOLT A.C. SWITCHBOARD ARRANGEMENTS

Heavy broken lines in the following diagram show alternate locations for apparatus furnished by the General Electric Company. Light broken lines show material to be furnished by the purchaser.

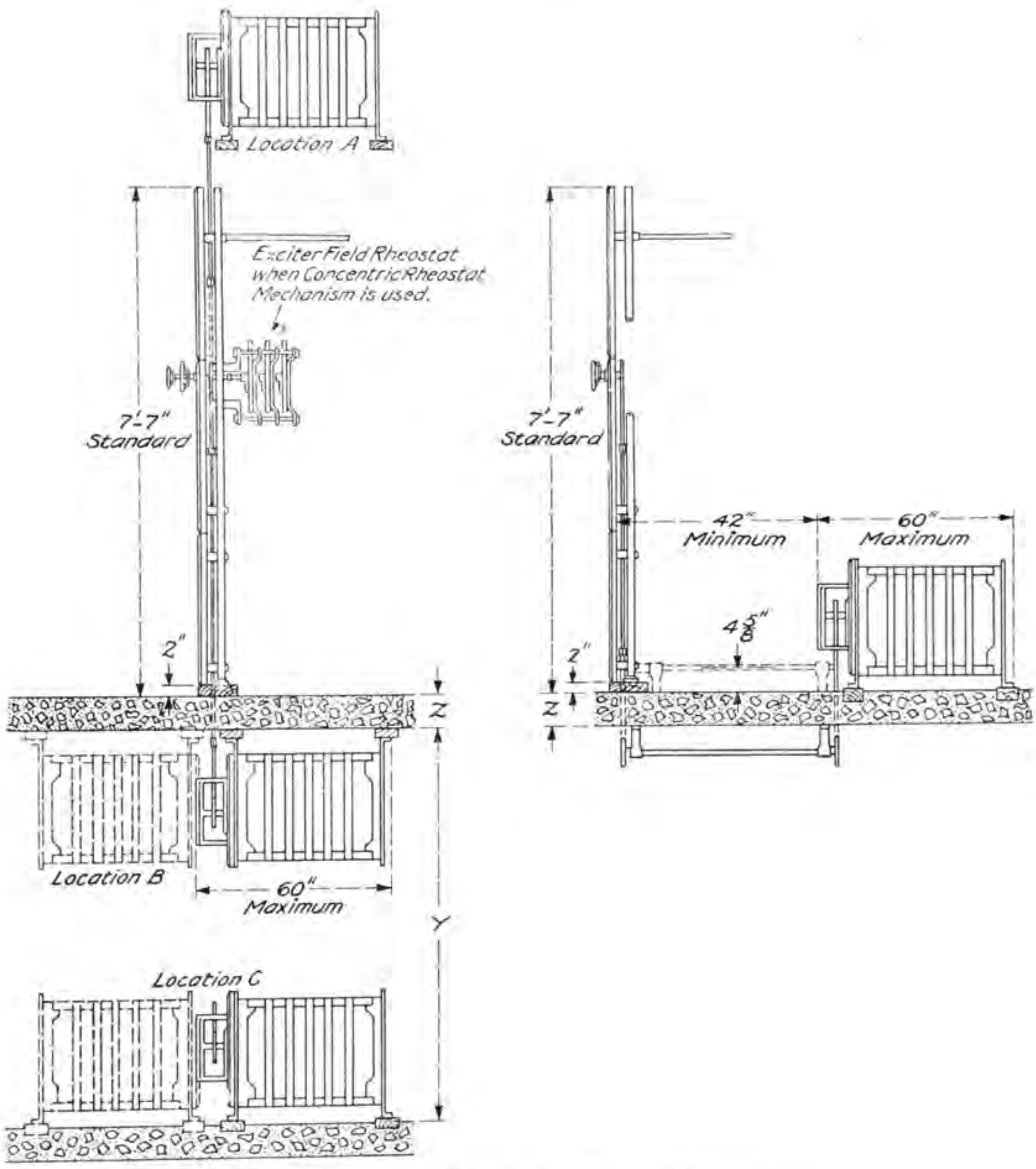


Single-Throw Oil Switch Mounted on Panel

When leads come in from below and a basement is not available for mounting current transformers as shown, the matter should be referred to the General Office for recommendations.

480 AND 600 VOLT A.C. SWITCHBOARD ARRANGEMENTS

ALTERNATE LOCATIONS OF GENERATOR FIELD RHEOSTAT



Dimensions Y and Z should be given with the order.

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Oklahoma City, Okla.	Insurance Building

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Canadian General Electric Co., Ltd., Toronto, Ont.

General Electric Company

Schenectady, N.Y.

SUPPLY DEPARTMENT

March, 1911

* *Bulletin No. 4820*

CURVE-DRAWING AMMETERS AND VOLTMETERS—TYPE CR AND CR-2

The curve-drawing instrument gives a clear, permanent record of the characteristics of the electric circuit to which it is applied. It is the "indicator card" of the electric equipment. The data obtained from a set of records can be readily tabulated and used to improve the efficiency of machines and workmen. This instrument is also valuable in locating trouble with electrical apparatus and has proven very useful in factories which have adopted the individual drive system, as a constant check may be kept on each machine, on the workmen and on the condition of tools.

SWITCHBOARD TYPE CR CURVE-DRAWING INSTRUMENT

PORTABLE TYPE CR INSTRUMENT

Another valuable feature of the curve-drawing instrument is its usefulness in determining the correct size and style of motor for use with new machines.

Type CR curve-drawing instruments are moderate in price so that a general introduction for even individual machines does not mean a prohibitive original investment.

They are of the round pattern type having circular charts 8 inches in diameter. They are well designed both electrically and mechanically and so constructed as to maintain their accuracy under all ordinary conditions of service. Where instruments with circular charts are desired, they will be found very satisfactory and may be relied upon to give accurate results and clear unblotted records.

CONSTRUCTION

The internal parts of these curve-drawing instruments consist of the clock mechanism and the measuring element. The spindle carrying the pen arm has cylindrical pivots and runs in ring-stone, end-stone jewels, thus keeping the pen always in correct alignment.

NOTE.—The prices and data in this publication are for the convenience of customers, and every effort is made to avoid error, but this Company does not guarantee their correctness, nor does it hold itself responsible for any errors or omissions in this publication. Both prices and data are subject to change without notice.

* *Supersedes 4706.*

The electrical element is of the solenoid type with gravity control. With this construction, a durable instrument is obtained which can be operated on either alternating or direct current. To render the needle dead-beat, an aluminum damping disk is operated from the armature shaft through gearing so that a large movement of the disk is obtained with a small movement of the pen.

PEN

The pen consists of a V-shaped metal punching with a sharp point. Under ordinary conditions, it will hold sufficient ink for several charts. The friction of this pen on the paper is very small and does not produce any appreciable error in the readings.

CLOCK

The clock is of simple, rigid construction and is held in place in the case by three screws. It is a high grade movement with marine escapement, and with ordinary chart speeds will run two days with one winding.

CHART DRIVE

The driving arbor to which the charts are attached projects through the inner case and the chart is clamped in place by a knurled nut. The chart is supported by a stationary metal dial and, to keep it flat, the edge runs under six clips on the periphery of this dial.

CHARTS

The charts are very carefully printed by a special process which eliminates all errors due to eccentricity. To insert new charts, it is necessary only to open the case and unscrew the knurled head and, after setting the chart at the correct time, clamp it in place.

SHIPPING DEVICE

All instruments are provided with a special shipping device which locks the moving element. After the instrument is installed, the knurled knob at the right should be pulled forward and turned clockwise until the pin catches. Before moving the instrument, the armature should be locked by pulling the knob forward and turning counter clockwise until the pin catches. There is a datum line on the knob and two reference lines on the plate marked "L" and "F" indicating the locked and free positions of the armature respectively.

TYPE CR CURVE-DRAWING INSTRUMENT—INTERIOR

CHART SPEED

The standard clock speed is arranged to drive the chart through one revolution in either 12 or 24 hours. Speeds of 1 and 6 hours can, however, be furnished on request.

CAPACITIES

The ammeters are made self-contained in capacities up to and including 200 amperes. For capacities over 200 amperes and on circuits above 750 volts alternating current, a 5 ampere instrument should be used in connection with standard current transformer. Direct current ammeters cannot be furnished above 200 amperes. Voltmeters are furnished for both alternating and direct current up to and including 750 volts. All capacities have external resistance boxes for mounting at the back of the board.

CONNECTIONS

The CR ammeters and voltmeters can be furnished with either front or back connections. The front connected instrument is equipped with lugs on the case for fastening to the front of the panel or to the wall, and the back connected case has studs for switchboard mounting. When back connected instruments Type CR-2 are desired the order should so specify as front connected instruments are furnished unless otherwise ordered.

SCALES

The scale distribution is such that good readings can be obtained above one-quarter scale. Standard voltmeter scales have suppressed zero but full scales can be furnished if desired. The suppressed zero feature is very desirable on voltmeter scales as a much wider space per volt can be obtained.

FINISH

The standard finish is dull black. All instruments have a circular glass window in the cover, which renders the entire record visible at all times.

TYPE CR (PORTABLE)

For portable work the standard instrument can be equipped with a metal handle and three metal feet with levelling screws as shown in the illustration.

The resistance for the voltmeter is attached to the back of the case. When desired, a voltmeter with an extra tap on the resistance can be furnished, suitable for use on either alternating or direct current.

The price of the portable instrument is $10.00 list additional to the price of the standard switchboard instrument of corresponding capacity. Voltmeters for both alternating and direct current will be $15.00 list in addition to price of standard voltmeters.

AMMETERS

Cat. No.	Amp. Cap.	List Price
69078	5	$90.00
69079	10	90.00
69080	15	90.00
69081	20	95.00
69083	30	95.00
69084	40	95.00
69085	60	100.00
69086	80	100.00
69087	100	100.00
69088	150	110.00
69089	200	110.00

VOLTMETERS

Cat. No.	Volt Cap.	List Price
69090	90–130	$85.00
69091	180–260	90.00
69092	450–650	100.00

100 charts and a bottle of ink will be furnished with each instrument.

Extra charts $0.75 net per hundred.

*Extra ink	2 oz. bottle	$0.20 net
	8 oz. bottle	.50 net
	1 pt. bottle	.85 net
	1 qt. bottle	1.50 net

Orders for instruments must always specify whether for alternating current or direct current, and the frequency if for alternating current.

*Ink for CR instruments is different from ink for Type C instruments and orders for ink should specify whether for CR or C instruments.

SECTION OF SOME STANDARD CHARTS

AMMETERS

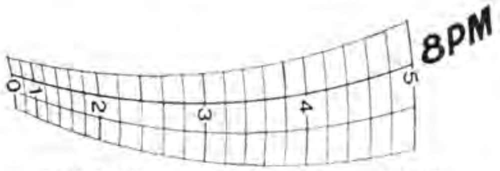


CHART 110 A.C. 24 HRS.

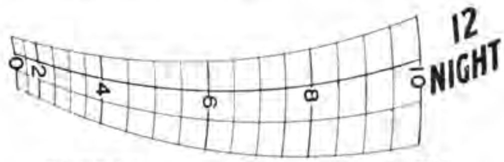


CHART 134 D.C. 24 HRS.

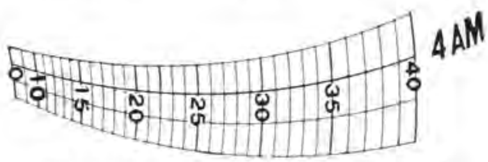


CHART 140 A.C. 24 HRS.

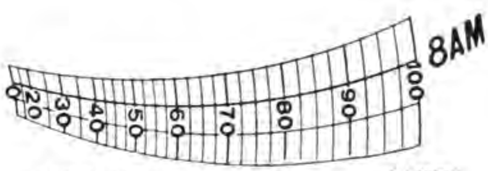


CHART 141 A.C. 24 HRS.

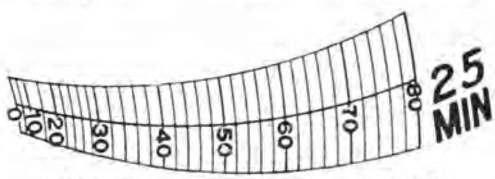


CHART 151 D.C. 1 HR.

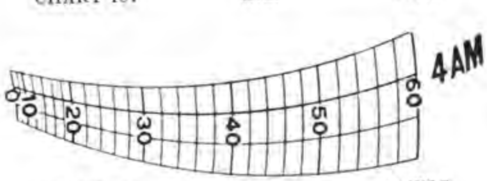


CHART 150 A.C. 24 HRS.

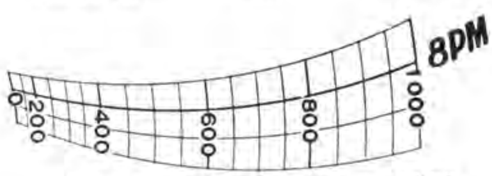


CHART 138 (C.T. RATIO 200:1) 24 HRS.

VOLTMETERS

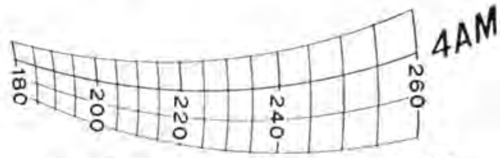


CHART 112 A.C. 24 HRS.

CHART 114 A.C. 24 HRS.

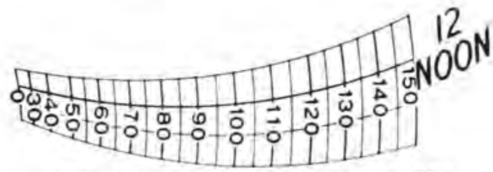


CHART 123 A.C. 24 HRS.

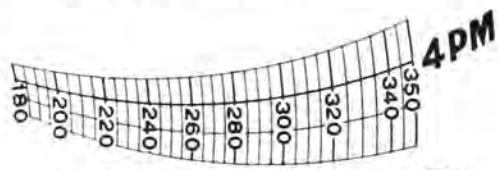


CHART 125 D.C. 24 HRS.

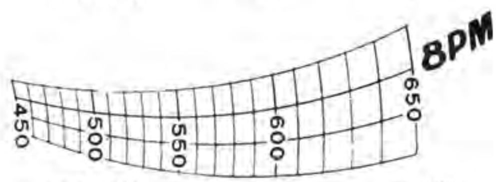


CHART 116 A.C. 24 HRS.

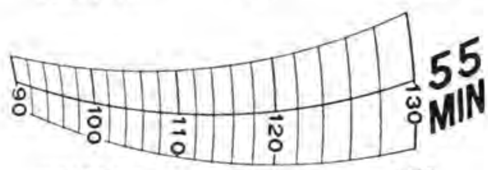


CHART 147 D.C. 1 HR.

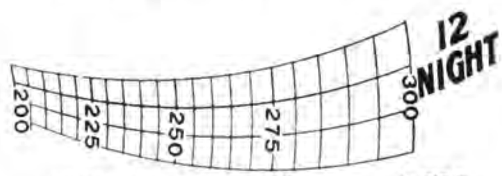
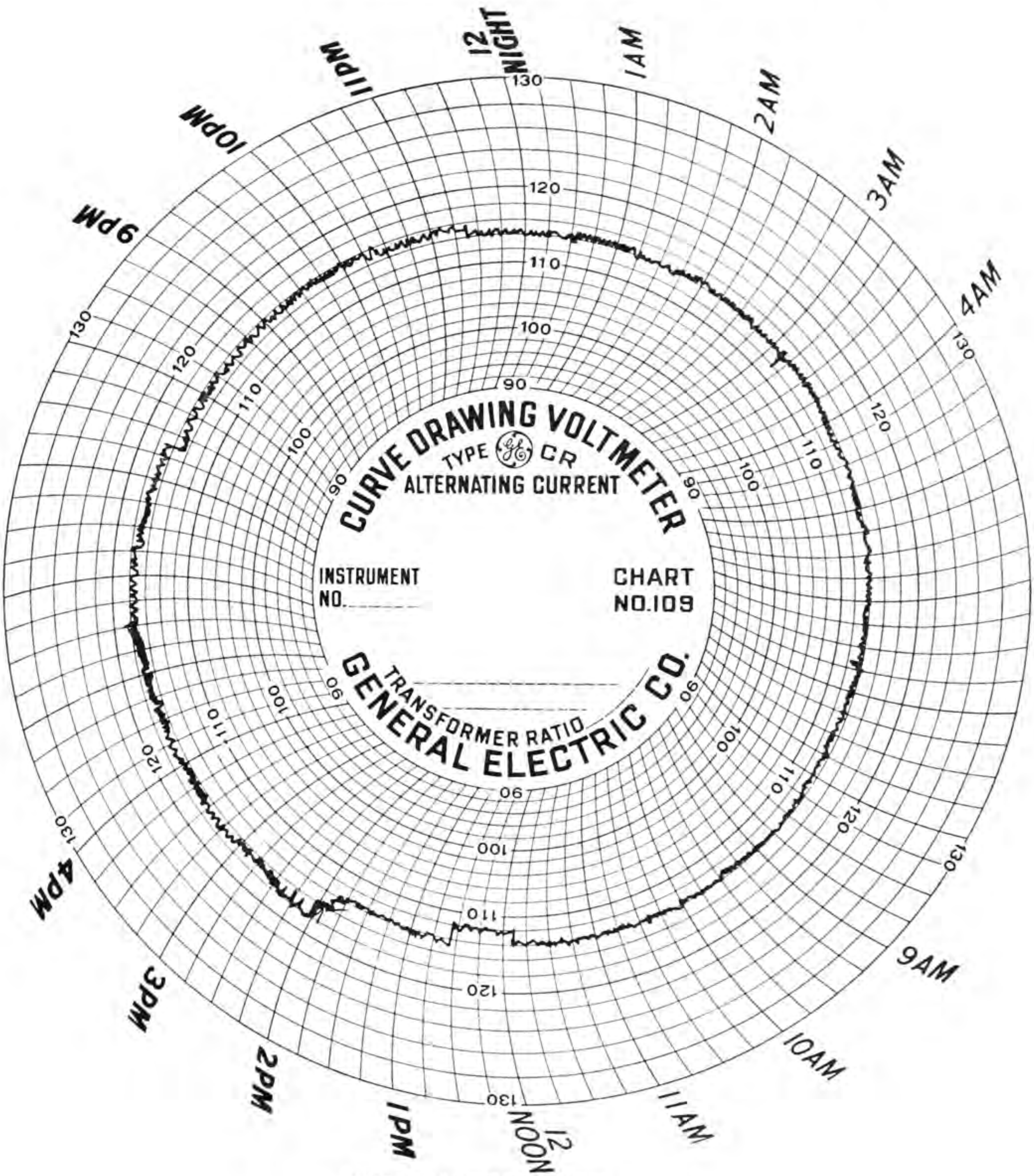
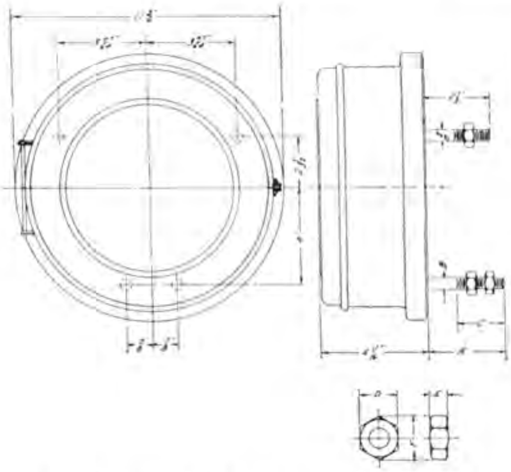


CHART 120 D.C. 24 HRS.

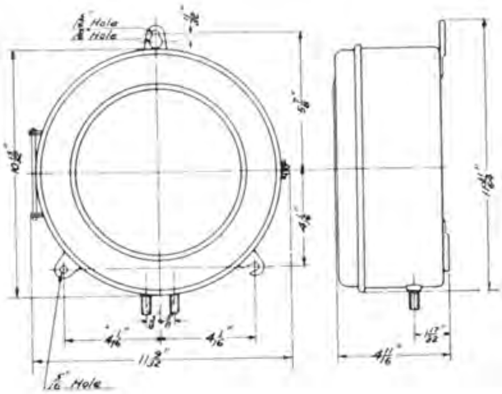


VOLTMETER CHART—FULL SIZE

4820-6 Curve-Drawing Ammeters and Voltmeters—Type CR and CR-2



DIMENSIONS OF BACK CONNECTED TYPE CR-2 CURVE-DRAWING INSTRUMENTS



DIMENSIONS OF FRONT CONNECTED TYPE CR CURVE-DRAWING INSTRUMENTS

Amp.	DIMENSIONS IN INCHES					
	A	B	C	D	E	F
0–40	3	3/8	2 1/2	25/32	3/8	29/32
60–100	3	3/8	1 3/4	25/32	3/8	29/32
150–200	3 1/2	1/2	2 1/4	1 1/16	1/2	1 7/32
Voltmeter	3	3/8	2 1/2	25/32	3/8	29/32

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General Electric Company

Schenectady, N.Y.

SUPPLY DEPARTMENT

March, 1911 *Bulletin No. 4821*

TYPE F, FORM K-12 OIL BREAK SWITCH

The Type F, Form K-12, oil break switch is designed for use on circuits not exceeding 15,000 volts.

The K-12 oil break switch is easy to install, and access to the contacts can be readily obtained by removing the oil vessel.

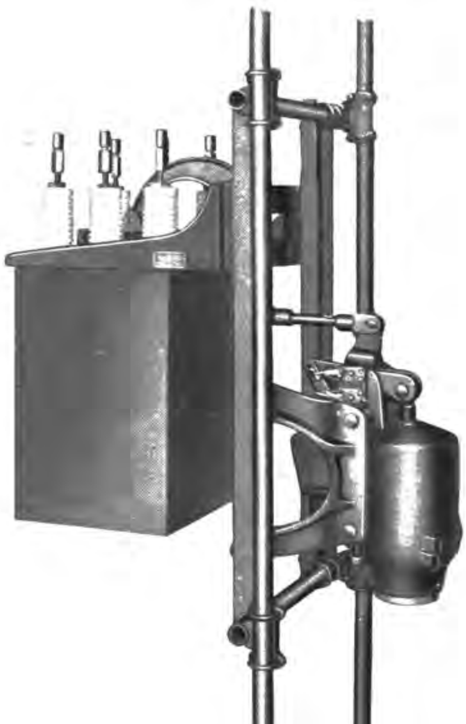


Fig. 1
T.P.S.T. FORM K-12 SOLENOID-OPERATED OIL BREAK SWITCH MOUNTED ON PIPE FRAMEWORK

All live parts are placed back of the panel; this removes the danger of the operator coming into accidental contact with the live parts of the switch, and facilitates inspection.

It is quite obvious that the oil vessel of any oil break switch should under no circumstances be removed while the switch is alive, whether open or closed. In all installations it should be possible to disconnect the switch from the line when necessary to change the oil or to inspect the switch.

The arc, incident to rupturing the circuit, is confined in the oil vessel under oil, and cannot involve adjacent apparatus. The circuit is ruptured at the zero point of the wave, decreasing the possibility of a surge occurring on the line.

Fig. 2
T.P.S.T. FORM K-12 300 AMPERE OIL BREAK SWITCH

CONSTRUCTION

The general construction of the Type F, Form K-12 oil break switch, which supersedes the Type F, Forms K-2 and K-4, will be readily understood by reference to the accompanying illustrations.

The frame is of cast iron and is adapted for mounting on a flat surface; or, equipped with proper fittings and base castings, it may be supported on 1¼ in. pipe. The frame serves as a support for the insulators and contacts, and as a cover and support for the oil vessel.

The insulators, supporting the stationary contacts and studs, are of one piece porcelain, being clamped between two metal plates, which in turn are bolted down to the switch frame. No babbitt or cement is employed, and the insulator, stud, and contact may be readily removed. Since the clamping surfaces are perfectly trued and drilled, the replacing or adjusting of parts is accomplished economically and quickly and perfect alignment is insured.

For each pole two insulators with studs, stationary contacts and terminals are provided. The circuit is closed between these two stationary contacts by means of a horizontal movable contact blade, which is connected across the contacts when the switch is closed. This blade moves in a vertical plane, being drawn up when the switch is closed and dropped when the switch is opened. Each contact blade is connected to the operating mechanism by a wooden rod, specially treated for the service. This rod passes through the frame of the switch in a porcelain bushing, which acts as an additional protection against abnormal potentials. The wooden rod is securely clamped to the contact blade, and, in the case of the single-pole switch, is fastened directly to the operating mechanism; in the double-, triple- and four-pole switches, these rods are securely clamped to an iron crosshead, which in turn is connected to the operating mechanism. The rods are operated by a vertical parallel movement, which gives freedom of action and eliminates any possible danger of friction or binding. This movement is accomplished by the main operating lever, and steel links which are pivoted to the frame, making the switch a complete unit.

The oil vessels are of heavy sheet metal riveted and double lapped and lined with an insulating material. Provision is made for readily removing the oil vessels when necessary and special insulating barriers in the oil vessel separate the poles of multipole switches.

OIL

For oil break switches, the General Electric Company recommends No. 6 transil oil, which is prepared by a special process and is of superior quality, because of its resistance to carbonizing and its high flashing point. A horizontal red stripe on the oil receptacle indicates the *exact* height to which the vessel should be filled, since proper air space above the oil is necessary for successful operation, and at the same time the contact surfaces must be completely submerged.

stationary contact fingers and the upper extremity of the movable contact blades; pitting or burning of the working contact surfaces is therefore impossible and perfect contact and long life are insured. As a further protection, one set of fingers on each stud contact block is extended to take any arcing which may occur. Fingers and blades are easily replaced when necessary.

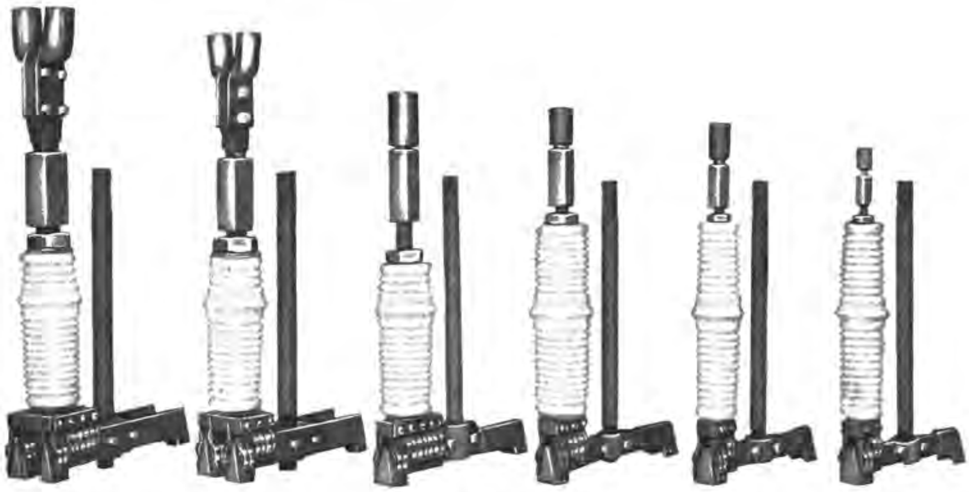


Fig. 3
CONTACTS AND INSULATORS FOR FORM K-12 OIL BREAK SWITCHES, 2000 TO 300 AMPERES

CONTACTS

The movable copper contact blades (except in switches above 1200 amperes) are wedge shaped and slotted at the upper edge. In opening the circuit, the oil is forced through the slot in the blade directly into the arc.

The stationary contacts consist of flared fingers of drop forged copper, secured by heavy flat steel springs, copper laminations, and screws to the contact blocks on the copper studs.

The studs pass through and are supported by the insulators, and at the top are connected to the terminals.

This construction of contacts imparts a distinct rubbing movement in opening and closing and insures clean surfaces and perfect contact throughout the entire contact surface.

In opening the circuit the final rupture takes place between the flared portion of the

TEMPERATURE RISE

At the full rated load these switch contact parts will have a temperature rise not exceeding 28 degrees C., above the surrounding atmosphere, provided the cables or bars to which they are connected are of sufficient capacity.

RUPTURING CAPACITY

The K-12 oil break switch has been designed to meet the average conditions of rupturing capacity on systems not exceeding 15,000 volts.

While an oil switch may be insulated for a given potential and designed to carry a definite amount of current, it should not be understood that, in the event of a short circuit, the switch will necessarily rupture that amount of normal energy, equivalent to the volt and ampere rating of the switch.

A source of electrical energy may have power greatly in excess of its normal capacity and the switch may therefore be required to interrupt not merely the normal energy delivered to the circuit in which it is connected; but the entire power which may be developed under short circuit conditions by all the generator and synchronous apparatus in parallel which are connected to the system. Under short circuit conditions, synchronous generators develop instantaneously many times their normal full load capacity, while the sustained short circuit current will be approximately two and one-half to three times normal. Therefore, instantaneous automatic switches must be capable of rupturing the circuit when the current is at a maximum, whereas non-automatic switches, and automatic switches with time limit relays, will be required to interrupt only the *sustained* short circuit current. The reason is evident since the delay in opening the switch allows the current to settle down to approximately two or three times normal.

The table of rupturing capacities on page 5 is based on exhaustive tests conducted by the company and upon records made under actual operating conditions. The limits given are conservative and are in terms of the normal full load capacity of the machine.

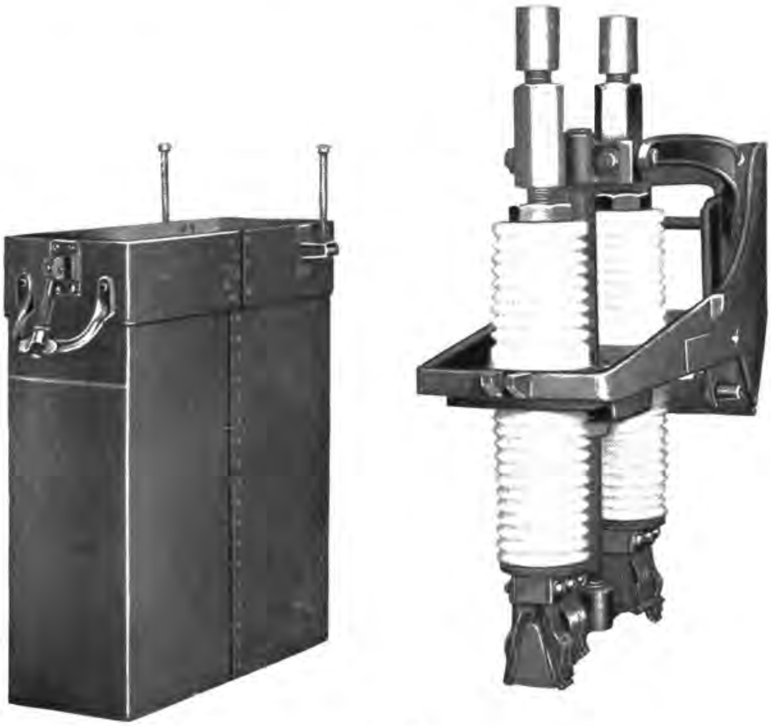


Fig. 4
S.P.S.T. FORM K-12 OIL BREAK SWITCH

INSTALLATION

The General Electric Company does not recommend the installation of apparatus on a panel or on the panel pipe supports when that apparatus is subjected to a potential in excess of 2500 volts. For such installations remote control apparatus is recommended.

When it is desired to have the K-12 switches directly back of the panel, it is recommended that instead of carrying the weight of the

KILOWATT RUPTURING CAPACITIES OF K-12 SWITCHES

Ampere Capacity	RUPTURING CAPACITY IN KILOWATTS			
	NON-AUTOMATIC OR AUTOMATIC WITH TIME LIMIT RELAY SET FOR A MINIMUM OF 2 SECONDS DELAY		AUTOMATIC (INSTANTANEOUS)	
	On Panel, Panel Pipes or Framework	In Cell	On Panel, Panel Pipes or Framework	In Cell
FOR * THREE-PHASE 2500 VOLT SERVICE				
300, 500, 800	12000	13800	4800	5500
1200, 1500, 2000	11000		5000	
FOR * THREE-PHASE 4500 VOLT SERVICE				
300, 500, 800	11000	12600	4400	5000
1200, 1500, 2000	11000		5000	
FOR * THREE-PHASE 7500 VOLT SERVICE				
300, 500, 800	9500	11000	3800	4400
1200	11000		5000	
FOR * THREE-PHASE 15,000 VOLT SERVICE				
300, 500, †800	6500	7500	2600	3000

* For single-phase multiply by .75, for quarter-phase, by 1.5. The capacities of switches for intermediate voltages can be obtained by inverse proportion.

† No automatic K-12 switch made in this capacity for 15,000 volts.

The switches listed above are capable of opening heavy overloads or short circuits on systems where the *normal full load rating* of all the synchronous apparatus connected to the system or section does not exceed the kilowatt ratings given.

switches entirely on the slate or marble, arrangement be made to mount the switches on supports fastened to the switchboard framework. Suitable pipe and channel iron supports can be supplied on order.

In the majority of cases, it is desirable to install K-12 oil break switches on pipe framework remote from the panel. In this location, switches may be operated by hand from the switchboard by means of operating rods through a system of bell cranks. This same arrangement is used when the switches are located in cells, provided the cells are not more than 12 feet from the panel.

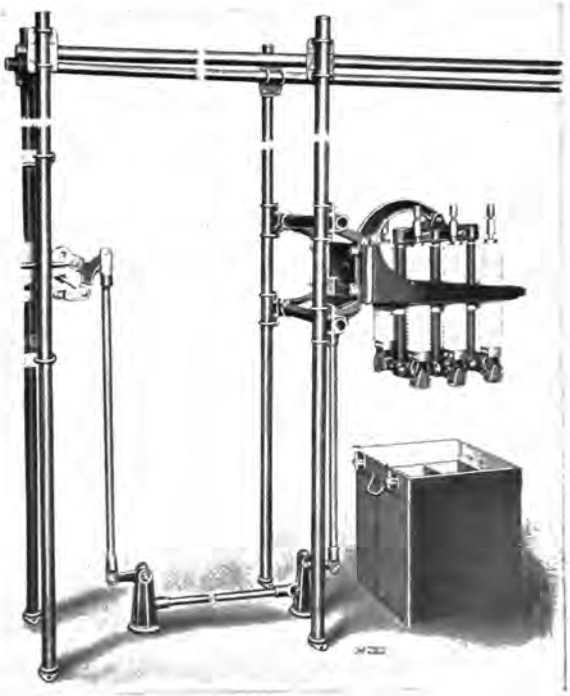


Fig. 5
T.P.S.T. FORM K-12 OIL BREAK SWITCH, REMOTE CONTROL HAND-OPERATED MOUNTED ON PIPE FRAMEWORK

By the use of electrically-operated K-12 switches, with solenoid mechanisms, the installation is greatly simplified and it is not necessary to have any mechanical connection with the switchboard. *It is preferable to use solenoid mechanism with switches of capacities greater than 800 amperes.*

When a switch made up of single-pole elements is used, it is usually installed in a concrete or brick cell, each element being separated by means of a barrier. The cell is closed on top by means of a slate slab, and doors of asbestos lumber with wooden frames are provided for the front. These doors are removable, allowing ready inspection or removal of the switch. They are hinged at the top and free to swing and should not be solidly fastened. The leads are carried through porcelain bushings in the slate top and connected to the switch terminals inside the compartment. In certain cases these leads may be taken through the rear walls of the

Fig. 6
SOLENOID-OPERATED T.P.S.T. FORM K-12 OIL BREAK SWITCH OF 3 SINGLE-POLE ELEMENTS MOUNTED IN CONCRETE CELL

cell or carried in conduits in the rear wall. In some installations, double-, triple- or four-pole switches are mounted in a cell, the entire switch being placed in one compartment. The General Electric Company is prepared to furnish slate tops, angle irons, channel irons, tie rods, bushings and doors for the ordinary types of masonry cells; the brick or concrete walls and barriers being supplied by the customer.

OPERATING MECHANISM

The hand-operating mechanism is designed for connecting the switch to the switchboard panel, the operating lever and trip coil for automatic switches being located on the front of the board. (See heading "Capacities 1200 to 2000 Amperes" on page 8.) The switch may be placed in the following locations:

With Hand-Operated Mechanism:

(1) On panel (but this is not recommended).
(2) On panel pipe supports directly back of the panel (not recommended above 500 amps.).
(3) On pipe framework behind, above or below panel, Fig. 5.
(4) In cell behind, above or below panel.

With Solenoid-Operated Mechanism:

(5) On pipe framework, remote from panel, Fig. 1.
(6) In cell, remote from panel, Fig. 6.

For locations 3 and 4, the oil switch must not be more than 12 feet from the panel.

In the case of solenoid-operated switches in cells, the solenoid should preferably be located on the rear wall, as shown in Fig. 6. But if conditions require, it may be located above or below, in which case the cell may be placed adjacent to the wall of the building.

Hand-Operating Mechanisms consisting of suitable handles, bell cranks, etc., are available for all the above conditions and for any ordinary location of the switch with relation to the panel. For the connecting rods of remote hand-operated mechanism, standard ¾ inch gas pipe is used. When possible, bell cranks should be arranged so that the pipe will be under tension when switches are being closed. These mechanisms may be either:

(1) Non-automatic.
(2) Automatic with one overload coil.
(3) Automatic with two overload coils.
(4) Automatic with three overload coils.

Method of Tripping Automatic Switches

For tripping automatic (overload) switches a.c. coils connected directly to the secondaries of the current transformers, may be used or coils separately energized from a low voltage a.c. or d.c. auxiliary circuit. When separately energized coils are employed, circuit closing overload relays are connected to the secondaries of the current transformers.

Hand-operated automatic switches (except those equipped with separately energized coils) have tripping devices calibrated 5-6-9-12-15 amperes (secondary current values). These values multiplied by the ratio of the current transformers used give the corresponding primary currents. Where relays are used, the oil switch should be set at its lowest point of calibration, the calibration or setting of the unit being effected from the relay.

Hand-Operated Oil Switches Include:

Switches complete with oil, sleeve cable terminals, and insulating sleeves.
Supports and pipe fittings for mounting on panel pipes or pipe framework, or base for mounting on flat surface.
Mechanism (less pipe connecting rods).
Current transformers (for automatic switches only).
Bell alarm switches (for automatic switches only).

tripping on overload, reverse current, low voltage, etc., is accomplished by means of switchboard relays of the circuit closing type connected in the secondaries of current transformers. (For information on relays see Relay Bulletin.)

Solenoid-Operated Switches Include:

Switch complete with oil, sleeve cable terminals, and insulating sleeves.
Supports for mounting switch and solenoid on pipe framework or on flat surface (masonry cell).
Solenoid and connecting mechanism between switch and solenoid.
Solenoid control relay, control switch and indicating lamps.

Fig. 7
FORM K-12 OIL BREAK SWITCH OPERATING LEVERS FOR CAPACITIES UP TO 800 AMPERES

Low Voltage Release Attachments can be used in connection with automatic switches. Information on these and on other automatic features, such as protection against reversal of current, etc., will be furnished on request. Overload coils of automatic switches may be connected directly to current transformers, or any of the standard types of relays may be interposed.

All hand-operated automatic switches trip free of the handle, and cannot be held closed on overloads.

Solenoid Mechanisms are available for all remote control K-12 switches. These consist of the ordinary closing and opening coils wound for 125, 250 or 600 volts *direct current* and are operated by suitable control switches and relays (Figs. 28, 29 and 30). Automatic

(A solenoid control relay is furnished as an essential part of each solenoid-operated oil switch unit. It is used to open and close the closing coil circuit and to relieve the control switch contacts from breaking the current of the operating circuit.)

To Obtain Complete Overload Protection Use:

For single-phase two-wire systems: (Fig. 9.)
D.P. switch with one trip coil
One current transformer.
For two-phase interconnected, four-wire systems: (Fig. 15.)
4 P. switch with three trip coils
Three current transformers.
For two-phase non-interconnected four-wire systems: (Fig. 14.)
4 P. switch with two trip coils
Two current transformers.
For two-phase non-interconnected four-wire systems: (Fig. 13.)
4 P. switch with one trip coil. (Middle tap, see following text.)
Two current transformers.

4821–8 Type F, Form K-12 Oil Break Switch

For three-phase ungrounded neutral, three-wire systems: (Fig. 11.)
T.P. switch with two trip coils
Two current transformers.
For three-phase ungrounded neutral, three-wire systems: (Fig. 10.)
T.P. switch with one trip coil. (Middle tap, see following text.)
Two current transformers.
For three-phase grounded neutral, three-wire systems: (Fig. 12.)
T.P. switch with three trip coils
Three current transformers.
For three-phase four-wire systems:
4 P. switch with three trip coils
Three current transformers.

Fig. 8
T.P.S.T. FORM K-12 OIL BREAK SWITCH

This table applies particularly to hand-operated switches tripped by current transformers either directly or through circuit opening relays. The same number of current transformers is used in connection with circuit-closing relays for tripping solenoid-operated switches. It is customary to use single-pole relay with one current transformer, double-pole relay with two current transformers, and triple-pole relay with three current transformers. When a separate source of power is used for tripping hand-operated switches, circuit-closing relays, single-, double- or triple-pole, and single coil switches are used.

Trip coils of hand-operated switches should not be connected in series with watthour meters or wattmeters; in such cases relays should be interposed or separate current transformers should be used.

Triple- and four-pole switches with single coil operating mechanisms are equipped with "middle tap" trip coils. Instruments or meters may under no circumstances be operated from the current transformers used with middle tap coil mechanisms.

CAPACITIES

K-12 oil switches are made in the following capacities:

15,000 volts—300, 500 and 800 amperes
800 ampere switch at 15,000 volts non-automatic only
7,500 volts—300, 500, 800 and 1200 amperes
4500 volts—300, 500, 800, 1200, 1500 and 2000 amperes

The Following Auxiliary Devices can be Furnished as Extras:

Pipe connecting rods (for hand-operated remote control switches).
Auxiliary switches (circuit opening, circuit closing, for electric interlocking, indicating, opening and auxiliary tripping circuit, etc.)
Current and potential transformers.
Relays for automatic tripping on overload or other abnormal conditions.
Signal relays (circuit closing).
Control relays (circuit closing) for solenoid-operated switches.
Control switches for solenoid-operated switches.
Indicating lamps.
Switch supports.
Material for masonry cells, consisting of:
Bushings for cell tops
Slate cell tops
Angle iron and channel iron supports
Cell doors
Tie rods.

CAPACITIES 1200 TO 2000 AMPERES

While hand-operated 1200, 1500 or 2000 ampere K-12 oil break switches can be furnished, a considerable effort is necessarily required to close them and solenoid-operated switches are recommended for these capacities.

When hand-operated switches of these capacities are desired they will be furnished with operating levers which in operating move through an arc of approximately 115 degrees.

It is not advisable to mount oil break switches of 800 amperes capacity and larger directly on the panel. The operating levers for remote control switches of these capacities should not be mounted on panels less than 2 in. thick.

DOUBLE-THROW SWITCHES

Form K-12 oil break switches are single throw only. Where double throw equipments are desired, two single throw switches are furnished, equipped with simple and positive mechanical interlock consisting of a bar mounted on the back of the panel and engaging with the mechanism of whichever switch is open, preventing its being closed until the closed switch is opened. With solenoid-operated switches the interlocking is accomplished electrically.

CONNECTIONS OF TYPE F FORM K-12 OIL BREAK SWITCHES WITH TRIP COILS FOR USE WITH CURRENT TRANSFORMERS*

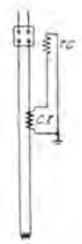


Fig. 9
Single-Phase

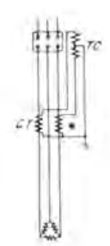


Fig. 10
Three-Phase

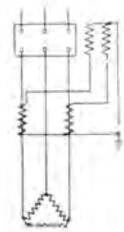


Fig. 11
Three-Phase

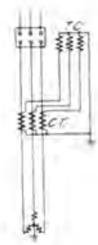


Fig. 12
Three-Phase
(Grounded neutral)

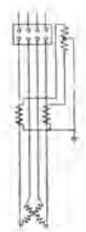


Fig. 13
Two-Phase

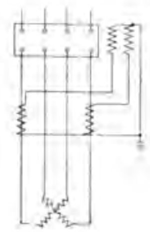


Fig. 14
Two-Phase

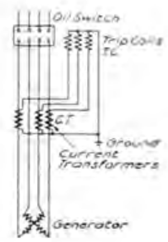


Fig. 15
Two-Phase
(Phases interconnected)

*See page 8 for use of meters and instruments in connection with trip coils for oil break switches.

CONNECTIONS OF RELAYS USED WITH K-12 OIL BREAK SWITCHES

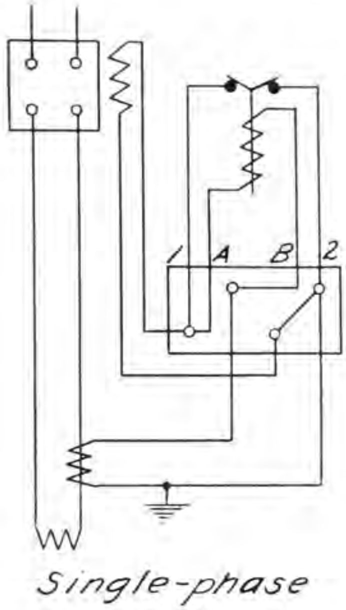


Fig. 16

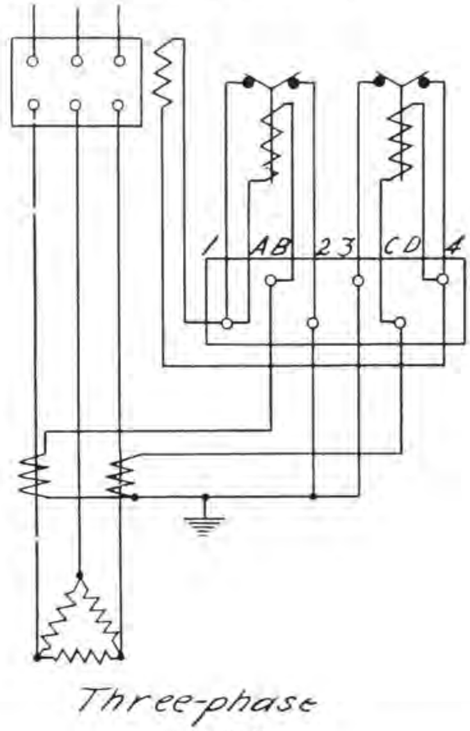


Fig. 17

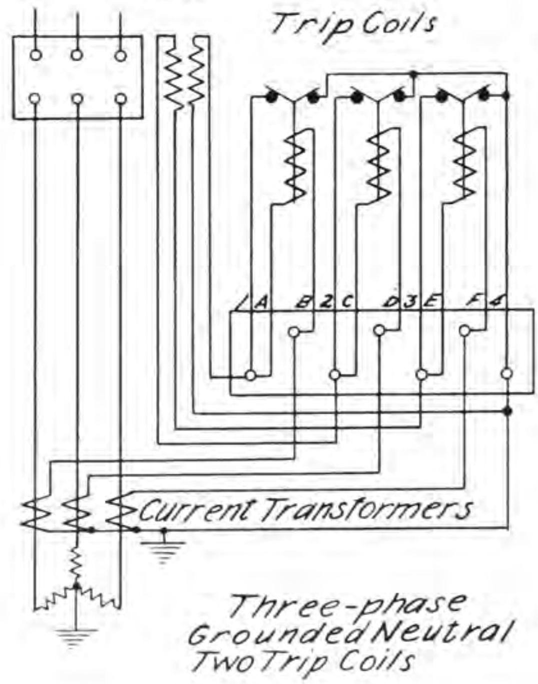


Fig. 18

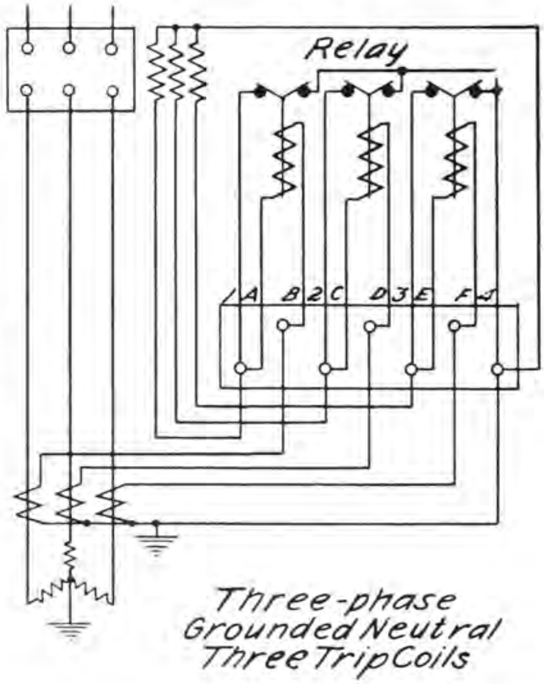


Fig. 19

CONNECTIONS OF RELAYS USED WITH K-12 OIL BREAK SWITCHES

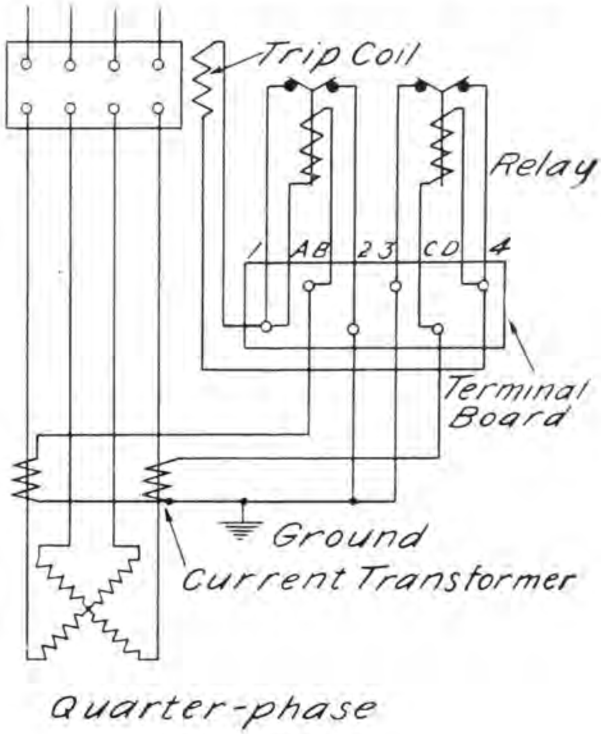


Fig. 20

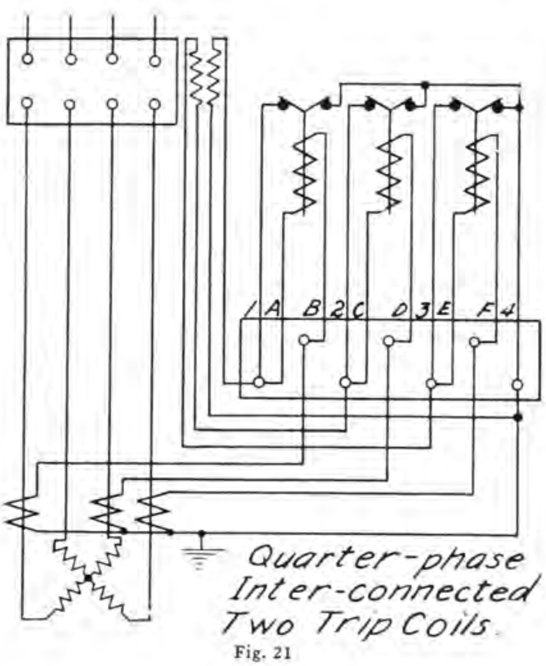


Fig. 21

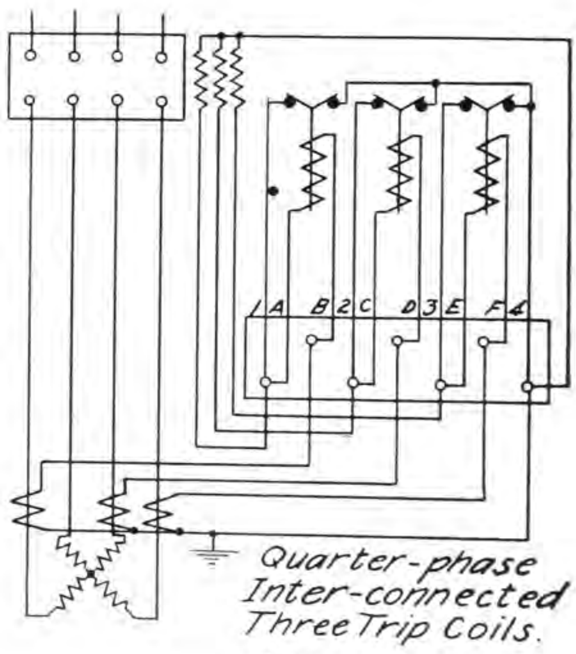


Fig. 22

CONNECTIONS OF RELAYS USED WITH K-12 OIL BREAK SWITCHES

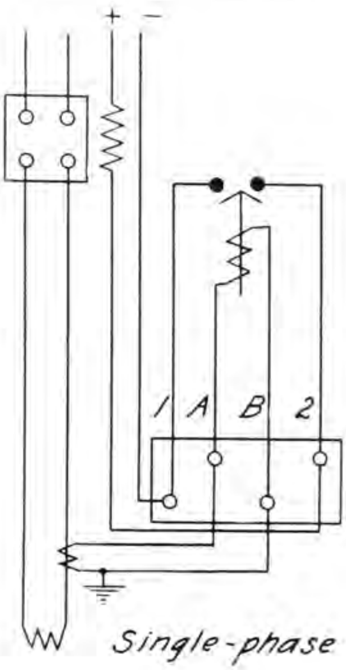


Fig. 23

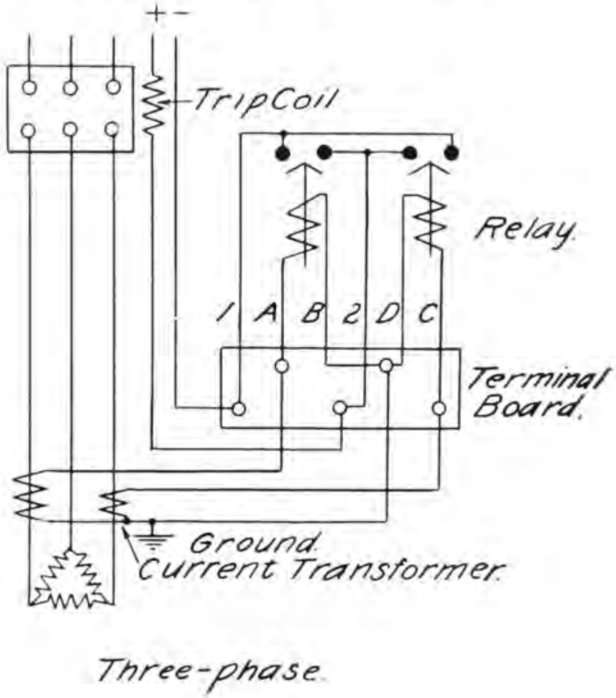


Fig. 24

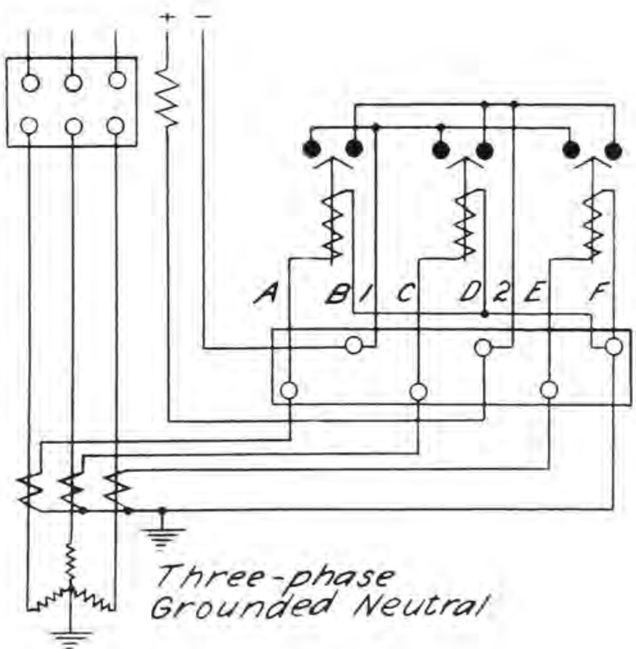


Fig. 25

CONNECTIONS OF RELAYS USED WITH K-12 OIL BREAK SWITCHES

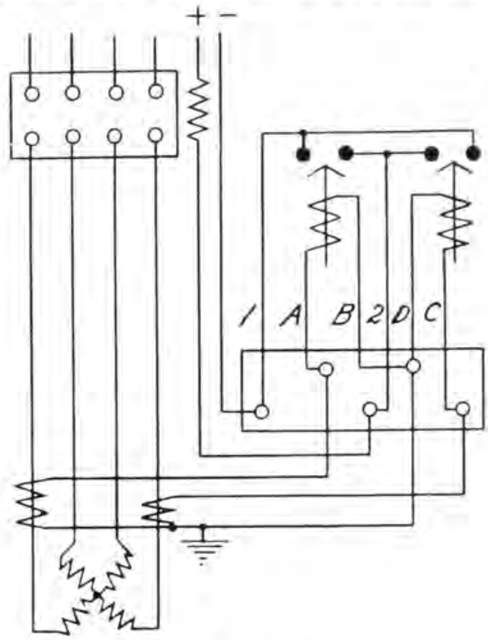


Fig. 26

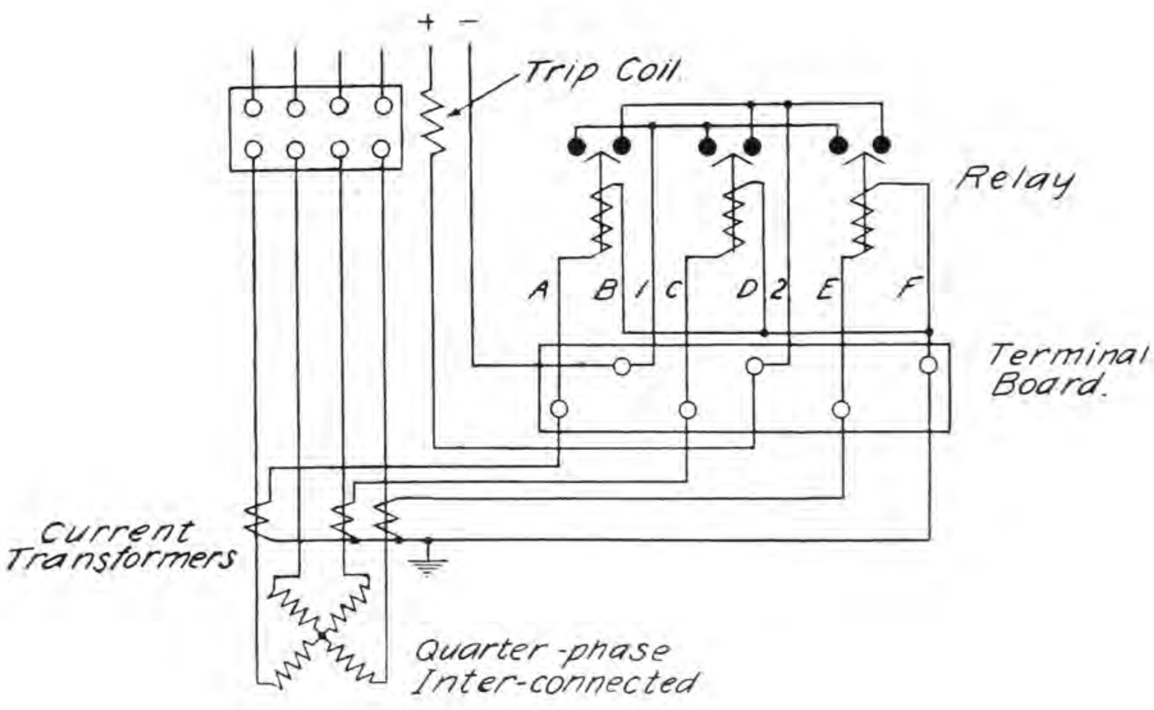


Fig. 27

CONNECTIONS OF DIRECT CURRENT CONTROL CIRCUITS

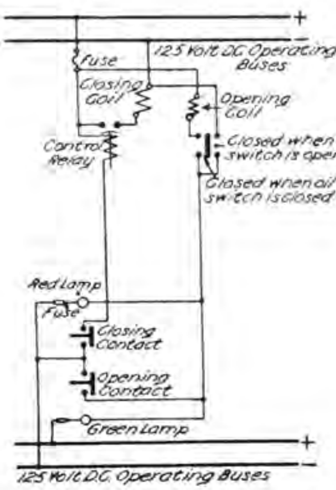


Fig. 28
125 VOLTS FOR SOLENOID-OPERATED SWITCH

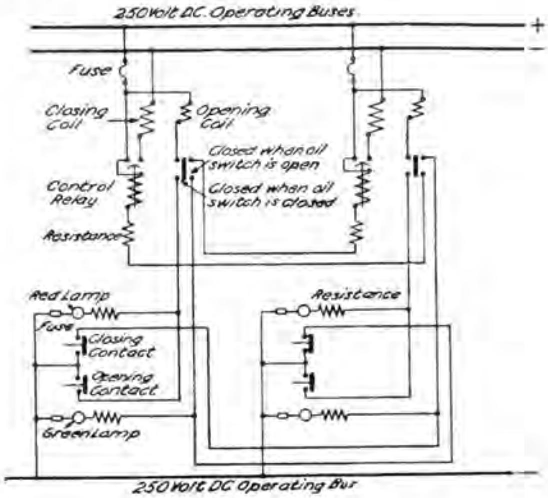


Fig. 29
250 VOLTS FOR TWO INTERLOCKED SOLENOID-OPERATED SWITCHES

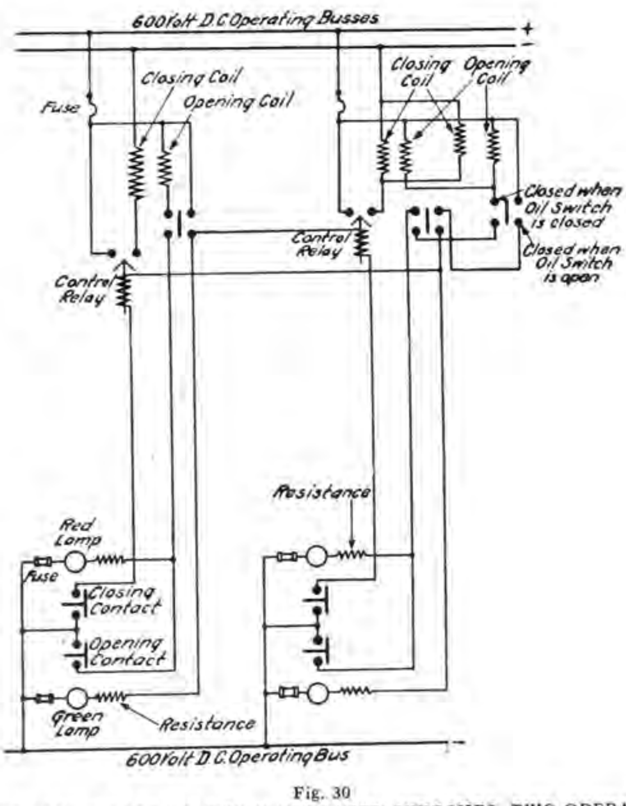


Fig. 30
600 VOLTS FOR THREE SOLENOID-OPERATED SWITCHES, TWO OPERATED BY ONE CONTROL SWITCH AND INTERLOCKED WITH THE THIRD

VARIOUS ARRANGEMENTS OF FORM K-12 OIL BREAK SWITCHES

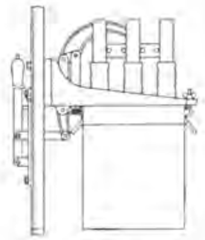


Fig. 31
SWITCH ON PANEL

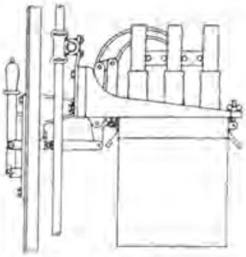


Fig. 32
SWITCH ON PANEL PIPES

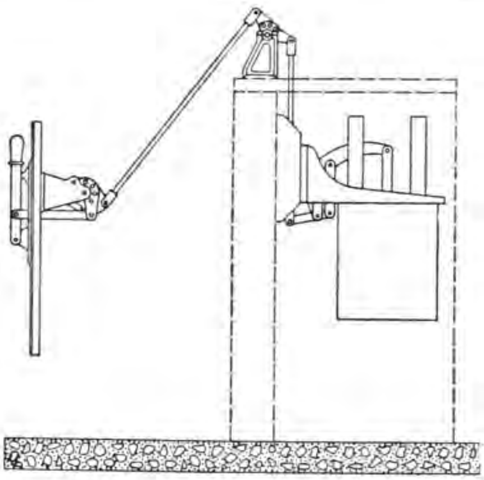


Fig. 33
SWITCH IN CELL DIRECTLY BEHIND PANEL

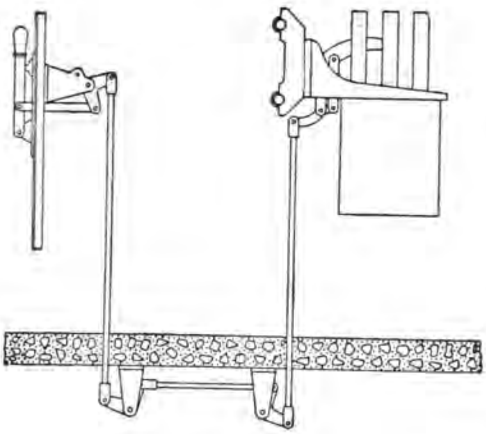


Fig. 34
SWITCH ON PIPE FRAMEWORK

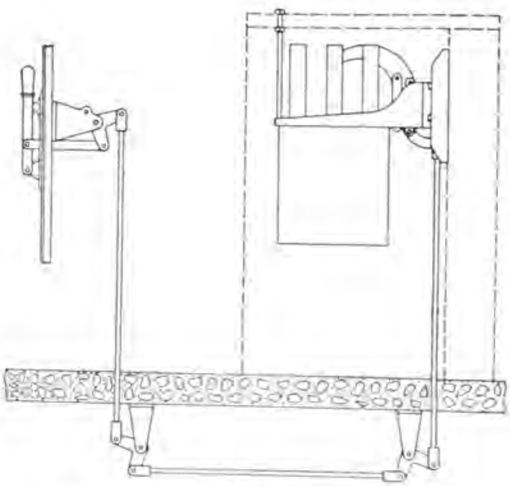


Fig. 35
SWITCH IN CELL REMOTE FROM PANEL

DIMENSIONS OF TYPE F, FORM K-12 OIL BREAK SWITCHES

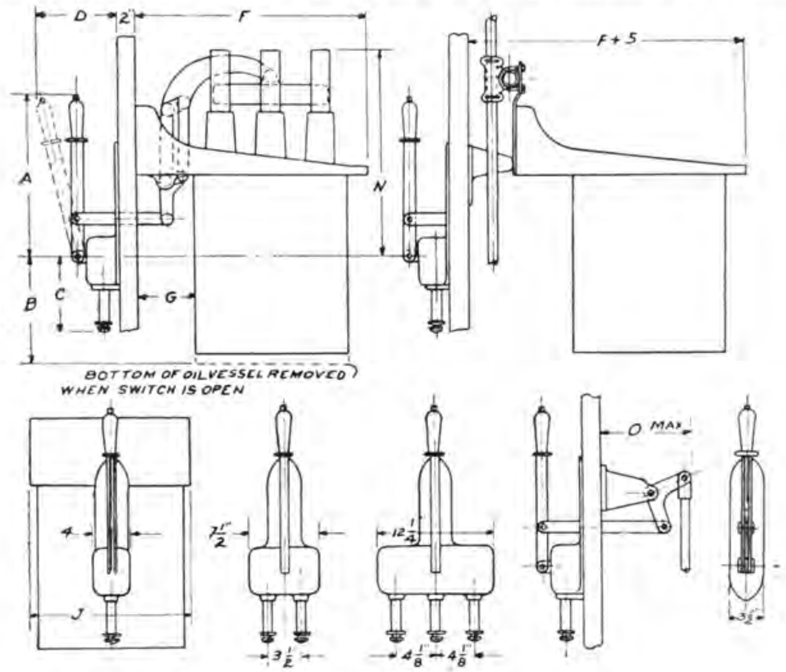


Fig. 36

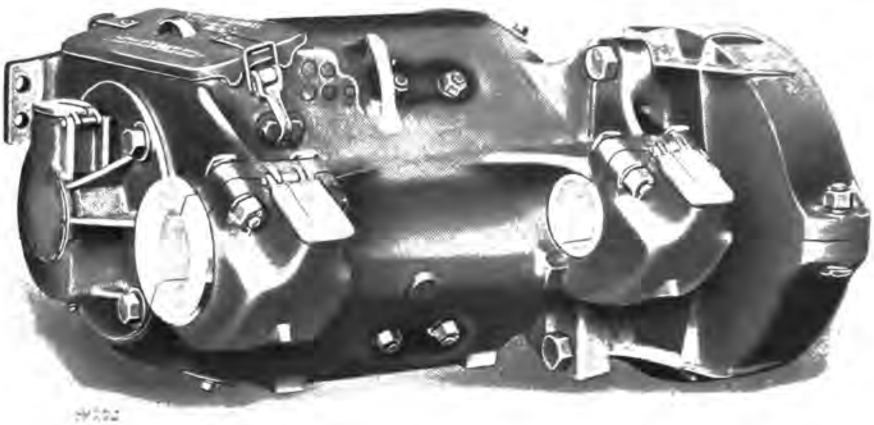
Pole and Throw	Amp.	ALL DIMENSIONS IN INCHES									
		A	B	C	D Automatic	D Non-automatic	F	G	J	N	O
S.P.S.T.	300	17	26⅞	8	12¾	12¾	23¾	6¼	9¼	23⅜	11¾
D.P.S.T.	300	17	28 7/16	8	12¾	12¾	24 3/16	6 3/32	17	22 13/16	11¾
T.P.S.T.	300	17	28 7/16	8	12¾	12¾	24 3/16	6 3/32	17	22 13/16	11¾
4 P.S.T.	300	17	28¼	8	11⅛	11⅛	30½	7¼	17	22	11¾
S.P.S.T.	500	17	26⅞	8	12¾	12¾	23¾	6¼	9¼	25½	11¾
D.P.S.T.	500	17	28 7/16	8	12¾	12¾	24 3/16	6 3/32	17	23 15/16	11¾
T.P.S.T.	500	17	28 7/16	8	12¾	12¾	24 3/16	6 3/32	17	23 15/16	11¾
4 P.S.T.	500	17	28¼	8	11⅛	11⅛	30½	7¼	17	24⅛	11¾
S.P.S.T.	800	17	26⅞	8	12 5/16	12 5/16	25	6 11/16	9¼	25 21/32	11¾
D.P.S.T.	800	17	28 7/16	8	12 5/16	12 5/16	25 9/16	6 3/32	17	24 3/32	11¾
T.P.S.T.	800	17	28 7/16	8	12 5/16	12 5/16	25 9/16	6 3/32	17	24 3/32	11¾
4 P.S.T.	800	17	28 7/16	8	11⅛	11⅛	31 13/16	6 27/32	17	24 3/32	11¾

General Electric Company
Schenectady, N.Y.

April, 1911 Bulletin No. 4822

GE-98 RAILWAY MOTORS

One of the most recent additions to the already large list of standard General Electric railway motors is the GE-98 motor which is rated at 50 h.p. when operating at 500 volts. This motor has been designed to meet the demands of heavy city and suburban service and is suitable for either two or four motor equipments.



GE-98-A RAILWAY MOTOR. AXLE SIDE

The frame is made in two styles. The Form A and the Form B. The former is a box frame and the latter is a split frame designed to open downward.

MAGNET FRAME

Form A

The box frame of the Form A motor is made of steel cast in one piece and is approximately octagonal in form. Bored openings are provided at each end of the frame which are of such size as to permit the armature, pole pieces and field coils being inserted or removed. The frame heads carry the armature shaft bearings and are supported in the recessed ends of the magnet frame. These ends are held in place by securely locked cap bolts, and each is provided with two tapped holes diametrically opposite to each other so that the frame head can be forced off by screwing two bolts into these holes. The axle bearing caps are tongued and bolted to machined surfaces which are inclined at an angle of 60 degrees from the horizontal. The seats for the pole pieces are machine finished.

Form B

The Form B frame is split horizontally with the suspension brackets on the top half so that the lower portion may be swung downward, but otherwise the shape is in general similar to the Form A frame. The armature bearing housings are of the solid head type in every way equal to those of the

NOTE.—The data in this publication are for the convenience of customers, and every effort is made to avoid error, but this Company does not guarantee their correctness, nor does it hold itself responsible for any errors or omissions in this publication. Subject to change without notice.

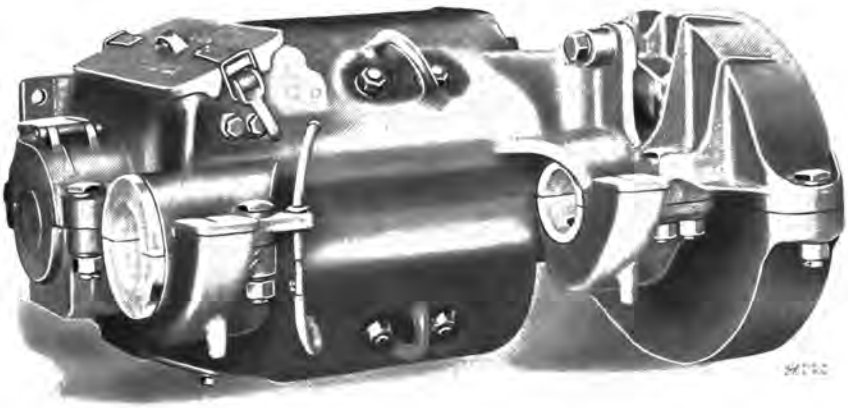
standard box frame, and the lubrication is equally good.

Each housing is secured to the upper frame by four bolts. By the removal of these bolts, and the lower half of the gear case, the armature can be lowered into a pit. The upper and lower portions of the frame casting are provided with machined surfaces which surround the bearing housing and prevent the armature from dropping on the lower pole pieces in case the housing bolts become loosened. The axle bearing caps are bolted to the top half of the frame.

in place under spring tension, and as no part of the locking device projects above the top of the cover it is not easily broken or knocked off. Reference to the illustrations will make the construction clear.

In addition to this opening there are three others, all having malleable iron covers fitted with gaskets so located as to provide for the proper inspection of the interior of the motor.

The armature and field leads are brought through rubber bushed holes on either the axle or suspension side as desired.



GE-98-B RAILWAY MOTOR. AXLE SIDE

The features which are common to both the Form A and Form B frames are as follows:

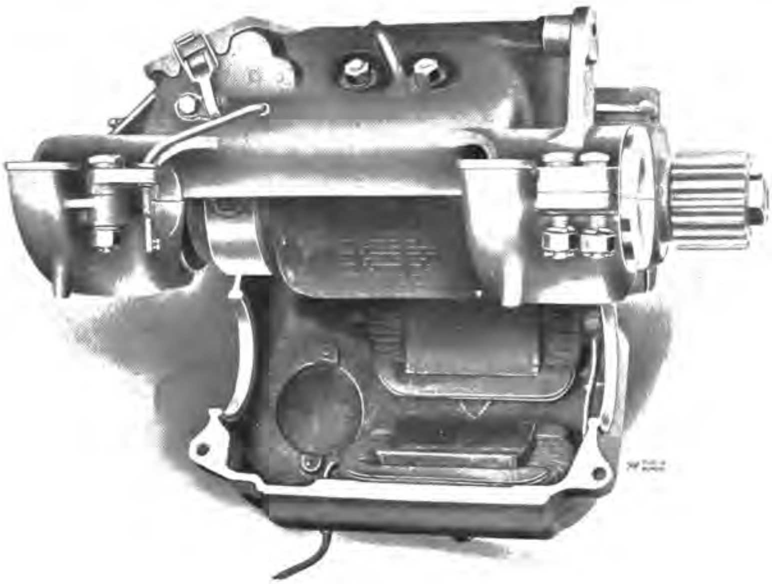
Bails are provided at convenient points for handling the motors.

A large opening inclined at a slight angle is provided over the commutator to facilitate inspection.

The malleable iron cover for this opening rests on a gasket and is held in place by a flat steel spring riveted to each end, which projects a little beyond the cover. The cover is fastened down by pushing one of the springs through a staple on the front side of the motor, after which the other spring is forced down and clamped in position by a link attached to a cam-locking device. This method of fastening the cover holds it firmly

BEARINGS AND LUBRICATION

The armature shaft bearings are provided with sleeves of malleable iron which are finished all over and lined with babbitt metal, the babbitt being securely anchored in place. These sleeves are prevented from turning in their housings by means of keys. In both the axle and armature bearings the oily waste is packed in large oil wells and presses on the shaft through openings provided in the low pressure side of the bearing linings. Any waste oil from the armature shaft bearing is prevented from entering the interior of the motor by oil deflectors which, by centrifugal force throws it into grooves from which it is conducted away. This form of bearing has been found to be thoroughly satisfactory as it is both simple and reliable. The oil boxes are reached through large handholes protected by swinging covers fitted with felt gaskets resting on finished seats. The covers are held in place by strong springs. While the oil pockets are of liberal design, the quantity of lubricating oil necessary is exceedingly small and consequently the attention required is reduced to a minumum.



GE-98-B RAILWAY MOTOR. FRAME LOWERED FOR INSPECTION

Another fact which greatly reduces the amount of inspection and maintenance required, is the liberal size of the bearings—the armature shaft bearing is 3 in. in diameter and 7½ in. in length at the commutator end, and is 3½ in. in diameter and 9 in. long at the pinion end. The linings on each end are made in one piece. The axle bearing linings are 9 in. long and are made of malleable iron and babbitt metal for all axles up to 5 in. in diameter.

FIELD COILS

The field coils are wound with standard asbestos and cotton covered wire. After the coils are wound they receive a wrapping of cotton tape and are well filled with an insulating compound by the vacuum process, after which they are thoroughly insulated with several wrappings of specially prepared tape and as a final protection, chiefly from mechanical injury, they are taped again with heavy cotton webbing and filled with japan. The field coils rest on pressed steel supports and are held in position by spring flanges which clamp the coil securely between the support and the pole piece projections. This construction eliminates the necessity of using canvas field coil pads and also insures the coil being held firmly in position without danger of abrasion.

ARMATURE

The armature core is built up of soft iron laminations and air ducts are provided at suitable intervals to insure good ventilation. The laminations are mounted directly upon and keyed to the armature shaft in such a way that the shaft may be removed from the armature without disturbing either the windings or the commutator connections. The commutator itself is mounted upon an extended hub on the front core head. The shaft is removed by inserting bolts through the rear core head and screwing them into tapped holes on the inside of the front head; these bolts securely hold the entire structure together while the shaft is being replaced. This form of construction eliminates the necessity of using a solid spider and thus improves ventilation and otherwise increases the service capacity.

The armature coils are form wound with insulation between the adjacent coils and afterward the formed coil is pressed into shape in a steam mould. The coils are then covered with insulating material of a high quality and as an additional protection, chiefly against mechanical injury, they are taped and finally filled with an insulating compound. This form of coil construction provides an excellent protection against dust, oil or mechanical injury. The core head at the pinion end extends under the end windings and it is provided with a flange which reaches up past the ends of the coils. The windings at both ends of the armature are covered with a strong canvas dressing securely bound in place. The binding bands are not allowed to project above the armature core, and the ends of the binding wires are secured by means independent of solder.

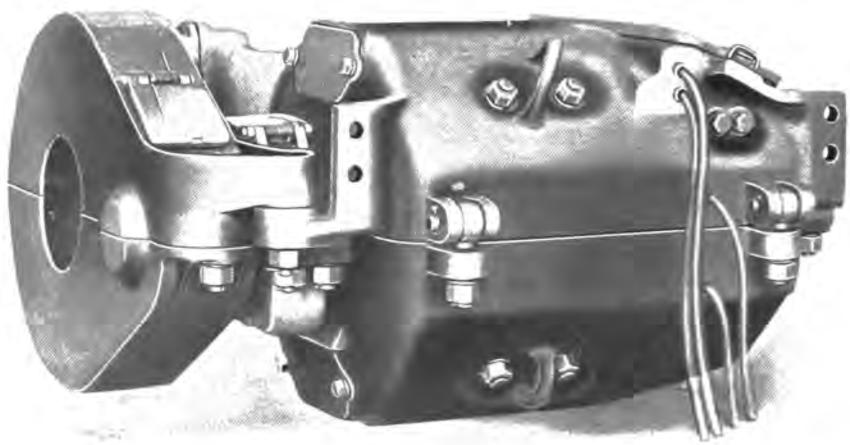
COMMUTATOR

The commutator segments are standard, that is to say, they are made of hard drawn copper bars insulated throughout with the best grade of mica. The commutator cones are built up of mica and are pressed to a compact form in steam moulds. It should be noted that the mica between the segments is made of such softness as to wear down evenly with the copper. The utmost mechanical skill is employed in the construction of the commutator; the cone surfaces being carefully machined and cleaned from burs and any sharp edges that would cause a short circuit between the segments. The creepage distances are made large to prevent grounding.

The shell and cap are made of cast steel of ample sections to guard against breakage and keep the shape of the commutator true. Before the commutator nut is tightened the segments are clamped by the cap which is pressed home by hydraulic pressure. The good commutation and the generous depth of segments provided insure a long life for the commutator.

BRUSH-HOLDERS

The brush-holders, which are made of cast bronze are designed to take two brushes per



GE-98-B RAILWAY MOTOR. SUSPENSION SIDE

holder. The brushes slide in finished ways and each is pressed against the commutator by an independent finger which gives a practically uniform pressure throughout the working range of the brushes. The design is such that the springs actuating the fingers bring but a slight pressure to bear on the pins on which the fingers turn. This eliminates the tendency of the fingers to stick on the pins and it also reduces the wear to a minimum.

The brush-holders are clamped to supports which are bolted to the magnet frame by mica insulated studs. The brush-holders slide in finished ways on these supports to afford a means of adjustment to accommodate commutator wear. The cable leads are connected to these supports so that the brush-holders can be removed without in any way disturbing the connections.

VENTILATION

Particular attention has been paid to the thorough ventilation of these motors. The field windings are well distributed, giving a large exposed area of radiation and the armature acts like a strong centrifugal blower keeping the air in the motor well agitated. The ventilation is secured without sacrificing in any way the proper protection of the armature windings, a strong point in the construction of the motor.

GEAR, PINIONS AND GEAR CASE

The gears are made of a superior grade of cast steel and the pinions from a special stock of forged steel which is tempered after cutting. The gears have a 5 in. face and the teeth are accurately cut to a 3 pitch. The gear case is made of malleable iron and is suspended from the magnet frame at three points to prevent vibration. Strengthening ribs radiate from the supporting points to prevent the case from cracking. The case is bolted to the motor frame in such a way as to minimize lateral vibration, and the contact surfaces between the case and frame are made amply large to prevent undue wear.

PARTS OF GE-98-B RAILWAY MOTOR

ADVANTAGES

The GE-98 motor, as a type possesses a number of advantages, some of which may be briefly summarized as follows:

The bearings employed have excellent lubricating qualities which prolong their life and reduce the cost of maintenance and cost of lubrication to a marked degree.

All bolts for the frame, caps and gear case are easily accessible from a pit.

The armature is easily removed.

The shaft can be removed without disturbing the commutator or windings.

An improved form of commutator cover fastener is used.

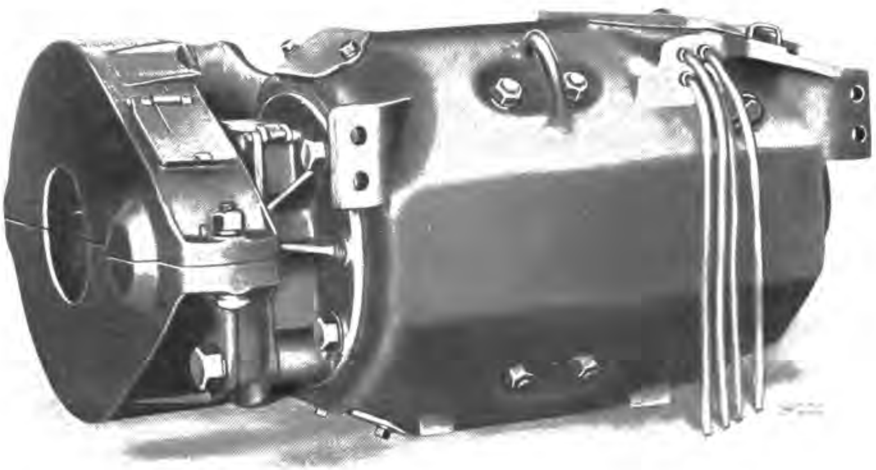
The gear case has three points of suspension, thus reducing the vibration and consequent danger of breaking the case.

The various parts of the motor are made exceptionally strong and substantial. The large bearing surfaces, size of bearings, width of gear face, size of bolts, etc., and the attention paid to small details of construction should be noted.

Attention is also called to the following points in this motor, which will commend it to all practical users of this class of apparatus:

This method of rating has been in use for a number of years, and while not necessarily giving an exact measure of the capacity of a motor to perform all classes of service, is convenient and well understood, and conveys a sufficiently close idea of the relative sizes of motors for general use.

A test is made on the motors at rated load, and all motors are also thoroughly tested for commutation and behavior of bearings, brush-holders, etc.



GE-98-A RAILWAY MOTOR. SUSPENSION SIDE

Good commutation and high efficiency.

Low iron and copper losses.

Superior brush-holder design and construction.

A large commutator with deep segments.

High class of insulation thoroughly protected from mechanical injury.

RATING

The capacity of the GE-98 motor for continuous service is high, owing to its good electrical efficiency and ventilation, and the motor is rated at 50 h.p. This rating based on a temperature rise by thermometer of not more than 75 degrees C. above the surrounding air after one hour's run at 500 volts at rated load, the temperature of the surrounding air not exceeding 25 degrees C.

The predetermination of the capacity of a motor to perform a given service is a problem, the solution of which necessitates a complete knowledge of the mechanical, electrical and thermal characteristics. It is possible to calculate the losses in a motor performing any specified service, but the only way of determining how hot a motor will run is by reference to actual tests of the motor under the same or similar service conditions.

The heating of a given motor in service manifestly depends entirely on the character of the service, and consequently no reliable estimate can be made of the necessary capacity or characteristics of the motor for successful operation without a complete knowledge of the operating conditions. The weight of the car or train, schedule speed, location, number and duration of stops, profile and plan of road, and voltage are necessary for a complete and careful analysis of the problem.

In order to obtain full information on these questions, the General Electric Company besides carefully testing each type of motor for efficiency, I^2R, core and friction losses, speed and commutation, etc., at various voltages and amperes, also makes exhaustive tests to determine the capacity of the motor for heat dissipation under operating conditions. For this purpose motors are put into

As the power required to operate an equipment affects not only the heating of the motors, but also the total amount and cost of power for operating the road, careful calculations are made to determine the most suitable characteristics of a motor for a given service and the most economical gear ratio to use. The possibilities of saving power by the careful design and proper selection of the gear ratio are much greater than ordinarily appreciated.

A table which is based on tests, such as has been described above, will be found on page 10 showing schedule speeds for various

PARTS OF GE-98-A RAILWAY MOTOR

actual service on the company's experimental track (more than two miles in length) and are run day after day under a wide range of known service conditions, careful temperature measurements being taken until sufficient data are obtained to show what temperature different parts of the motor will reach, not only with various total losses, but also with different distributions of these losses.

From the data obtained in the above tests, which cover all the characteristics of a given type of motor, the company's engineers possess all the information required to determine with practical certainty, the adaptability of the motor to handle any specified service, and the problem has become not a matter of guesswork, but of calculation.

gear ratios with varying number of stops per mile and different weights per motor. This table has been prepared to enable customers to determine quickly and with considerable accuracy the capacity of the GE-98 motor to handle cars or trains under ordinary service conditions, and it will also be found useful for laying out operating schedules.

As the reputation of the General Electric Company's motors and the interests of its customers are affected by the proper selection of motors for any given service, the General Electric Company desires to aid and co-operate with customers in selecting motors best adapted for their service. For this purpose, blank service data sheets are furnished, which are of assistance to show the character of the service it is desired to operate. The General Electric Company's great experience enables it to render valuable assistance in this class of work, and long experience has shown that co-operation is mutually beneficial.

The blank form shown on page 17 will be gladly furnished to prospective customers.

Speed torque and efficiency curves for the GE-98 motor, with various gear ratios corresponding to the gear ratios given in the table, will be found on pages 11 to 14. These curves are convenient for general reference.

The diagrams of the motor on pages 15 and 16 which show the external dimensions and axle preparation, will enable truck builders and car manufacturers to adapt their trucks and cars for the proper reception of the motor.

The table on page 10 giving the estimated schedule speeds in miles per hour for the GE-98 motor is calculated on the basis of a 500 volt pressure at the motor terminals.

The duration of each stop has been taken as 10 seconds.

The maximum temperature rise of the motors above the surrounding air has been taken as not more than 65 degrees C. with the motors closed, this temperature being based on the operation of motors under average normal conditions. Though the temperature rise will not usually exceed the estimate of 65 degrees C., it should be noted that this temperature rise cannot be guaranteed, as motor temperatures depend on the manner in which motormen handle the equipments.

Since there may be services for which it is advisable to use series running in cities and multiple running outside, it sometimes happens that a heavier car than is indicated in the table can be handled by a given equipment, or that a higher speed gearing can be used for a given weight of car. Further, motors with high speed gears may be able to handle heavier cars than indicated in the table, in city service where the stops are frequent, without the temperature rise exceeding 65 degrees C., provided a sufficiently large part of the whole run is suburban or interurban, where but few stops are made. It is of importance when taking advantage of these points to furnish full information to the General Electric Company for complete analysis.

When applying the tables to services requiring two or more different schedules, such as a city service with many stops per mile combined with a suburban or interurban service with but few stops per mile, the schedule for each class of service should be taken separately and a resulting schedule for the combined service obtained.

The schedule speeds given in the table are based on the operation of motors under favorable conditions, and are 10 per cent. below the theoretical schedule speeds, in order to allow for the normal delays due to curves, grades, slowdowns, etc.; in other words it is assumed that the delays due to these causes will equal six minutes in every hour. If this allowance is considered insufficient, due to special local conditions, the schedule should be reduced 1.84 per cent. for each additional minute of delay. The improper handling of the cars or excessive track or car friction may also reduce the schedule, and this will also be the case if, in addition to the regular stops, there is an unusual number of slowdowns, curves or grades. If curves and grades are numerous or excessive, or the conditions are special or abnormal and an extensive analysis is necessary, complete information should be furnished to the General Electric Company before deciding on the motor equipment to be used.

The schedule speeds given in the table should be decreased by the percentages given below for any voltages below 500. For each one per cent. reduction in the voltage, there will be approximately the following reduction in the schedule:

1 stop per mile . . .	0.5 per cent.
3 stops per mile . . .	0.2 per cent.
7 stops per mile . . .	0.1 per cent.

Where the voltage is greater than 500, the schedule may be increased by approximately the same per cent. as it is decreased for a reduction of voltage. It should, however, be borne in mind that there will be an increase in temperature at the higher voltages and schedules. Nevertheless, as there will be somewhat less heating of the motors at a lower voltage and schedule, it is permissible to increase the schedule in parts of the line by increasing the voltage, provided there is a corresponding decrease in the voltage on the other portions.

As the number of stops per mile increases, the schedules that can be made with the same car weights, but with different speed gears, become nearly equal.

When the same schedule is made with different speed gears, the heating of the motors is less with the low speed than with the high speed gear.

Under ordinary service conditions the watt-hours per ton mile for a given schedule are less with a low than with a high speed gear. Therefore, in order to operate with the lowest power consumption and also with the minimum heating of the motors, the lowest speed gear, that is, the highest gear ratio which will make the required schedule, is generally best suited for the given service.

The maximum speeds given in the table are approximately free running speeds on the level under favorable conditions. Excessive track or car friction or head winds will affect the speed.

The tractive effort is taken at 16 lb. to 25 lb. per ton, depending on the speed and weight of the car. An examination of the motor curves will show the tractive effort assumed for the various speeds.

In determining "tons per motor" the total weight of the car or train, including the load, motors, controllers, rheostats, etc., divided by the number of motors, should be taken.

In ordinary service the average and not the maximum load should be taken. The average passenger load may be represented by the seating capacity and the average weight per passenger can be assumed to be 140 lb. If the cars carry a maximum load for a large part of the time, the maximum and not the average load should be taken.

The tables do not apply when the motors are used for electric brakes, as the heating of the motors is increased thereby.

APPROXIMATE NET WEIGHT IN POUNDS

	GE-98-A	GE-98-B
Motor complete with gear, gear case and pinion . . .	3310	3290
Double motor equipment complete with two K-36 controllers	7855	7815
Four motor equipment complete with two K-35 controllers .	14910	14830
Four motor equipment complete with Sprague-General Electric control	15865	15785

GEAR RATIOS, CHARACTERISTIC CURVES, ETC.

Gear ratios with characteristic letters and numerals corresponding with three turn armatures and 93.5 turn fields are as follows:

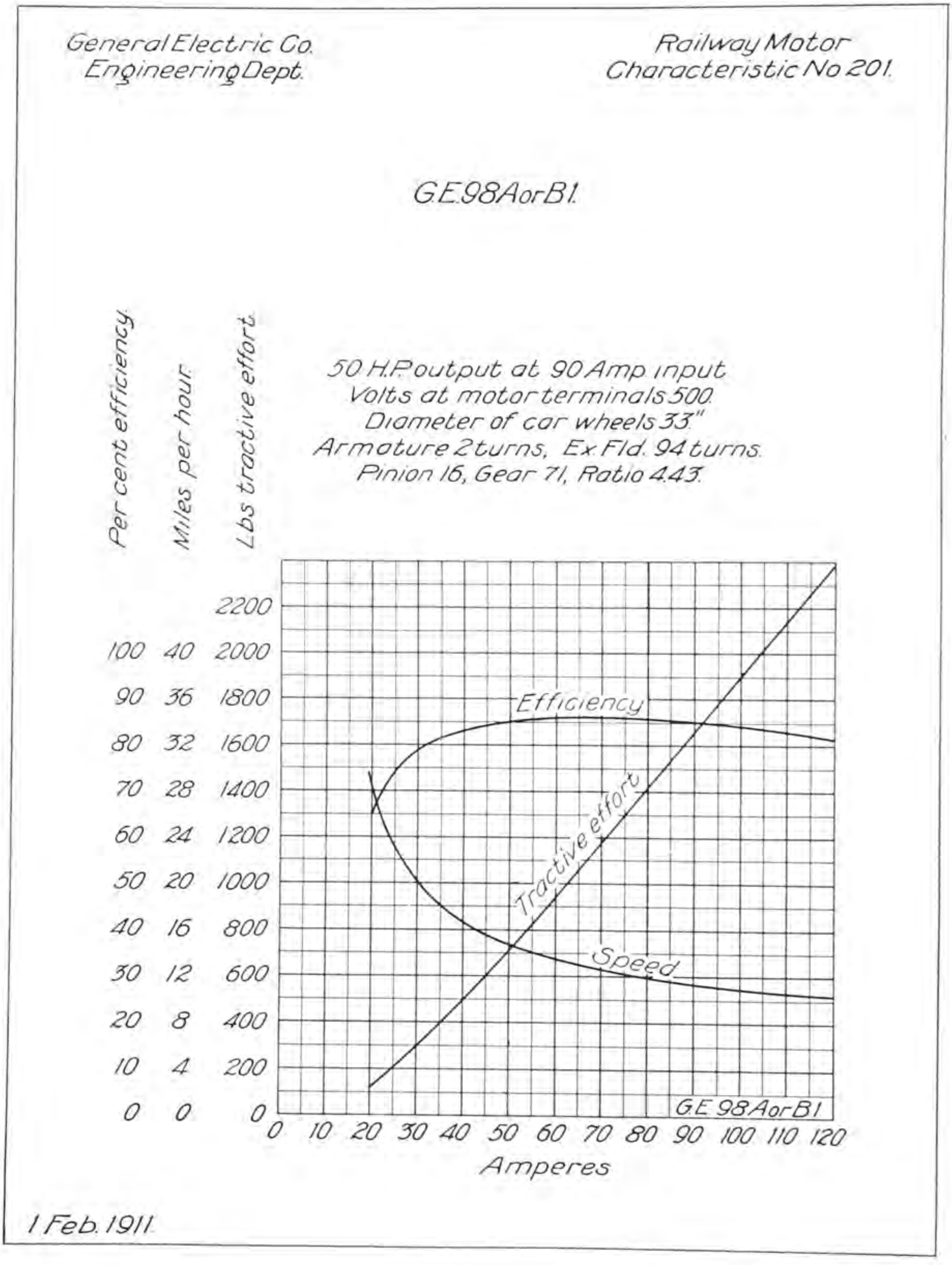
Pinion	Gear	Gear Ratio	Classification	Characteristic No.
16	71	4.43	GE-98-A-1	201
18	69	3.83	GE-98-A-2	202
20	67	3.35	GE-98-A-3	203
24	63	2.62	GE-98-A-4	204

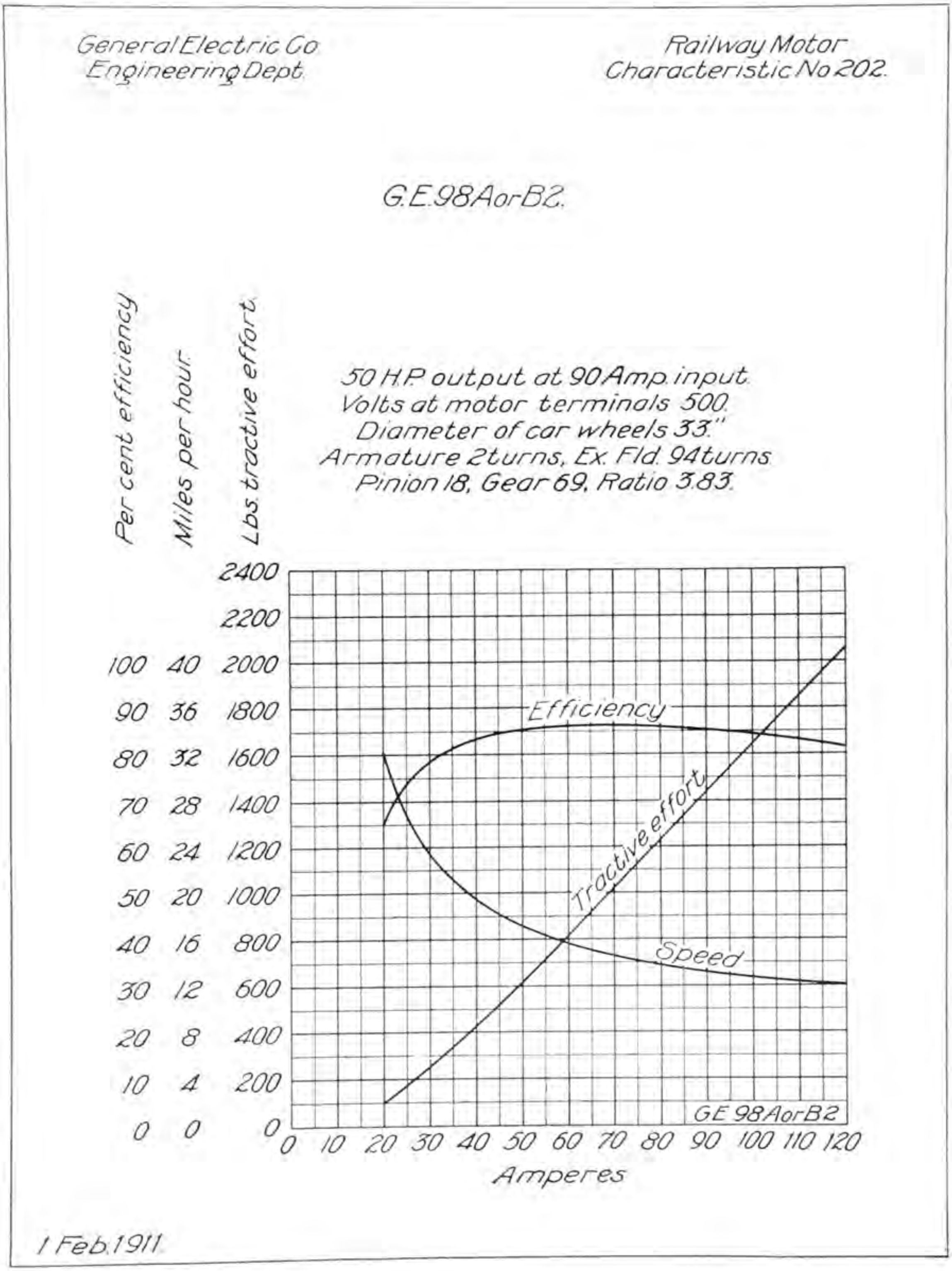
SCHEDULE SPEED GE-98 MOTOR IN MILES PER HOUR

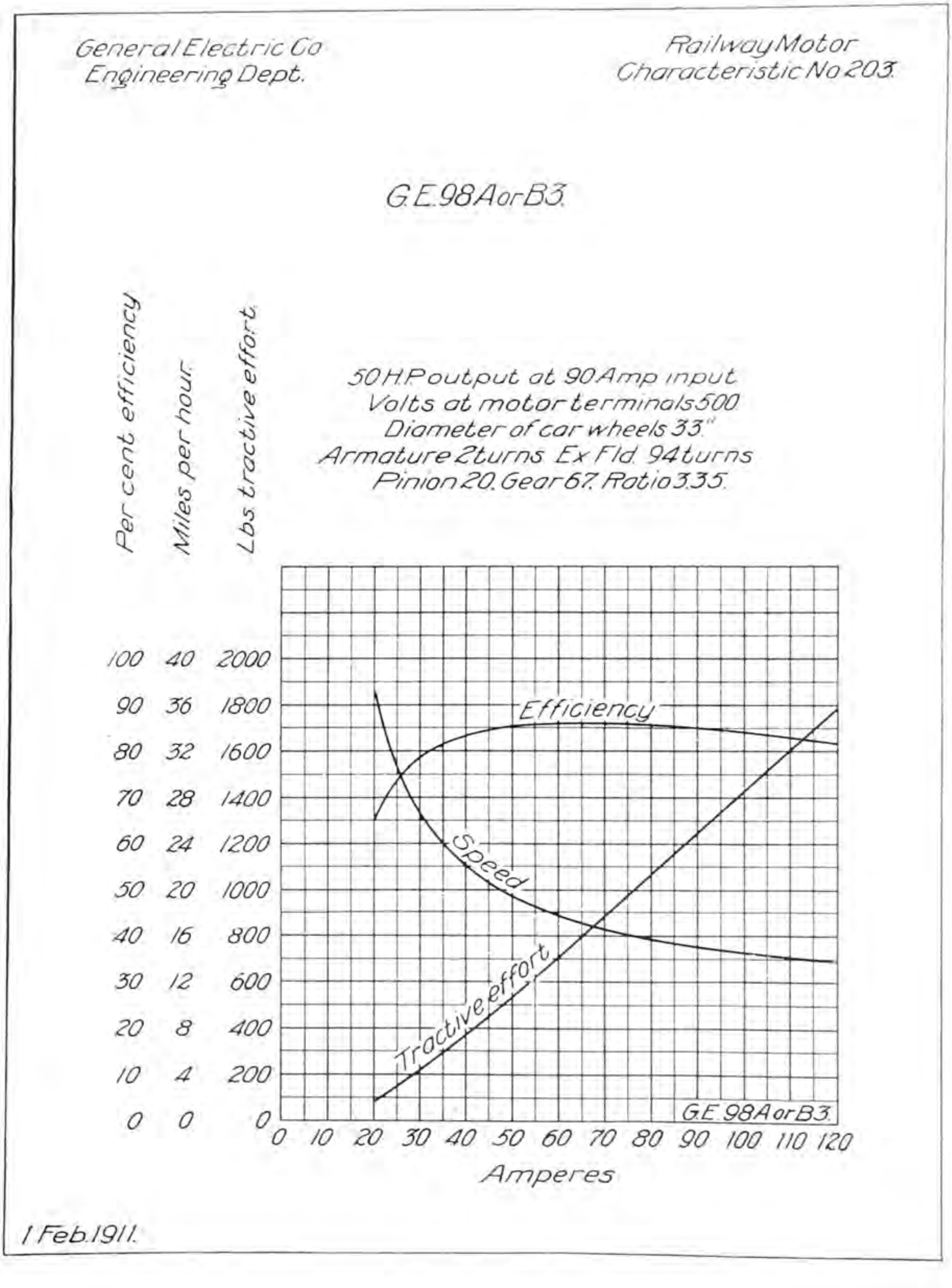
ARMATURE 2 TURNS, FIELD 93.5 TURNS, 500 VOLTS, 33 IN. WHEELS

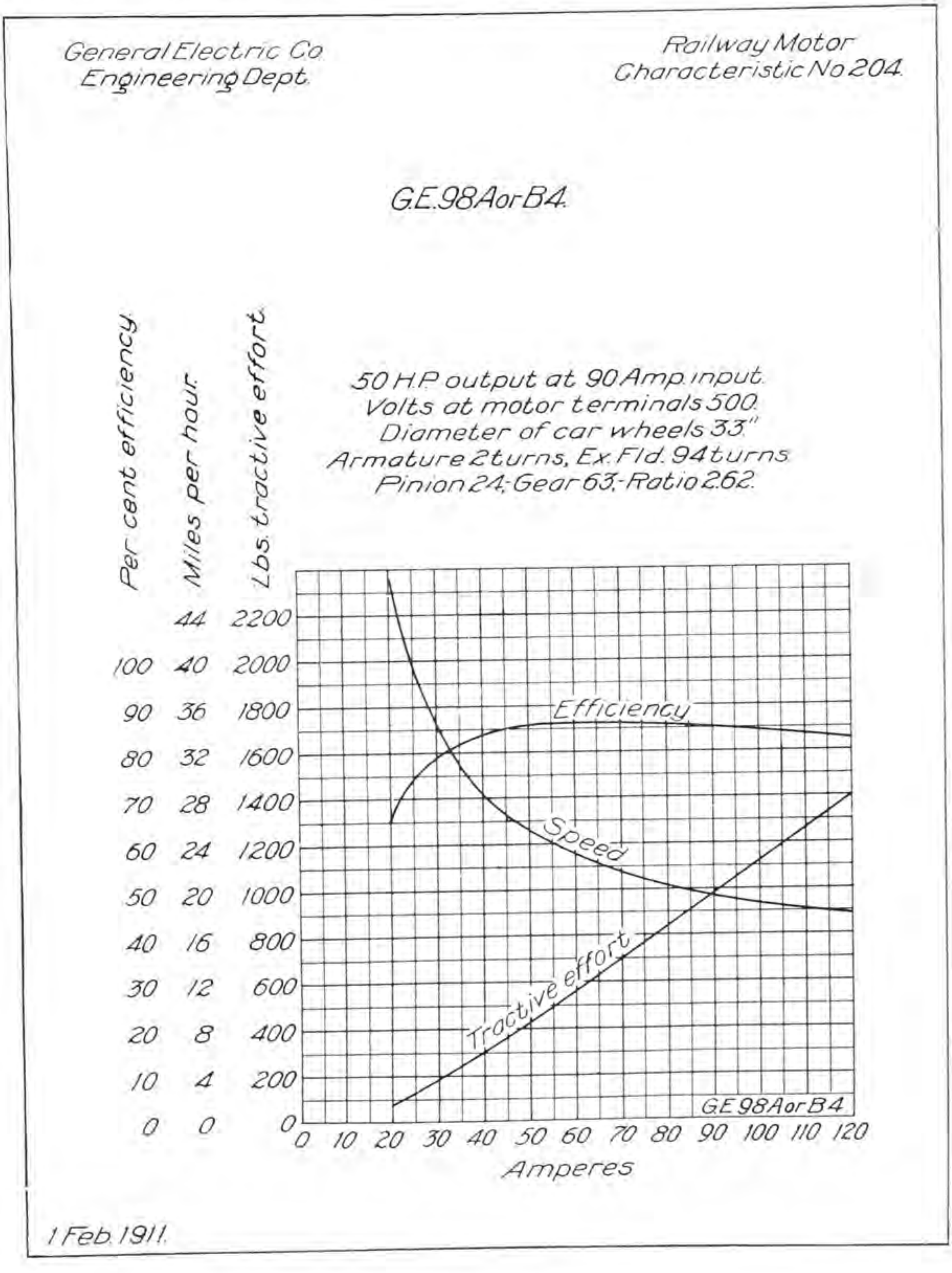
Read Bulletin carefully before applying tables.

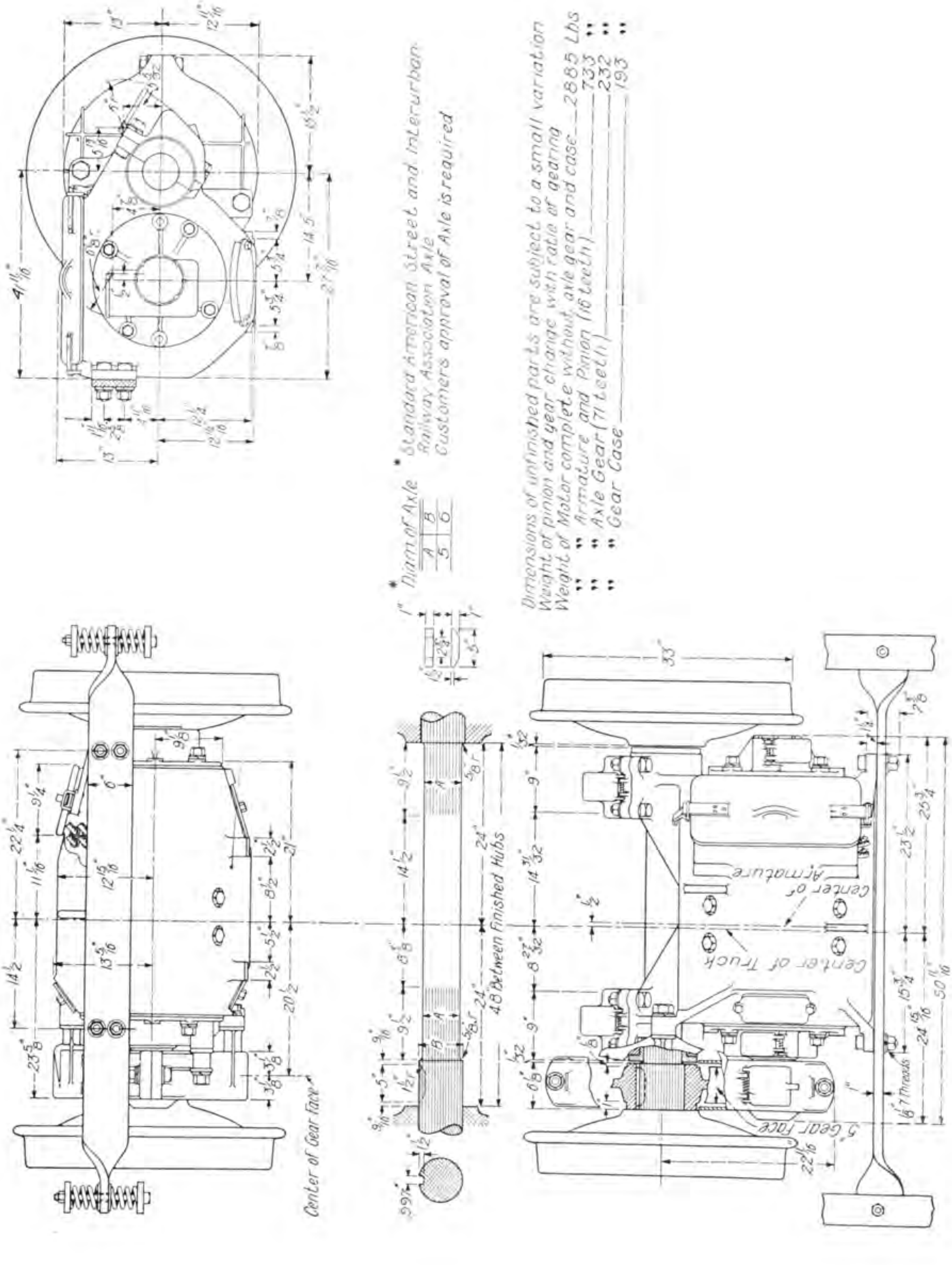
Stops per Mile	Gear Ratio	TONS PER MOTOR									
		5.5	6	6.5	7	8	9	10	11	12	13
½	4.43	22.5	22.2	21.7	21.2	19.9	19.4	18.7	18.1	17.7	17.2
½	3.83	24.1	23.8	23.3	22.8	21.9	21	20.4	19.7	19.2	18.8
½	3.35	25.2	24.9	24.5	24	23	22.2	21.6	21.1	....	....
½	2.62	27.1	26.8	26.5	26.1	25.1	24.4	....	....	....	....
1	4.43	19.6	19.3	19	18.7	17.9	17.5	16.9	16.5	16.2	15.7
1	3 83	20.7	20.4	20.2	19.9	19.2	18.5	18.2	17.7	17.3	....
1	3.35	21.6	21.3	21.1	20.8	20.1	19.5	19.1	....	....	....
1	2.62	23.2	22.9	22.6	22.2	21.5	....	....	....	....	....
2	4.43	16.1	15.9	15.8	15.7	15.1	14.75	14.4	14.1	13.8	13.5
2	3.83	16.7	16.5	16.35	16.2	15.75	15.4	15.1	....	....	....
2	3.35	17.3	17.1	16.9	16.7	16.5	16.2	....	....	....	....
2	2.62	18.1	17.9	....	....	....	....	....	....	....	....
3	4.43	13.9	13.8	13.75	13.7	13.15	12.9	12.7	12.5	12.2	12
3	3.83	14.3	14.2	14.10	14	13.6	13.3	13.1	....	....	....
3	3.35	14.7	14.6	14.45	14.3	14.1	....	....	....	....	....
3	2.62	15.2	15.1	....	....	....	....	....	....	....	....
4	4.43	12.3	12.2	12.2	12.2	11.75	11.5	11.4	11.2	11	....
4	3.83	12.7	12.6	12.5	12.4	12 1	11.8	11.7	....	....	....
4	3.35	12.9	12.8	12.7	12.6	12.5	....	....	....	....	....
4	2.62	13.3	13.2	....	....	....	....	....	....	....	....
5	4.43	11.2	11.1	11.1	11.1	10.7	10.5	10.4	10.2	10	....
5	3 83	11.4	11.3	11.25	11.2	10.9	10.75	10.65	....	....	....
5	3.35	11.6	11.5	11.45	11.4	11.25	....	....	....	....	....
5	2.62	11.8	11.7	....	....	....	....	....	....	....	....
6	4.43	10.2	10.1	10.1	10.1	9.85	9.7	9.65	9.45	9.25	....
6	3.83	10.4	10.3	10.25	10.2	10	9.8	9.75	....	....	....
6	3.35	10.6	10.5	10.45	10.4	10.1	....	....	....	....	....
6	2.62	10.7	10.6	....	....	....	....	....	....	....	....
7	4.43	9.35	9.30	9.3	9.3	9.15	9.1	9	8.8	8.7	....
7	3.83	9.5	9.45	9.4	9.4	9.3	9.15	....	....	....	....
7	3.35	9.55	9.55	9.55	9.55	9.4	....	....	....	....	....
7	2.62	9.75	9.70	....	....	....	....	....	....	....	....
8	4.43	8.6	8.6	8.6	8.6	8.6	8.55	8.4	8.3	8.2	....
8	3.83	8.7	8.7	8.7	8.7	8.7	8.6	....	....	....	....
8	3.35	8.8	8.8	8.8	8.8	8.75	....	....	....	....	....
Max.	4.43	29	28.7	28.3	28	27.5	26.4	25.2	24.6	23.6	....
Speed	3.83	32.5	31.6	31.2	30.9	30.4	28.8	28.5	27.6	26.7	....
Quadruple	3.35	32.8	32.1	31.9	31.6	31.3	31	30.2	29.2	28.5	....
Equip.	2.62	36.5	36	35.7	35.5	35	34.4	34	33	32.2	....


General Electric Co.
Engineering Dept.
Railway Motor
Characteristic No 201.
G.E.98 A or B1.
50 H.P. output at 90 Amp. input.
Volts at motor terminals 500.
Diameter of car wheels 33"
Armature 2 turns, Ex. Fld. 94 turns.
Pinion 16, Gear 71, Ratio 4.43.
Per cent efficiency
Miles per hour
Lbs tractive effort
2200
100 40 2000
90 36 1800
80 32 1600
70 28 1400
60 24 1200
50 20 1000
40 16 800
30 12 600
20 8 400
10 4 200
0 0 0
0 10 20 30 40 50 60 70 80 90 100 110 120
Amperes
Efficiency
Tractive effort
Speed
G.E. 98 A or B1
1 Feb. 1911.


General Electric Co.
Engineering Dept.
Railway Motor
Characteristic No 202.
G.E.98 A or B2.
50 H.P. output at 90 Amp. input.
Volts at motor terminals 500.
Diameter of car wheels 33."
Armature 2 turns, Ex. Fld. 94 turns.
Pinion 18, Gear 69, Ratio 3.83.
Per cent efficiency
Miles per hour
Lbs. tractive effort.
Efficiency
Tractive effort
Speed
GE 98 A or B2
Amperes
1 Feb. 1911.

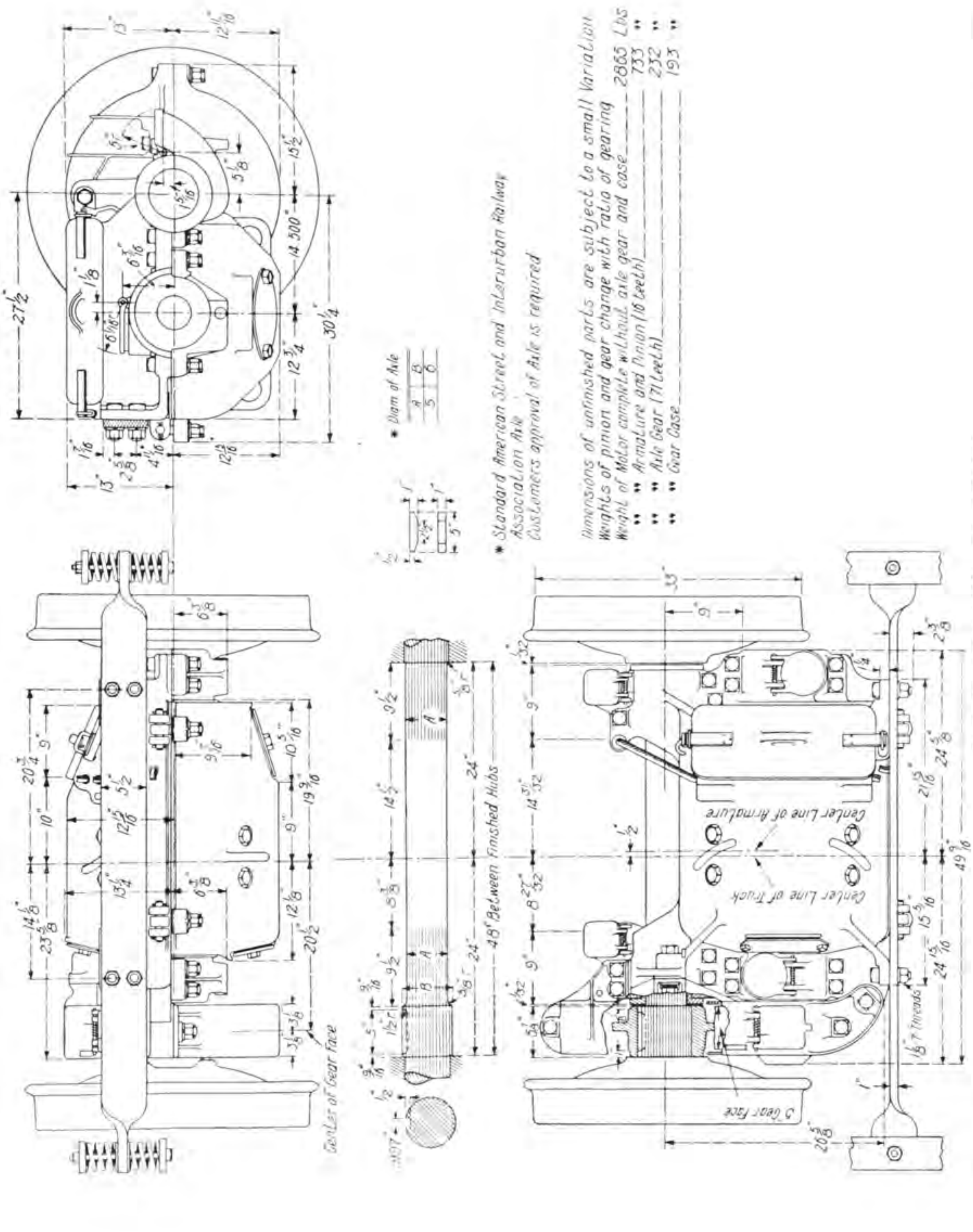

General Electric Co
Engineering Dept.
Railway Motor
Characteristic No 203.
G.E. 98 A or B3.
Per cent efficiency
Miles per hour
Lbs tractive effort
50 H.P. output at 90 Amp input
Volts at motor terminals 500
Diameter of car wheels 33"
Armature 2 turns Ex Fld 94 turns
Pinion 20 Gear 67 Ratio 3.35
100 40 2000
90 36 1800
80 32 1600
70 28 1400
60 24 1200
50 20 1000
40 16 800
30 12 600
20 8 400
10 4 200
0 0 0
Efficiency
Speed
Tractive effort
G.E. 98 A or B3.
0 10 20 30 40 50 60 70 80 90 100 110 120
Amperes
1 Feb. 1911.


General Electric Co.
Engineering Dept.
Railway Motor
Characteristic No 204.
G.E.98A or B4.
50 H.P. output at 90 Amp. input.
Volts at motor terminals 500.
Diameter of car wheels 33"
Armature 2 turns, Ex. Fld. 94 turns.
Pinion 24; Gear 63; Ratio 2.62.
Per cent efficiency.
Miles per hour.
Lbs. tractive effort.
Efficiency
Speed
Tractive effort
GE 98A or B4.
Amperes
1 Feb. 1911.



DIMENSION DIAGRAM GE-98-A MOTOR

No. 14553



DIMENSION DIAGRAM GE-98-B MOTOR

GENERAL ELECTRIC COMPANY SERVICE DATA SHEET FOR RAILWAY EQUIPMENTS

on the.. Railway.

MOTOR CARS: (OPEN OR CLOSED)......................... No. of motors per car........................

Weight of empty cars and trucks not including electrical equipment........................tons (2000 lbs.)

Length of car over all,.................Length of car body,................Seating capacity,.................

Capacity with standing load,.....................If open car give number of benches,.....................

Have cars single or double trucks?.....................Diameter of car wheel is................inches.

TRAIL CARS: (OPEN OR CLOSED).........................

Weight of empty cars and trucks............tons (2000 lbs.) Length of car over all,.................

Length of car body,............Seating capacity,............Capacity with standing load,............

No. of trail cars handled by motor car,....................Hours during which trail cars are operated,..

LINE POTENTIAL: Maximum voltage is................Minimum voltage is................Average voltage is.........................

TIME: (excluding layovers) required to make round trip....................minutes. Length round trip.........................miles.

Distance **round trip** in city service........................miles. Suburban........................miles. Interurban........................miles.

STOPS: Average number on **round trip** in city service is....................Suburban is.................... Interurban is....................

(It is assumed that the average duration of stops will be 10 seconds each.)

LAYOVERS: (If any) number and duration..

....

....

GRADES: Underscore grades which cars both ascend and descend in round trip.

Length in Ft.	%	Length in Ft.	%	Length in Ft.	%	Length in Ft.	%	Length in Ft.	%

REMARKS: (Pertaining to character of service not covered above, particularly with reference to curves and slowdowns.)

Dated..191........ Signed..

By..

GENERAL ELECTRIC COMPANY

PRINCIPAL OFFICES, SCHENECTADY, N. Y.

SALES OFFICES

(Address nearest office)

BOSTON, MASS.	84 State Street
NEW YORK, N. Y.	30 Church Street
Syracuse, N. Y.	Post-Standard Building
Buffalo, N. Y.	Ellicott Square Building
New Haven, Conn.	Malley Building
PHILADELPHIA, PA.	Witherspoon Building
Baltimore, Md.	Electrical Building
Charlotte, N. C.	Trust Building
Charleston, W. Va.	Charleston National Bank Building
Erie, Pa.	632 State Street
Pittsburg, Pa.	Park Building
Richmond, Va.	Mutual Building
ATLANTA, GA.	Empire Building
Birmingham, Ala.	Brown-Marx Building
Macon, Ga.	Grand Building
New Orleans, La.	Maison-Blanche Building
CINCINNATI, OHIO	Provident Bank Building
Columbus, Ohio	Columbus Savings & Trust Building
Cleveland, Ohio	Citizens Building
Chattanooga, Tenn.	James Building
Memphis, Tenn.	Randolph Building
Nashville, Tenn.	Stahlman Building
Indianapolis, Ind.	Traction Terminal Building
CHICAGO, ILL.	Monadnock Building
Detroit, Mich.	Majestic Building (Office of Soliciting Agent)
St. Louis, Mo.	Wainwright Building
Kansas City, Mo.	Dwight Building
Butte, Montana	Electric Building
Minneapolis, Minn.	410-412 Third Ave., North
DENVER, COLO.	First National Bank Building
Salt Lake City, Utah	Newhouse Building
SAN FRANCISCO, CAL.	Nevada Bank Building
Los Angeles, Cal.	124 West Fourth Street
Portland, Ore.	Electric Building
Seattle, Wash.	Colman Building
Spokane, Wash.	Paulsen Building

For TEXAS and OKLAHOMA Business refer to
General Electric Company of Texas,

Dallas, Tex.	Lamar & Caruth Sts.
El Paso, Tex.	Chamber of Commerce Building
Oklahoma City, Okla.	Insurance Building

FOREIGN SALES OFFICES

Schenectady, N. Y., Foreign Dept.
New York, N. Y., 30 Church St.
London, E. C., England, 83 Cannon St.

For all CANADIAN Business refer to
Canadian General Electric Co., Ltd., Toronto, Ont.

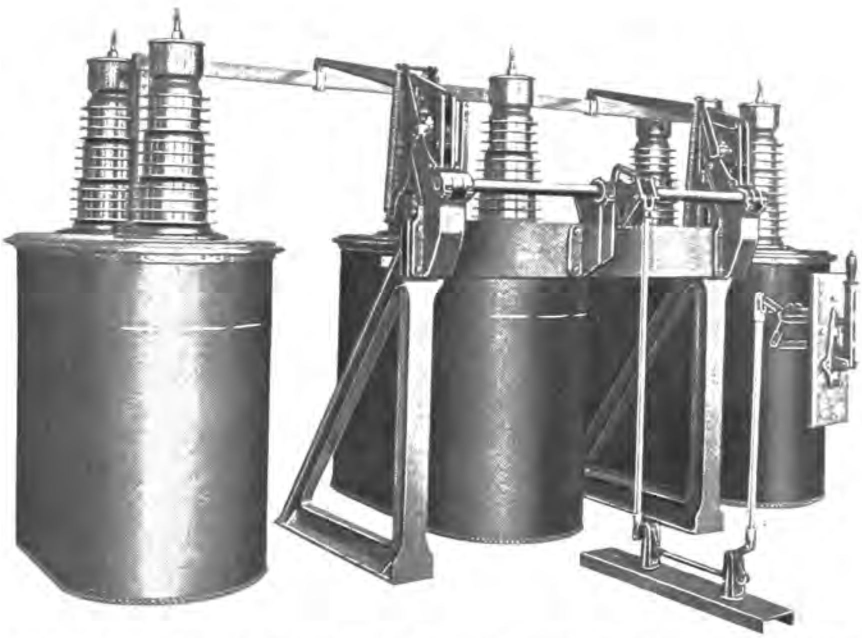
General Electric Company
Schenectady, N.Y.

SUPPLY DEPARTMENT

March, 1911 | | *Bulletin No. 4823*

TYPE F, FORMS K-10 AND K-15 OIL BREAK SWITCHES

Type F, Form K-10 and Form K-15 oil break switches are built for voltages from 22,000 to 110,000 and are adapted to meet the requirements in modern stations employing these voltages. The switch tanks which contain the oil and which also support the switch leads and the operating parts are of such dimensions that proper spacing between leads is secured without the necessity of using barriers or cells.



K-10, 100 AMPERE 110,000 VOLT OIL BREAK SWITCH, HAND-OPERATED WITHOUT OVERLOAD RELEASE

These switches are top connected and are therefore especially adapted for overhead station wiring which makes possible a simple and flexible layout. The absence of cell work and barriers tends to greatly reduce the cost of installation.

In general, the construction is similar to the other lines of Form K switches in that they have a vertical motion of the contact rods, and a double break for each pole. When the switches are opened, the contact blades move quickly downward, the break taking place in clear oil. The open position is maintained by gravity. The switches have ample air space above the oil, and vents in the covers protected by baffles prevent oil from being thrown out when the switches are opened on extreme overload or short circuit.

The Forms K-10 and K-15 switches differ mainly in size and in the construction of the contacts.

BUSHINGS

Except for some of the lower voltages, where one piece, porcelain bushings are used, all bushings are of the well known built-up type, similar to those which have been successfully used for some time on 45,000 volt oil break switches and on high voltage transformers. The built-up bushings have porcelain ends, intermediate rings of compound and treated fiber washers between joints. These washers are of large diameter and increase the creepage surface of the bushing. The bushings are filled with a special insulating compound of high dielectric strength. The parts are securely clamped together by nuts on a rod, passing through the center, which also serves as the contact stud of the switch. They are supported by plates bolted to the top of the switches which may be easily removed to permit inspection or repair.

CONTACTS

The contacts of the Form K-10 oil break switch are of the usual Form K construction. The fingers of the stationary contacts are widely flared so that the movable wedge-shaped contact blades will enter contact without possibility of failure.

The stationary contacts consist of a double set of contact fingers made of drop-forged copper fastened to the stud at the bottom of each insulator by flat springs with copper laminations and reinforcing springs. The tension of these springs insures good contact but does not retard the opening of the switch. On opening the switch, the stationary contact fingers follow the bevel of the blade to the point of breaking contact. The arc is broken on the flared portion of the stationary contacts and above the working surface of the movable contact blade, thus keeping the working contact surfaces free from burning or pitting.

The contacts of the Form K-15 oil break switch are similar to those in the well known Form H-3 switch. A cylindrical rod makes contact with the inner surface of four segments of a cylinder, secured in position by helical springs. This not only insures heavy contact pressure, but also compensates for wear of either the stationary contacts or the surface of the cylindrical contact rod. When the arc is ruptured whatever burning results takes place on the bell mouth of the stationary contact and on the upper end of the movable contact rod, and in no case causes damage to the working contact surface. The contacts are self-aligning and easily renewed.

HEATING

For mechanical reasons, the current carrying parts of the Form K-10 and Form K-15 oil break switches are much larger than would be required to carry the rated current; consequently the switches have a very low temperature rise, in no case exceeding 28 degrees centigrade.

OIL

Transil oil No. 6 should always be used with Form K-10 and Form K-15 oil break switches. It is especially prepared for this class of service, has a very high flash point and will not easily carbonize. Only treated oil should be used.

OPERATING MECHANISM

Three kinds of mechanism are available. The switches can be operated *by hand, by a solenoid mechanism* requiring a direct current source of power or *by a diaphragm mechanism* using compressed air. The uses of the different kinds of operating mechanism and the determining factors in its selection are given in the following description. Devices for automatic operation on overload can be used with any of the three forms mentioned.

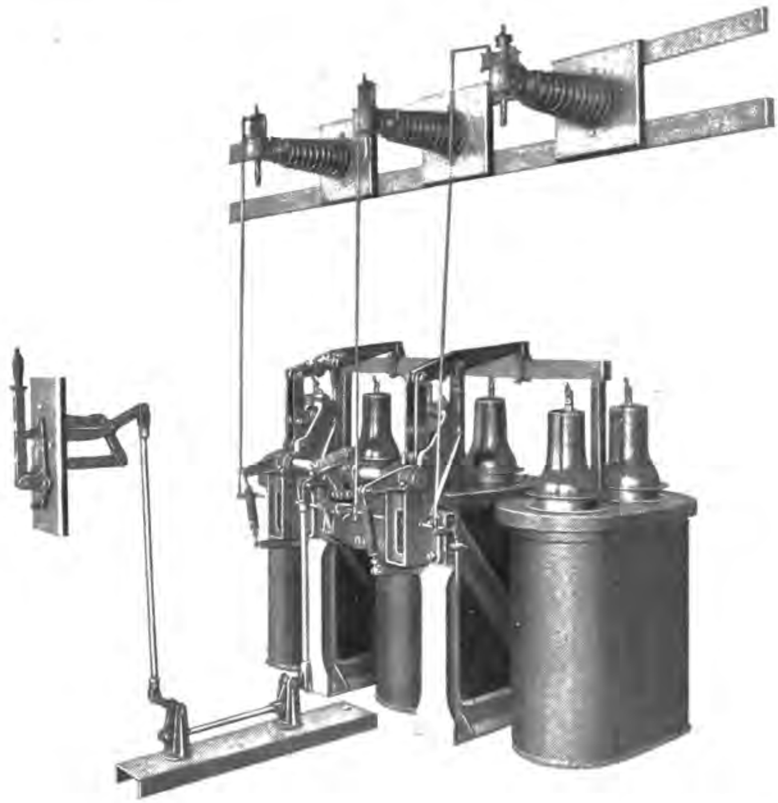
Hand Mechanism

The hand mechanism consists of a handle or operating lever mounted on a panel or other suitable support. In closing the switch, the lever moves through an arc of 180 degrees. It has a very powerful toggle which exerts the maximum power at the end of the stroke and makes it possible to close the switch contacts under heavy spring pressure. The switch arms carrying the wooden cross heads, support the wooden contact rods. The necessary mechanism for controlling the switch arms is supported on a substantial framework of channel irons held by heavy cast iron floor brackets, all of which are included with the switch. The weight of the cross head and moving elements of the switch is counterbalanced by adjustable tension springs, so that the switches close easily and open without excessive jar. On all non-automatic mechanisms, provision is made for adding overload operation at any time without difficulty. The mechanism for overload operation has a trip-free from the handle feature so that the switch cannot be held closed on overload or short circuit.

Hand-operated switches include:

(1) Switches complete with oil, and switch mechanism with its supports.

(2) Operating lever with bell cranks (customer supplies pipe connections and panel or support for operating lever.)



K-10, 300 AMPERE, 45,000 VOLT OIL BREAK SWITCH, HAND-OPERATED WITH SERIES RELAY MECHANICAL TRIP

Solenoid-Operated Mechanism

Solenoid mechanism can be used on both Forms K-10 and K-15 oil break switches and is similar to the hand mechanism except that the operating handle, bell cranks and pipe connections are replaced by one or more solenoid mechanisms.

Each solenoid mechanism has a large coil to close the switch and a small coil to trip it.

A control relay is used to close and open the closing coil circuit. This relieves the control switch which thus has only to handle the small current of the control relay coil. The

SINGLE ELEMENT OF FORM K-15, 100 AMPERE 110,000 VOLT OIL BREAK SWITCH SOLENOID-OPERATED

trip coil of the solenoid-operated switch is energized from the control switch or the overload circuit closing relay when used. Solenoids are furnished for use on 125, 250 or 650 volts, direct current.

Solenoid-operated switches include:

(1) Switch complete with oil, and switch mechanism with its supports.

(2) Solenoid and connecting mechanism between switch and solenoid and supports for solenoid.

(3) Solenoid control relay.

(4) Control switch and indicating lamps complete with resistance.

Air-Operated Mechanism

Where remote control is desired but where a convenient source of direct current for operating the switch is unavailable, air-operated mechanism can be used.

Always specify voltage available for solenoid operation.

In such cases a small alternating current air compressor equipment should be installed. This outfit should be complete with the necessary storage tank. Prices on application.

Air-operated switches include:

(1) Switch complete with oil, and switch mechanism with its supports.

(2) Air diaphragm, connecting mechanism between switch and diaphragm and supports for diaphragm.

(3) Electrically-operated valves for remote control of air connections to diaphragm.

SINGLE ELEMENT OF FORM K-15, 100 AMPERE 110,000 VOLT OIL BREAK SWITCH PNEUMATICALLY-OPERATED

Alternating current is used (usually 110 volts taken from the station lighting circuit).

(4) Control switch and indicating lamps complete with resistance.

Always specify voltage available for control circuit.

SERIES AMMETERS

Series ammeters, mounted on post type insulators similar to those used with high tension series relays, are satisfactory as current indicating devices. When used with series relays they form a compact and cheap equipment. The open, large, well lighted scales of the ammeters are easily read when mounted well out of reach, and accidental contact with them by a station attendant is impossible.

OVERLOAD OPERATION

To provide for the automatic protection of apparatus under abnormal conditions of overload or short circuit, two methods are commonly employed. The selection between them and the various combinations used under each, depend upon the conditions and requirements of operation in any given case, as well as upon the cost of installation.

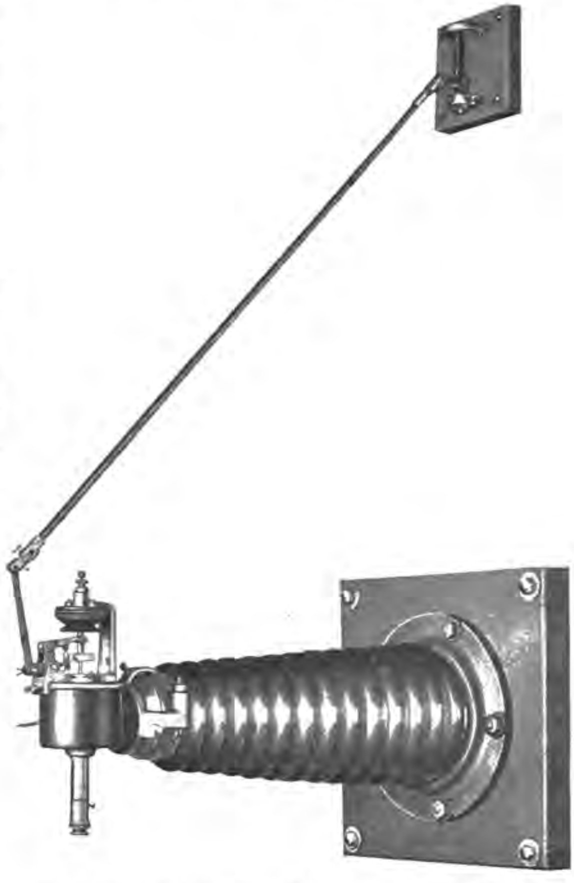
CONTROL RELAY

CONTROL SWITCH

These means of protection will be described in the order of their general use, namely: "overload operation by means of series relays" (series relay trip) and "overload operation by means of current transformers" (current transformer trip).

SERIES RELAY TRIP

Series relays are similar to standard switchboard relays with or without bellows attachment for time limit or instantaneous operation, respectively. All series relays are single-pole. Each one is mounted upon a post insulator, the size of which depends upon the line voltage. The insulators are clamped to bases which may be mounted on the side wall of the station or to a support directly above the switch. There is also a special form of relay for ceiling mounting. The relays are connected in series with the line, one or more being used according to the system employed.



SERIES OVERLOAD RELAY WITH ELECTRICAL TRIP

For three-phase ungrounded neutral, three-wire systems, use *two* series relays.

For three-phase, grounded neutral, three-wire systems, use *three* series relays.

(*1*) *Series overload relays with mechanical trip.*—This form of relay with or without inverse time limit feature is used with hand-operated switches where a convenient source of direct current for tripping is unavailable.

All Form K-10 and Form K-15 switch mechanisms are provided with bushed holes

HIGH VOLTAGE CURRENT TRANSFORMER

to take a tripping shaft to which the small treated wooden insulating rods from the relay are connected. The relay mechanism acts directly through the rods and tripping shaft upon a small auxiliary toggle which releases the main switch toggle and opens the oil switch. Each relay is furnished with twelve feet of treated wooden rod. This is sufficient to permit the relay to be mounted at a proper distance from the switch. The inverse time limit relay has a special quick trip mechanism, so both it and the instantaneous relay impart a quick, powerful impulse to the tripping shaft and make the operation positive. The lever system of the relay is adjustable for operation in different positions.

(2) *Series overload relays with electrical trip* (circuit closing).—This form of series relay, with or without inverse time limit, is similar to the one just described, except that the wooden connecting rod actuates a small switch and closes an electrical circuit through a trip coil, which in turn opens the oil switch.

This series relay is used with solenoid-operated oil switches, the relay switch being connected to the tripping coil of the solenoid in parallel with the opening side of the control switch.

It may also be used with air-operated oil break switches, being connected in similar manner to that described for solenoid-operated switches except that low tension alternating current (generally 110 volts) is used, as described under the heading "Air-Operated Mechanism."

CURRENT TRANSFORMER TRIP

Where wattmeters or watthour meters are required on high voltage circuits it is necessary to use current transformers. For high voltages, accurate and reliable current transformers are more expensive than series relays and are seldom used except with meters or reverse current relays.

In general, the operation with Form K-10 and Form K-15 oil break switches is the same as with lower voltage apparatus using standard switchboard relays, and varies only in

SERIES AMMETER

the combinations for the different operating mechanisms.

For three-phase ungrounded neutral, three-wire systems, use *two* current transformers and a *double-pole* switchboard type relay. When direct current is available, circuit-closing relays are used with a direct current trip coil on the oil switch or solenoid mechanism. If direct current is not available, circuit opening relays are used with a single trip coil on the oil switch, in the secondaries of current transformers.

For three-phase grounded neutral, three-wire systems, use *three* current transformers with one *triple-pole* or *three single-pole* relays. Where direct current is available, circuit closing relays are used with direct current trip coil on the oil switch or solenoid mechanism. Where direct current is not available propositions should be referred to the general office.

(1) Current transformer trip used with hand mechanism.—With this combination it is necessary to have a trip coil on the oil switch mechanism. Provision for this is made so that it may be added at any time without difficulty. With direct current trip, a single direct current coil is used; with alternating current, a similar coil or coils are used.

(2) Current transformer trip with solenoid-operated mechanism.—In this case, direct current is available and circuit closing relays are used connected in parallel with the opening side of the control switch and tripping coil of the solenoid mechanism.

(3) Current transformer trip with air-operated mechanism.—With this combination, it is customary to have the trip coil on the switch mechanism as described under (1). Circuit-opening relays are used with a single trip coil in the secondary of current transformers and entirely separate from the alternating current control circuit for the electrically-operated air valve.

REVERSE CURRENT OPERATION

Automatic operation on reversal of current is obtained by the use of standard relays in the secondaries of current transformers and the combinations are similar to those described under "Current Transformer Trip."

RUPTURING CAPACITY

While an oil switch may be insulated for a given potential and designed to carry a definite amount of current, it will not necessarily rupture that amount of normal energy, equivalent to the volt and ampere rating of the switch in the event of a short circuit. A source of electrical energy may have power greatly in excess of its normal capacity and the switch may, therefore, be required to interrupt not merely the normal energy delivered in the circuit to which it is connected but the entire power that may be developed on short circuit by all synchronous apparatus working in parallel on the system.

On short circuit conditions, synchronous generators, develop instantaneously many times their normal load capacity while the sustained short circuit current will be approximately three times normal. Therefore, instantaneous automatic switches must be capable of rupturing the circuit when the current is at a maximum, whereas, non-automatic switches and automatic switches with time limit relays will be required to interrupt only the *sustained* short circuit current. The reason is evident, since the delay in opening the switch, allows the current to settle down to approximately three times normal.

The Form K-10 oil break switch is used on systems with voltages of from 22,000 to 110,000 volts, on which the combined energy of apparatus in parallel is not greater than 20,000 kilowatts.

The Form K-15 oil break switch is used on systems with voltages of from 70,000 to 110,000 volts on which the combined energy of apparatus in parallel is not greater than 50,000 kilowatts. If conditions involve more than 50,000 kilowatts, the proposition should be referred to the general office.

POTENTIAL TEST

Each switch bushing is given a high potential test of three times its normal rated voltage for thirty seconds. All wood rods, cross heads, relay trip rods, etc., are of treated wood and are given an insulation test of 110,000 volts for each 10 inches of rod.

FORM K-10 WITHOUT OVERLOAD RELEASE (NON-AUTOMATIC)

HAND-OPERATED—TRIPLE-POLE—SINGLE-THROW

With Operating Lever for Mounting on Two Inch Panel

Voltage	Amp. Cap.	Ship. Wt. of Sw. in Lb.	Gal. of Oil	Ship. Wt. of Oil in Lb.
22000	300	3640	171	1401
45000	300	3640	171	1401
70000	150	6900	405	3300
110000	100	14750	1185	9710

SOLENOID-OPERATED—TRIPLE-POLE—SINGLE-THROW

One Solenoid Operating Three-Pole Switch

Voltage	Amp. Cap.	Ship. Wt. of Sw. in Lb.	Gal. of Oil	Ship. Wt. of Oil in Lb.
22000	300	3900	171	1401
45000	300	3900	171	1401
70000	150	7100	405	3300
110000	100	14750	1185	9710

AIR-OPERATED—TRIPLE-POLE—SINGLE-THROW

Single-Pole Elements, Each with Individual Diaphragm

Voltage	Amp. Cap.	Ship. Wt. of Sw. in Lb.	Gal. of Oil	Ship. Wt. of Oil in Lb.
22000	300	3900	171	1401
45000	300	3900	171	1401
70000	150	7100	405	3300
110000	100	14750	1185	9710

FORM K-15 WITHOUT OVERLOAD RELEASE (NON-AUTOMATIC)

HAND-OPERATED—TRIPLE-POLE—SINGLE-THROW

With Operating Lever for Mounting on Two Inch Panel

Voltage	Amp. Cap.	Ship. Wt. of Sw. in Lb.	Gal. of Oil	Ship. Wt. of Oil in Lb.
70000	150	8500	555	4550
110000	100	16250	1320	10850

SOLENOID-OPERATED—TRIPLE-POLE—SINGLE-THROW

Single-Pole Elements, Each with Individual Solenoid

Voltage	Amp. Cap.	Ship. Wt. of Sw. in Lb.	Gal. of Oil	Ship. Wt. of Oil in Lb.
70000	150	8500	555	4550
110000	100	16250	1320	10850

Require one control switch and one control relay for three-pole switch.

AIR-OPERATED—TRIPLE-POLE—SINGLE-THROW

Single-Pole Elements, Each with Individual Diaphragm

Voltage	Amp. Cap.	Ship. Wt. of Sw. in Lb.	Gal. of Oil	Ship. Wt. of Oil in Lb.
70000	150	8500	555	4550
110000	100	16250	1320	10850

HIGH TENSION SERIES OVERLOAD RELAYS

SINGLE-POLE—CIRCUIT CLOSING—MOUNTED ON "POST-TYPE" INSULATORS

For Use with Separate Tripping Circuit—Including Switch and 12 Feet of Treated Wood Rod

Voltage	Ampere Capacity	Instantaneous			Inverse Time Limit			Minimum Length of Rod in Feet	Ship. Weight in Lb.
		Type	Form	Cat. No.	Type	Form	Cat. No.		
22000	3	P	B-31	64709	P	C-31	64749	8	50
22000	5	P	B-31	64710	P	C-31	64750	8	50
22000	10	P	B-31	102809	P	C-31	102814	8	50
22000	15	P	B-31	64711	P	C-31	64751	8	50
22000	30	P	B-31	64712	P	C-31	64752	8	50
22000	60	P	B-31	64713	P	C-31	64753	8	50
22000	100	P	B-31	64714	P	C-31	64754	8	50
22000	200	P	B-31	64715	P	C-31	64755	8	50
22000	300	P	B-31	64716	P	C-31	64756	8	50
35000	3	P	B-31	64717	P	C-31	64757	8	60
35000	5	P	B-31	64718	P	C-31	64758	8	60
35000	10	P	B-31	102810	P	C-31	102815	8	60
35000	15	P	B-31	64719	P	C-31	64759	8	60
35000	30	P	B-31	64720	P	C-31	64760	8	60
35000	60	P	B-31	64721	P	C-31	64761	8	60
35000	100	P	B-31	64722	P	C-31	64762	8	60
35000	200	P	B-31	64723	P	C-31	64763	8	60
35000	300	P	B-31	64724	P	C-31	64764	8	60
45000	3	P	B-31	64725	P	C-31	64765	8	70
45000	5	P	B-31	64726	P	C-31	64766	8	70
45000	10	P	B-31	102811	P	C-31	102816	8	70
45000	15	P	B-31	64727	P	C-31	64767	8	70
45000	30	P	B-31	64728	P	C-31	64768	8	70
45000	60	P	B-31	64729	P	C-31	64769	8	70
45000	100	P	B-31	64730	P	C-31	64770	8	70
45000	200	P	B-31	64731	P	C-31	64771	8	70
45000	300	P	B-31	64732	P	C-31	64772	8	70
70000	3	P	B-31	64733	P	C-31	64773	10	90
70000	5	P	B-31	64734	P	C-31	64774	10	90
70000	10	P	B-31	102812	P	C-31	102817	10	90
70000	15	P	B-31	64735	P	C-31	64775	10	90
70000	30	P	B-31	64736	P	C-31	64776	10	90
70000	60	P	B-31	64737	P	C-31	64777	10	90
70000	100	P	B-31	64738	P	C-31	64778	10	90
70000	200	P	B-31	64739	P	C-31	64779	10	90
70000	300	P	B-31	64740	P	C-31	64780	10	90
110000	3	P	B-31	64741	P	C-31	64781	12	150
110000	5	P	B-31	64742	P	C-31	64782	12	150
110000	10	P	B-31	102813	P	C-31	102818	12	150
110000	15	P	B-31	64743	P	C-31	64783	12	150
110000	30	P	B-31	64744	P	C-31	64784	12	150
110000	60	P	B-31	64745	P	C-31	64785	12	150
110000	100	P	B-31	64746	P	C-31	64786	12	150
110000	200	P	B-31	64747	P	C-31	64787	12	150
110000	300	P	B-31	64748	P	C-31	64788	12	150

See cut, page 5.

4823–10 Type F, Forms K-10 and K-15 Oil Break Switches

HIGH TENSION SERIES OVERLOAD RELAYS

MECHANICAL TRIP

Mounted on "Post-Type" Insulators—For Use with Type F, Forms K-10 and K-15 Oil Break Switches

Voltage	Ampere Capacity	Poles	INSTANTANEOUS Type	INSTANTANEOUS Form	INSTANTANEOUS Cat. No.	INVERSE TIME LIMIT Type	INVERSE TIME LIMIT Form	INVERSE TIME LIMIT Cat. No.	Minimum Length of Rod in Feet	Ship. Weight in Lb.
22000	3-5-15-25-50-100-200 and 300 amperes. *Specify capacity desired.*	S	P	B-31	63970	P	C-31	63985	8	60
22000		D	P	B-31	63971	P	C-31	63986	8	120
22000		T	P	B-31	63972	P	C-31	63987	8	180
35000		S	P	B-31	63973	P	C-31	63988	8	70
35000		D	P	B-31	63974	P	C-31	63989	8	140
35000		T	P	B-31	63975	P	C-31	63990	8	210
45000		S	P	B-31	63976	P	C-31	63991	8	80
45000		D	P	B-31	63977	P	C-31	63992	8	160
45000		T	P	B-31	63978	P	C-31	63994	8	240
70000		S	P	B-31	63979	P	C-31	63996	10	100
70000		D	P	B-31	63980	P	C-31	63998	10	200
0000		T	P	B-31	63981	P	C-31	64000	10	300
110000		S	P	B-31	63982	P	C-31	64002	12	160
110000		D	P	B-31	63983	P	C-31	64004	12	320
110000		T	P	B-31	63984	P	C-31	64006	12	480

See cut, page 3.

AUXILIARY DEVICES

The following auxiliary devices can be furnished as extras:

Standard ¾ in. pipe connecting rods (usually furnished by customer).

Auxiliary switches (circuit closing, circuit opening, for electrical interlocking, indicating, opening a tripping circuit, etc.).

Current and potential transformers.

Protective relays.

Signal relays (circuit closing).

Control switches for solenoid- and air-operated switches.

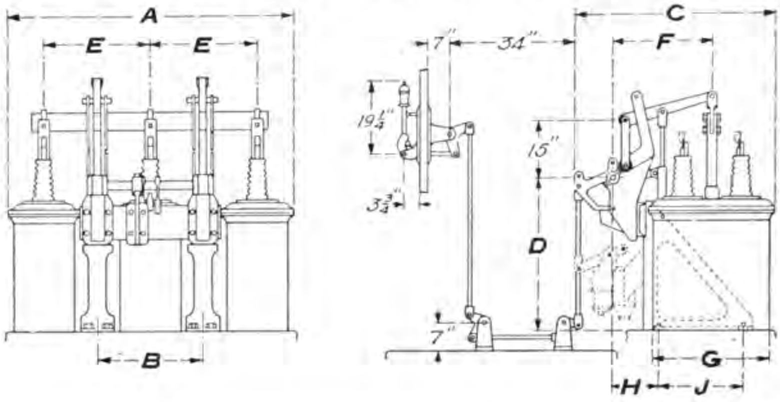
Indicating lamps, receptacles, red and green lenses.

Air compressors.

Air storage reservoirs.

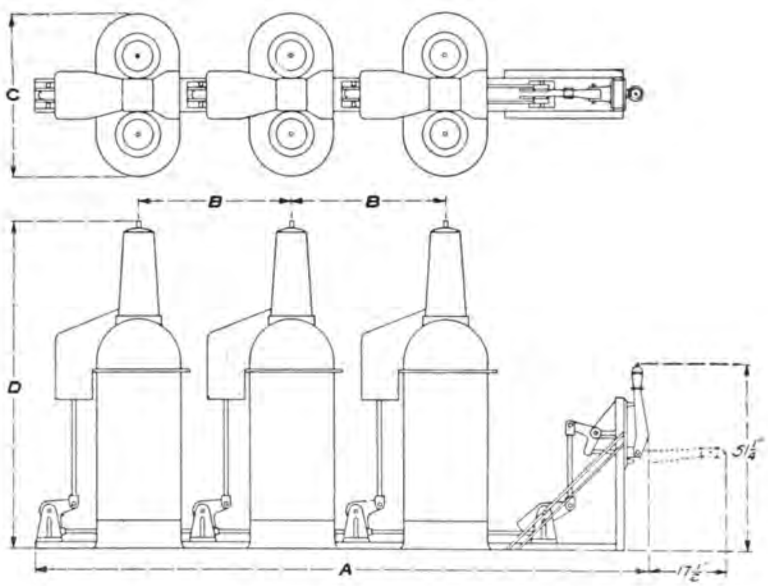
Air control valves.

DIMENSIONS OF K-10 OIL BREAK SWITCHES



Volts	Amp.	A	B	C	D	E	F	G	H	J
22000	300	80¾	30	53½	40⅝	30	26⅜	32¼	10⅞	25
45000	300	80¾	30	53½	40⅝	30	26⅜	32¼	10⅞	25
70000	150	124¾	48	73⅜	54⅞	48	38¼	48¼	11$\frac{9}{32}$	31
110000	100	187¾	74	99$\frac{3}{16}$	69⅛	74	52$\frac{1}{16}$	72¼	11$\frac{9}{32}$	43

DIMENSIONS OF K-15 OIL BREAK SWITCHES



Volts	Amp.	*A	B	C	D
70,000	150	193	48	51¾	103$\frac{7}{16}$
110,000	100	228	60	75¾	124

* Approximate.

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Indianapolis, Ind.	Traction Terminal Building
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Kansas City, Mo.	Dwight Building
Butte, Montana	Electric Building
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Spokane, Wash.	Paulsen Building

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Oklahoma City, Okla.	Insurance Building

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General Electric Company
Schenectady, N.Y.
SUPPLY DEPARTMENT

March, 1911

*Bulletin No. 4825

GENERAL ELECTRIC SWITCHBOARD INSTRUMENTS TYPES R-4 AND R-6

TYPES R-4 and R-6 voltmeters and ammeters have been developed to meet the demand for a compact, accurate and moderate priced line of instruments for use on alternating and direct current switchboards.

TYPE R-6 VOLTMETER

Particular attention is called to the new features of these instruments, consisting of large window openings, wide pointers, and the printing "Amperes" and "Volts" on the scale. These points facilitate reading the indications and enable one to identify at a glance an ammeter or voltmeter.

CONSTRUCTION

Types R-4 and R-6 instruments are constructed on the well-known Thomson inclined coil principle and embody the same high grade construction which characterizes the various instruments of this type.

The design and manufacture have received the most careful consideration, with the result that a mechanism has been produced which will maintain a high degree of accuracy under the most severe operating conditions.

MOVING ELEMENTS

The moving elements are extremely simple and light in weight, and are mounted on highly polished pivots suspended in sapphire jewels. Friction is thus reduced to a minimum and the possibility of injury to the jewels and pivots is rendered very remote.

TORQUE

These instruments have been designed to give a maximum torque or directive force. This, in combination with the light moving elements, enables the pointer to take up a definite position with each change of current, and insures accuracy over long periods of service.

CONTROLLING FORCE

A permanent and reliable controlling or restraining force, one of the essentials of

TYPE R-4 AMMETER

continued accuracy, is effected by the use of a high grade phosphor bronze spring.

NOTE.—The prices and data in this publication are for the convenience of customers, and every effort is made to avoid error, but this Company does not guarantee their correctness, nor does it hold itself responsible for any errors or omissions in this publication. Both prices and data are subject to change without notice.

*Supersedes No. 4700.

DAMPING QUALITIES

Types R-4 and R-6 instruments are highly dead-beat. This important quality allows quick and accurate reading and also protects the pointer and moving element from injury due to violent load fluctuations.

The damping system is of the magnetic type employing a sector of aluminum which moves across the field of a permanent magnet.

This method of damping is very effective, introduces no friction, and is free from the objectionable features common to many liquid or air damping systems.

INTERIOR OF SWITCHBOARD AMMETER, TYPE R-6

FREEDOM FROM EFFECT OF STRAY FIELDS

The measuring element of Types R-4 and R-6 instruments is thoroughly protected from the disturbing influences of stray magnetic fields by a laminated soft iron shield and a cast iron case. The instruments can thus be placed close to each other without danger of mutual interference, a feature of the highest importance on crowded switchboards.

SCALES

The scales are very satisfactory as to length, legibility and distribution. The various calibration points are carefully determined by comparison with a laboratory standard, which insures accuracy throughout the entire range.

CONNECTIONS

Types R-4 and R-6 instruments are made in back connected form only, and are provided with connection studs which also serve to secure the instruments to the switchboard.

FINISH

The standard finish is dull black with raised portions of polished copper.

The Type R-4 ammeters and voltmeters are exactly like the Type R-6 instrument in every way except the size of the case, which is approximately 9½ in. in diameter. This instrument corresponds in size to the Type D-7 direct current instrument and owing to the longer scale is preferable to the Type R-6 for some work.

AMMETERS

Ammeters of this type are self-contained in capacities up to and including 200 amperes. Instruments for alternating current use on potentials in excess of 2500 volts or of current capacities greater than 200 amperes will be furnished with current transformers. It is recommended that current transformers be used with all ammeters on circuits of more than 1150 volts, as a safeguard to the switchboard attendant. Direct current instruments of capacities above 200 amperes cannot be furnished.

VOLTMETERS

Types R-4 and R-6 voltmeters are made in capacities up to and including 750 volts, alternating or direct current, and may be used in connection with potential transformers on alternating current circuits of any higher voltage. When ordered with potential transformers the scales are marked in secondary volts unless the order calls for marking in primary volts. When instruments are intended for use with transformers the frequency of the circuit must always be given in order that the proper transformers may be supplied.

All voltmeters are furnished with a movable voltmarker which is operated by a small screw below the monogram on the dome.

The resistance is external in all capacities above 175 volts and is secured in a cage suitable for mounting on the back of the switchboard.

PRICES OF TYPE R-4 INSTRUMENTS
AMMETERS

Cat. No.	Amperes	Approx. Ship. Wt. in Lb.	List Price
114272	5	22	$40.00
114273	10	22	40.00
114274	15	22	40.00
114275	20	22	40.00
114276	30	22	40.00
114277	40	22	40.00
114278	60	22	45.00
114279	80	22	45.00
114280	100	22	45.00
114281	150	22	45.00
114282	200	22	45.00

VOLTMETERS

Cat. No.	Volts	Approx. Ship. Wt. in Lb.	List Price
114283	175	22	$45.00
114284	350	22	50.00
114285	500	22	55.00
114286	750	22	60.00

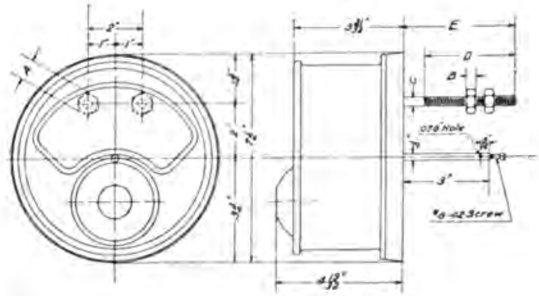
PRICES OF TYPE R-6 INSTRUMENTS
AMMETERS

Cat. No.	Capacity Amperes	List Price
35756	5	$30.00
35757	10	30.00
35758	15	30.00
35759	20	30.00
35760	30	30.00
35761	40	30.00
35762	60	35.00
35763	80	35.00
35764	100	35.00
35765	150	35.00
35766	200	35.00

VOLTMETERS

Cat. No.	Capacity Volts	List Price
35776	175	$35.00
35777	350	40.00
35778	500	45.00
35779	750	50.00

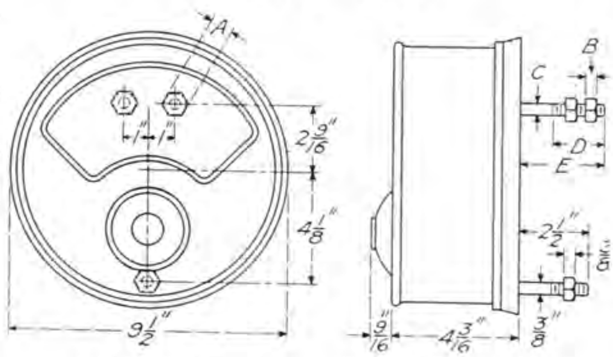
DIMENSIONS OF TYPE R-6 AMMETERS AND VOLTMETERS



DIMENSIONS OF STUDS AND NUTS

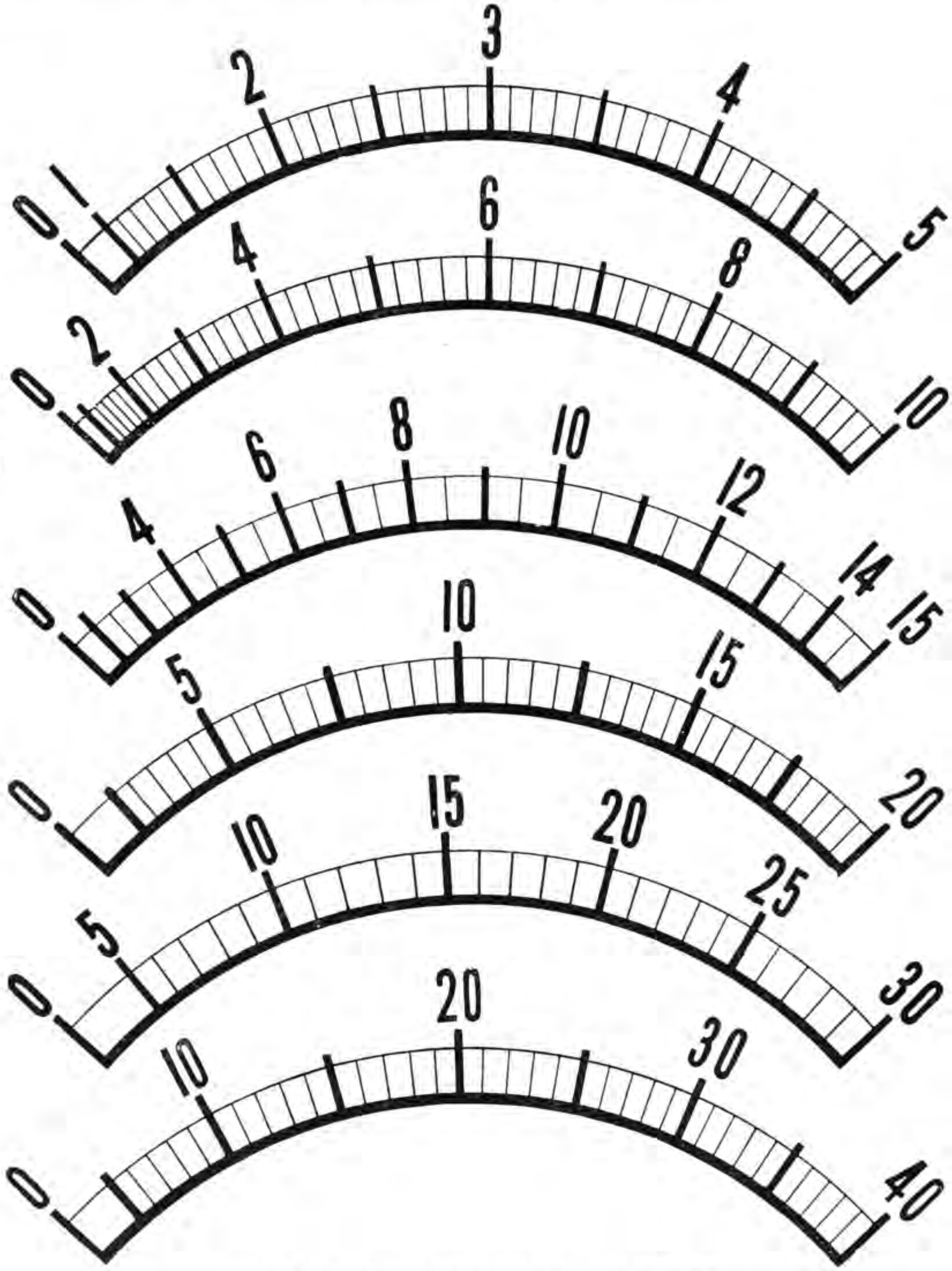
Capacity in Amps.	Dimensions in Inches				
	A	B	C	D	E
4– 20	$\frac{25}{32}$	$\frac{3}{8}$	$\frac{3}{8}$	$1\frac{3}{4}$	3
30–100	$\frac{25}{32}$	$\frac{3}{8}$	$\frac{3}{8}$	3	3
150–200	$1\frac{1}{16}$	$\frac{1}{2}$	$\frac{1}{2}$	$3\frac{1}{2}$	$3\frac{1}{2}$
Voltmeter	$\frac{25}{32}$	$\frac{3}{8}$	$\frac{3}{8}$	$1\frac{3}{4}$	3

DIMENSIONS OF TYPE R-4 AMMETERS AND VOLTMETERS

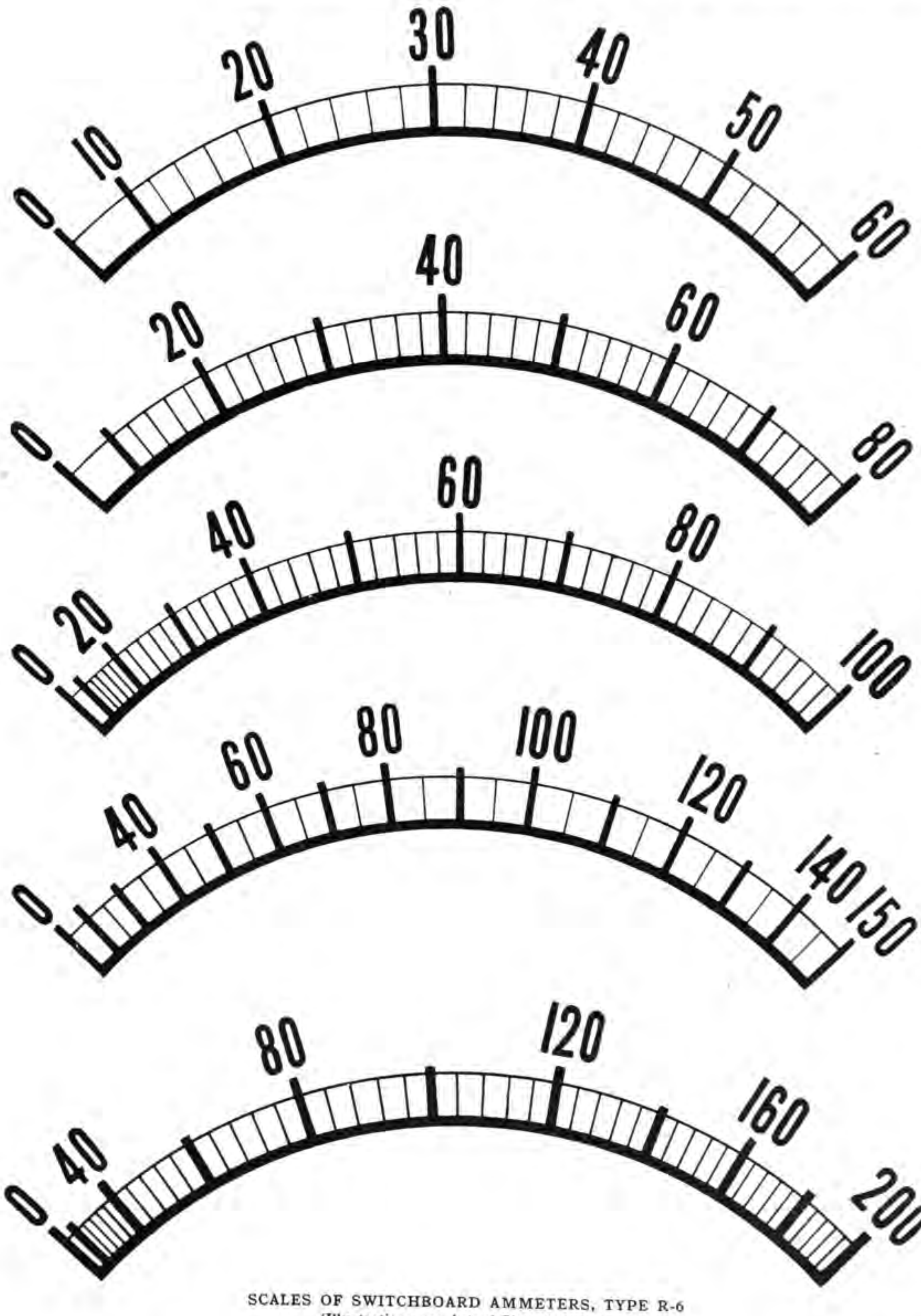


DIMENSIONS OF STUDS AND NUTS

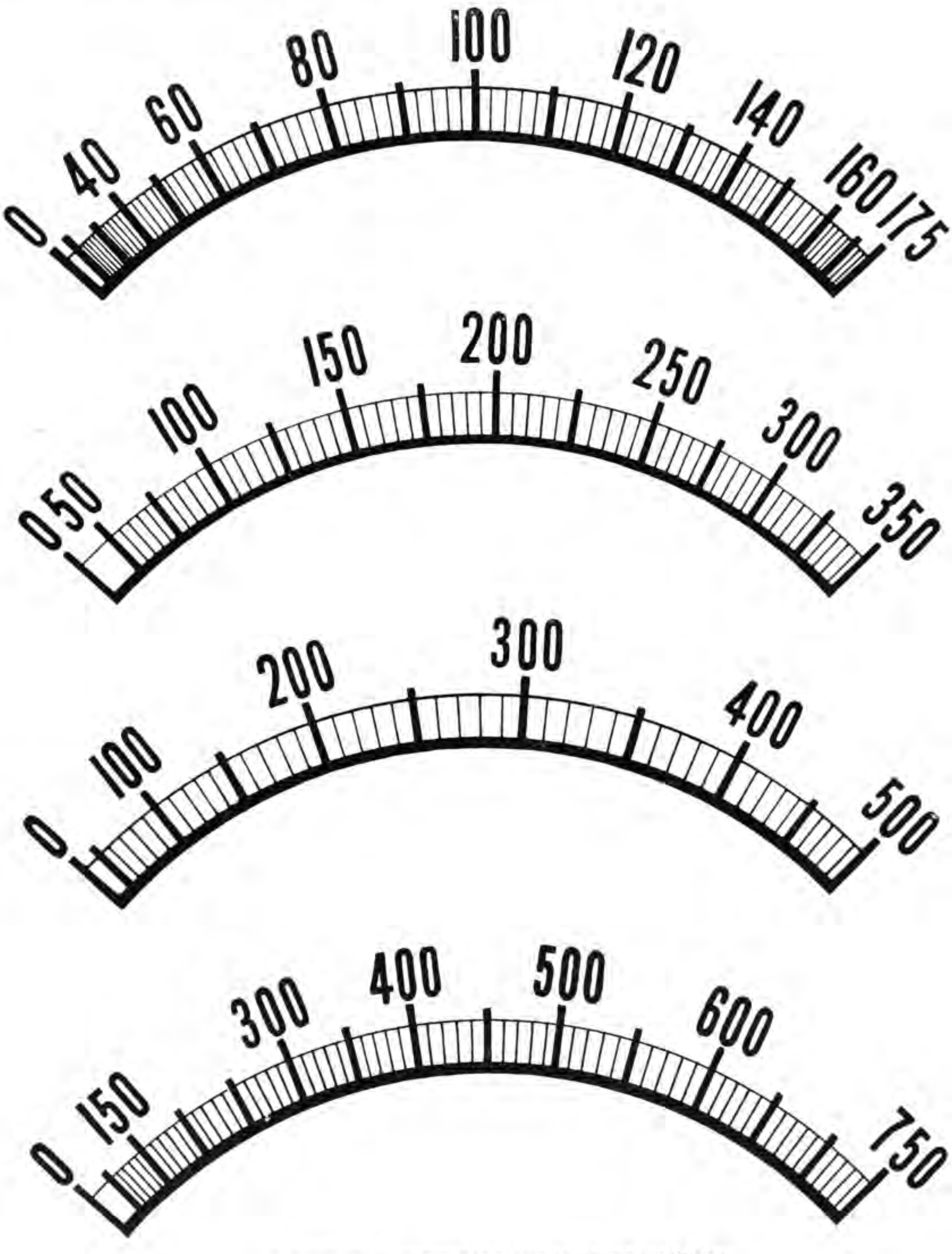
Capacity in Amps.	Dimensions in Inches				
	A	B	C	D	E
4– 20	$\frac{25}{32}$	$\frac{3}{8}$	$\frac{3}{8}$	$2\frac{1}{2}$	3
30–100	$\frac{25}{32}$	$\frac{3}{8}$	$\frac{3}{8}$	3	3
150–200	$1\frac{1}{16}$	$\frac{1}{2}$	$\frac{1}{2}$	$3\frac{1}{2}$	$3\frac{1}{2}$
Voltmeter	$\frac{25}{32}$	$\frac{3}{8}$	$\frac{3}{8}$	$2\frac{1}{2}$	3



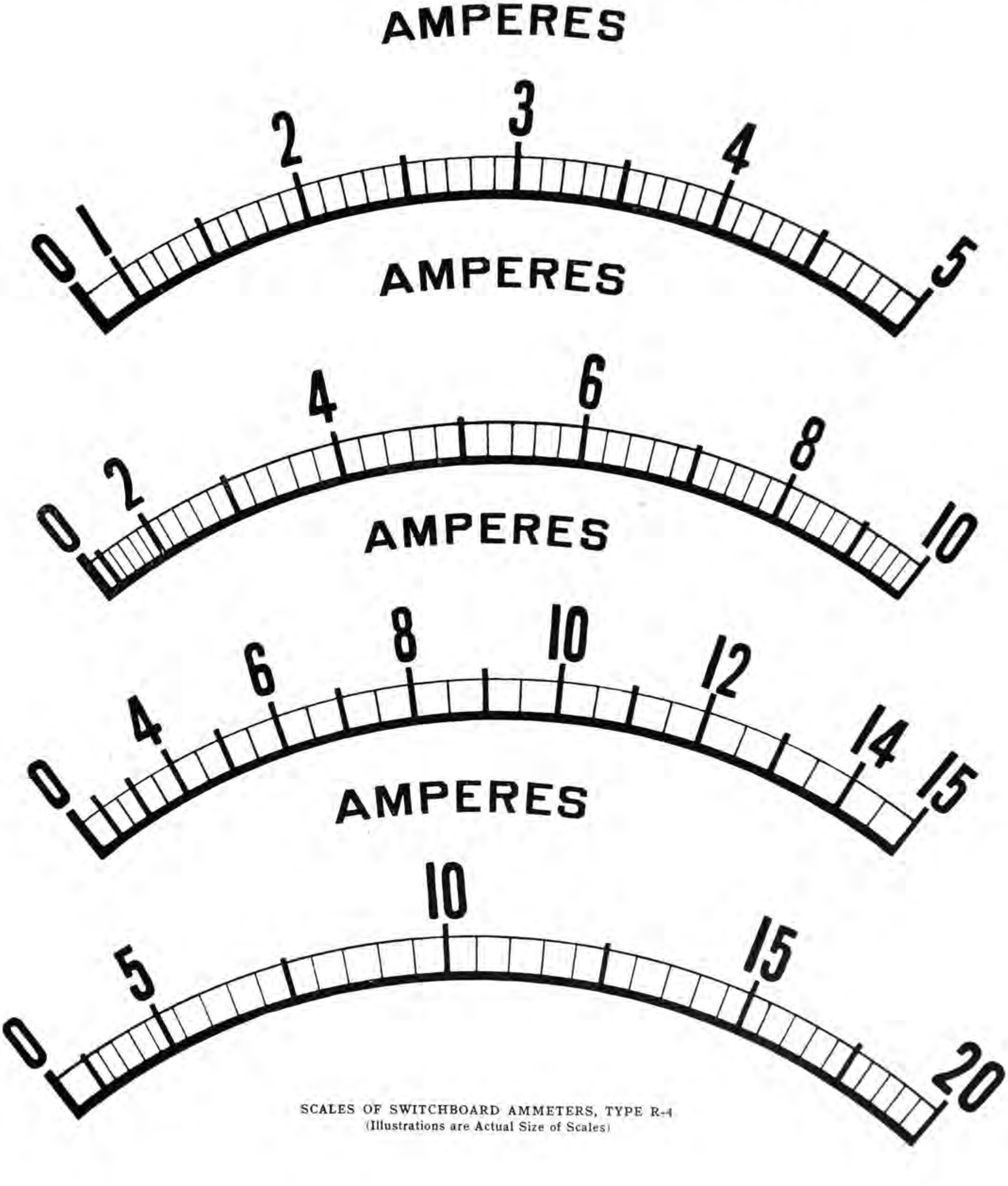
SCALES OF SWITCHBOARD AMMETERS TYPE R-6
(Illustrations are Actual Size of Scales)



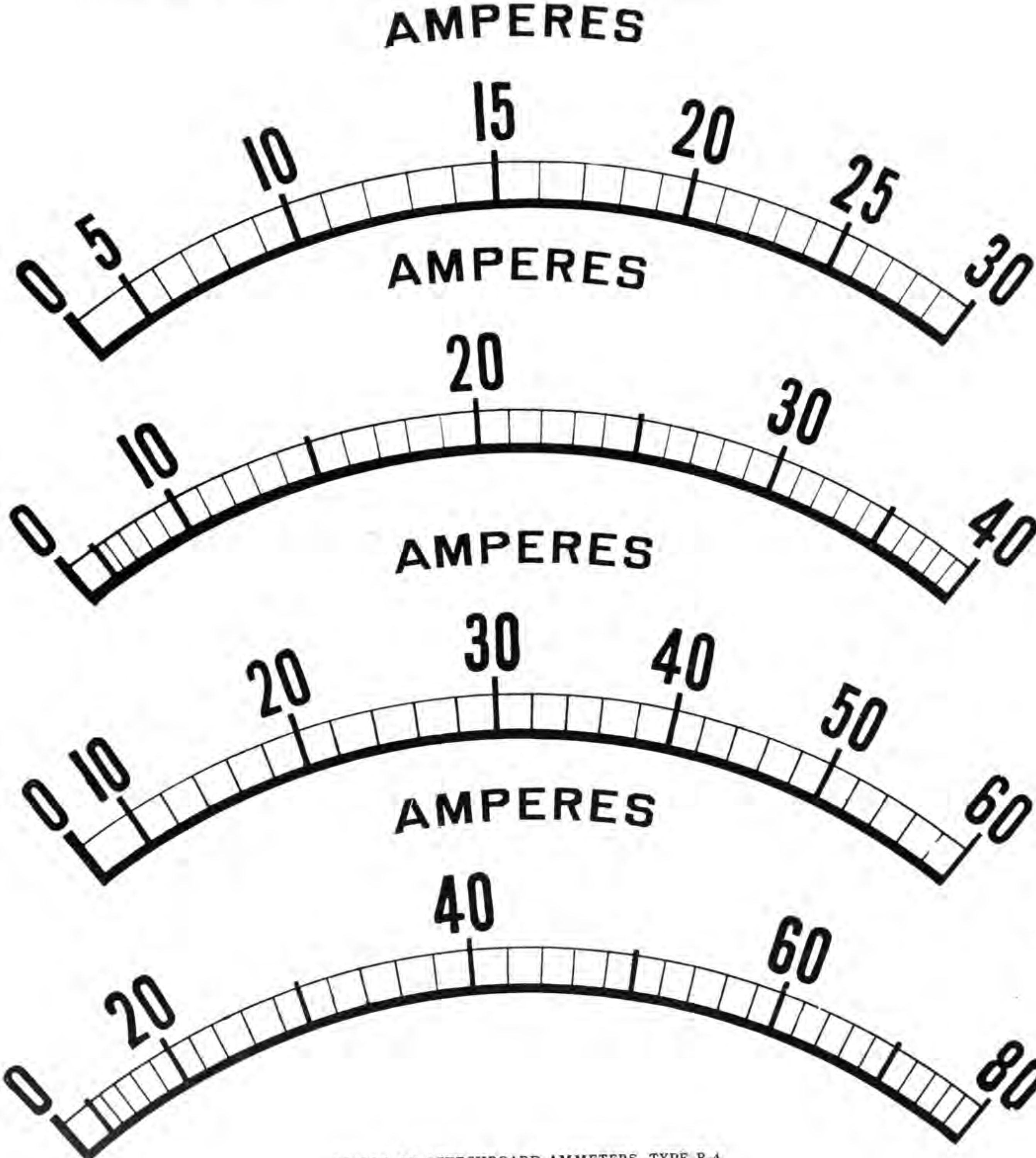
SCALES OF SWITCHBOARD AMMETERS, TYPE R-6
(Illustrations are Actual Size of Scales)



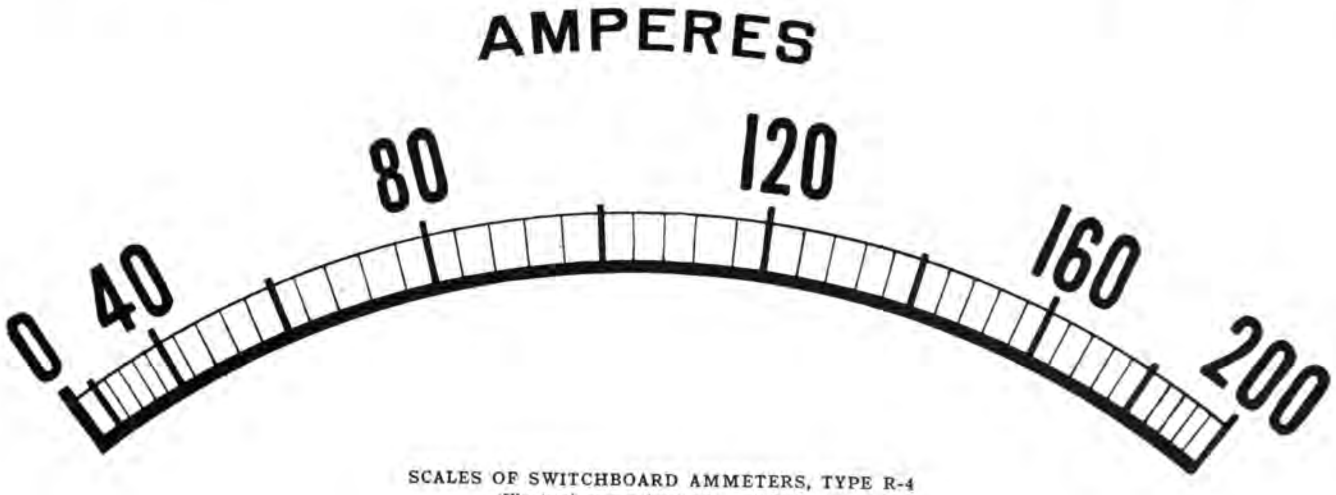
SCALES OF SWITCHBOARD VOLTMETERS, TYPE R-6
(Illustrations are Actual Size of Scales)



SCALES OF SWITCHBOARD AMMETERS, TYPE R-4
(Illustrations are Actual Size of Scales)



SCALES OF SWITCHBOARD AMMETERS, TYPE R-4
(Illustrations are Actual Size of Scales)



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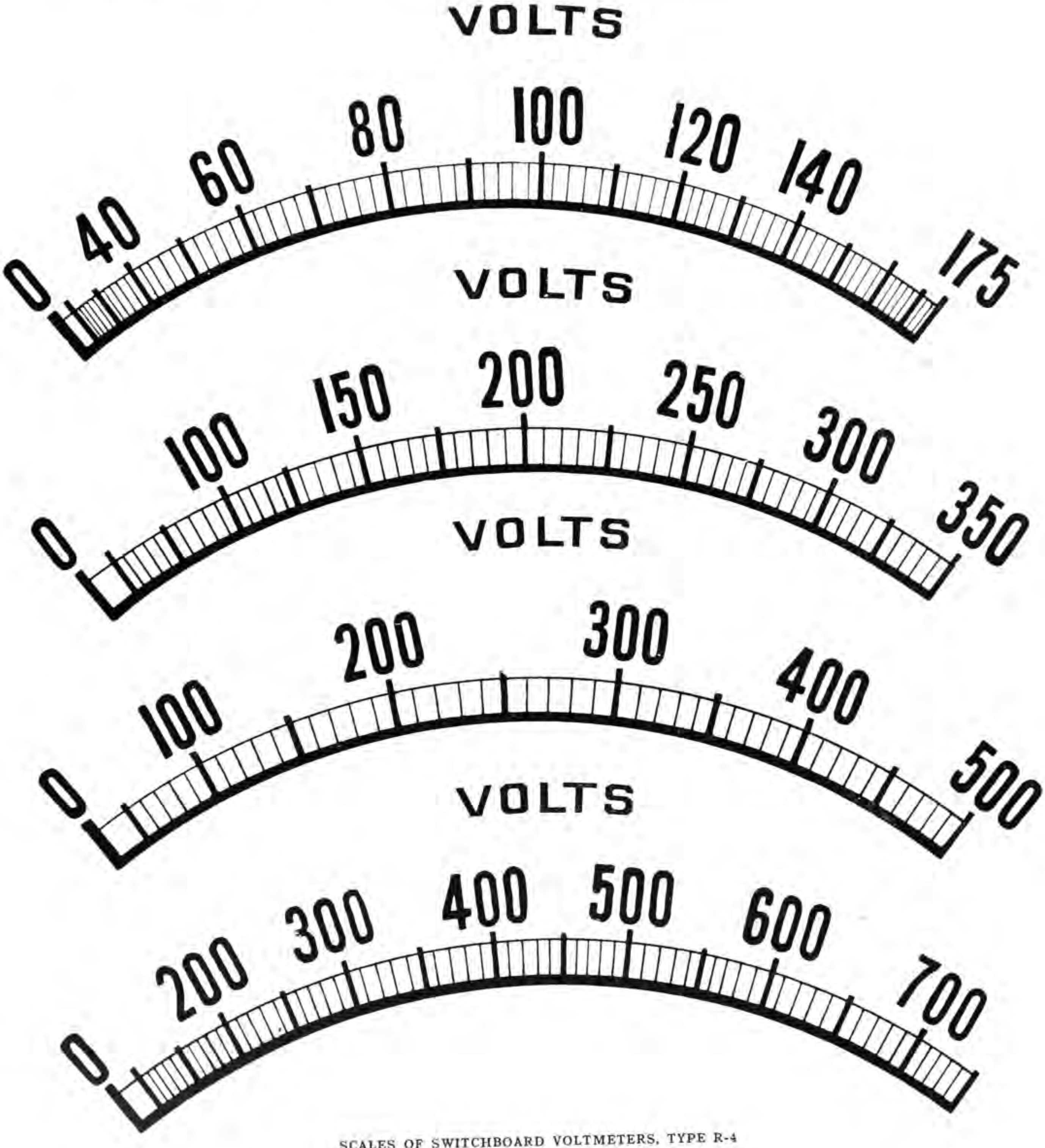
(Illustrations are Actual Size of Scales)



SCALES OF SWITCHBOARD VOLTMETERS, TYPE R-4
(Illustrations are Actual Size of Scales)

GENERAL ELECTRIC COMPANY

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General Electric Company
Schenectady, N.Y.

SUPPLY DEPARTMENT

April, 1911 | *Bulletin No. 4826*

THE G.E. WATER FLOW METER

THE economical handling of water, like that of electricity, gas and other commodities, depends on accurate information which will show the amount pumped, consumed or distributed.

The G.E. water flow meter provides a means of obtaining such information.

PRINCIPLE OF OPERATION

If the temperature of the water be constant, the rate of flow in the pipe will be proportional to the velocity. To measure this velocity, a nozzle plug is screwed into the pipe at the point where the water flow is to be measured. One set of openings, called the leading set, extends horizontally across a diameter of the water main and faces against the direction of flow. The other three openings, one opposite, the others at right angles to the leading holes, near the center of the plug, constitute the trailing set. The water, impinging against the leading set of openings, sets up a pressure in them which equals the static pressure plus a pressure due to the velocity head. The pressure in the trailing set is equal to the static pressure minus a pressure due to the velocity head.

RECORDING WATER FLOW METER, TYPE RW

Since the leading set of openings extends approximately across a diameter of the pipe, the velocity pressure transmitted to the meter is the mean velocity pressure due to flow of the water.

The introduction of the nozzle plug in the water main causes an inappreciable drop in pressure even at very high rate of flow. The nozzle plugs can be used interchangeably on either vertical or horizontal pipes.

OPERATION ON RECIPROCATING PUMPS

The meter will give accurate results when measuring water delivered by reciprocating as well as centrifugal pumps or gravity flow, provided the water flow at the point of installing the nozzle plug is not periodically intermittent. This condition will not occur if the reciprocating pumps are fitted with air chambers which have sufficient capacity to eliminate pulsations in the water mains. If the pump should not have such an air chamber, one may be installed very easily either on the pump itself or in the water main.

UNITS OF CALIBRATION

The G.E. water flow meters are calibrated to read in gallons per minute at 39.1 deg. F.

SERVICE FOR WHICH THE METER IS ADAPTED

Recording the output of a pumping plant.

Recording the total amount of water consumed by a municipality, or the amount distributed to different sections of it.

Recording the water input to water turbines, and deterioration of their efficiencies.

Recording the amount of water consumed in manufacturing processes.

Recording the amount of feed water delivered to a boiler or a battery of boilers.

NOZZLE PLUG FOR WATER FLOW METER

INSTALLATION

To install the meter under normal conditions, there is no interference with the water piping, all that is necessary being to drill and tap a ½ in. hole in pipes of less than 4 in. in diameter, or a ¾ in. hole in pipes 4 in. and over in diameter. The hole should be drilled in the pipe so that the axis of the nozzle plug is in the plane of the preceding elbow.

The nozzle plug must be placed in a straight run of pipe at least eight pipe diameters in length and with its axis in the plane of the preceding elbow.

The meter may be located in any desired place below the nozzle plug to which it is connected by ¼ in. iron pipe.

THE G.E. RECORDING WATER FLOW METER, TYPE RW

The G.E. recording water flow meter Type RW is a curve drawing instrument giving an accurate record of the rate of flow of water in gallons per minute in pipe of any size, at any condition of temperature or pressure within the range of the meter.

Recording the amount of cooling water used in condensers.

Determining the slippage in pumps due to leaky plunger packing or to worn valves.

Discovering losses due to leaks in water mains, etc.

DESCRIPTION

The meter consists of two cylindrical, hollow cups filled to about half their height with mercury and joined at the bottom by a hollow tube. This arrangement of cups and connecting tube forms a "U" tube, which is supported on, and is free to move as a balance about a set of knife edges.

A difference of pressure in the nozzle plug is communicated to the cups by flexible steel tubing placed inside the case. This difference of pressure causes the mercury to rise in the left-hand cup and fall the same amount in the right-hand cup until the unbalanced columns of mercury exactly balance the difference in pressure.

By the displacement of the mercury, the beam carrying the cups moves downward on the left-hand side of the knife edges.

This side will descend until the moment of the weights on the right side of the knife edges exactly balances the moment caused by the displacement of the mercury into the left-hand cup. The motion of the beam is multiplied by levers, and actuates the pen which moves in proportion to the amount of mercury displaced.

The time element of the meter consists of an eight day clock which drives the drum feeding the paper. The paper on which the record is made is so calibrated that the rate of flow in gallons per minute may be read at any instant or the average rate calculated for a given time.

Meters are equipped with a reroll device operated by a spring mechanism, and this device is of sufficient capacity to accommodate one complete roll of paper.

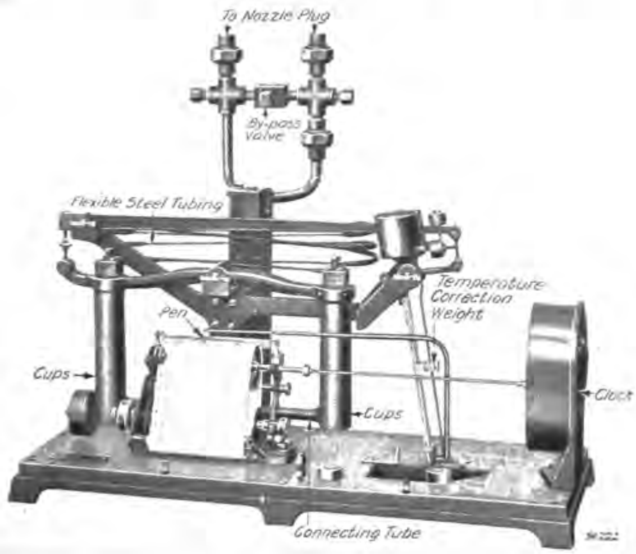
ADJUSTMENTS FOR PIPE DIAMETER TEMPERATURE AND AMOUNTS OF FLOW

The meter may be readily set by the attendant for different pipe sizes, temperature and amounts of flow.

This adjustment consists of setting the temperature and pipe diameter correction weight a given distance on the graduated arm, and this distance for the existing condition of temperature, pipe diameter and flow is determined by means of a curve sent out with each meter.

FLEXIBILITY OF OPERATION

The Type RW meter may be used to measure the flow under normal conditions in any number of different pipes; since it is necessary only to provide the pipe with a nozzle plug of the proper length to which the meter can be connected, and place on the meter a record roll of suitable range.



RECORDING WATER FLOW METER, TYPE RW

PAPER FEEDS

Meters are furnished with standard paper feed of 3 inches per hour, though 1 inch or 6 inches per hour feed can be supplied.

FINISH

The interior and the working parts of the meter are finished in dull black and nickel; the case is finished in dull black with glass front.

4826–4 The G.E. Water Flow Meter

WEIGHT

The meter weighs complete 55 lb.

DIMENSIONS

23 in. by 9 in. by 13 in.

G.E. RECORDING WATER FLOW METERS

TYPE RW

Pressure range, any pressure up to 250 lb. gauge.

Temperature range, 39.1 deg. to 300 deg. F.

Cat. No.	Pipe Diameter in In.	Cat. No.	Pipe Diameter in In.
116189	2	116200	22
116190	3	116201	24
116191	4	116202	26
116192	6	116203	28
116193	8	116204	30
116194	10	116205	32
116195	12	116206	34
116196	14	116207	36
116197	16	116208	38
116198	18	116209	40
116199	20		

Cat. Nos. include meter complete with nozzle plug.

Meters can be furnished for pipes larger than 40 inches if desired.

Extra clocks for 1 inch, 3 inch or 6 inch per hour feed can be supplied.

Shipping weight, 85 lb.

ADDITIONAL NOZZLE PLUGS FOR USE WITH THE RECORDING WATER FLOW METER

TYPE RW

Cat. No.	Pipe Diameter in In.	Cat. No.	Pipe Diameter in In.
103565	2	116272	22
103566	3	116273	24
103567	4	116274	26
103568	6	116275	28
103569	8	116276	30
103570	10	116277	32
103571	12	116278	34
103572	14	116279	36
116269	16	116280	38
116270	18	116281	40
116271	20		

Cat. Nos. include two valves, two tees and piping between tees and nozzle plugs.

Nozzle plugs can be furnished for pipes larger than 40 inches if desired.

Shipping weight, 15 lb.

When Ordering Recording Water Flow Meters Always Give the Following Information:

Cat. Nos. of meters desired.

Cat. Nos. of additional nozzle plugs desired.

Approximate maximum flow through each pipe to be metered.

For what purpose is water used?

Will the water flow by gravity or will it be pumped by centrifugal or by reciprocating pumps? If by the latter, send a simple sketch showing the plan and elevation of piping with dimensions, including all branch mains, location of air chambers and indicate the point at which it is desired to locate the nozzle plug.

Can the nozzle plug be placed in a straight run of pipe at least eight pipe diameters in length and with its axis in the plane of the preceding elbow?

FLOW RANGE

The following table gives the maximum and minimum rates of flow in gallons per minute, which can be accurately measured with different charts and in pipes of various diameters.

If the actual rate of flow of water to be metered is more or less than can be accurately measured under existing conditions of pipe diameter, accurate results can be obtained by inserting in the water main a section of pipe of greater or less diameter, in which section the nozzle plug is installed. This section of pipe should be eight pipe diameters or more in length.

FLOW RANGE TABLE

Pipe Diam. in In.	Max. Flow in Gal. per Min.	Min. Flow in Gal. per Min.
2	50	22
	60	22
	80	22
3	120	60
	160	60
	200	60
4	240	100
	300	100
	400	100
6	500	236
	600	236
	800	236
8	1000	416
	1200	416
	1600	416
10	1600	660
	2000	660
	2400	660
12	2000	940
	2400	940
	3000	940
14	3000	1280
	4000	1280
	5000	1280
16	4000	1680
	5000	1680
	6000	1680
18	5000	2120
	6000	2120
	8000	2120
20	6000	2630
	8000	2630
	10000	2630
22	8000	3200
	10000	3200
	12000	3200
24	10000	3800
	12000	3800
26	10000	4460
	12000	4460
	16000	4460
28	12000	5200
	16000	5200
	20000	5200
30	16000	6050
	20000	6050
32	16000	6870
	20000	6870
	24000	6870
34	20000	7650
	24000	7650
	30000	7650
36	20000	8700
	24000	8700
	30000	8700
38	24000	9500
	30000	9500
40	24000	10780
	30000	10780
	40000	10780

NOTE.—By furnishing a special compensating weight the maximum flow ranges may be increased from 5 to 25 per cent. without changing the water piping.

GENERAL ELECTRIC COMPANY

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Canadian General Electric Co., Ltd., Toronto, Ont.

General Electric Company
Schenectady, N.Y.

SUPPLY DEPARTMENT

April, 1911 | Bulletin No. 4827

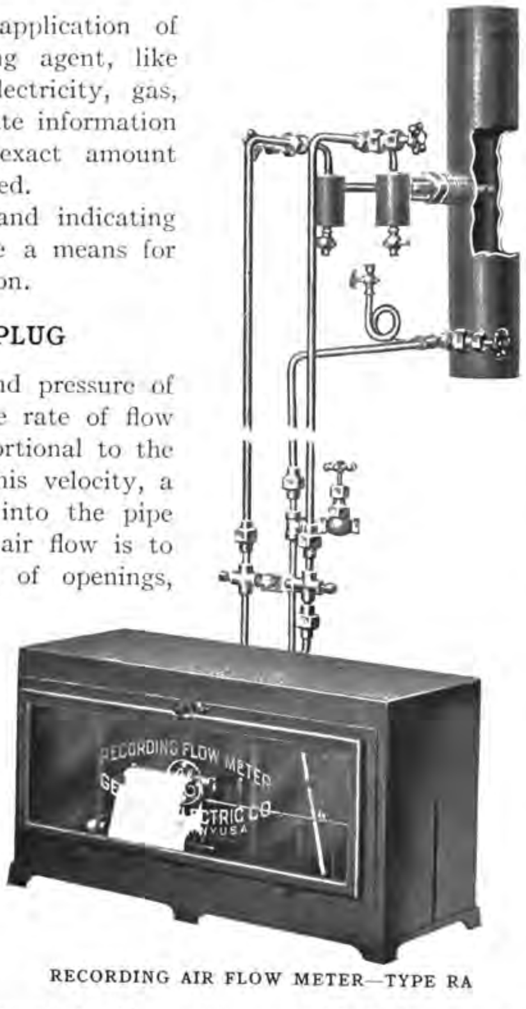
THE G.E. AIR FLOW METER

THE economical application of air as a working agent, like that of steam, electricity, gas, etc., depends on accurate information which will show the exact amount compressed or distributed.

The G.E. recording and indicating air flow meters provide a means for obtaining this information.

THE NOZZLE PLUG

If the temperature and pressure of the air be constant, the rate of flow in a pipe will be proportional to the velocity. To measure this velocity, a nozzle plug is screwed into the pipe at the point where the air flow is to be measured. One set of openings, known as the leading set, extends horizontally across the air main and faces against the direction of flow. The other three openings near the center of the plug constitute the trailing set. The air, impinging against the leading set of openings, sets up a pressure in them which is equal to the static pressure plus a pressure due to the velocity head. The pressure in the trailing set is equal to the static pressure minus a pressure due to the velocity head. Since the leading set of openings extends approximately across a diameter of the pipe, the velocity pressure transmitted to the meter is the mean velocity pressure due to the flow of the air.



RECORDING AIR FLOW METER—TYPE RA

The introduction of the nozzle plug in the air main causes an inappreciable drop in pressure even at very high rates of flow.

OPERATION ON RECIPROCATING COMPRESSORS

The meters will give accurate results when measuring air compressed by reciprocating as well as rotary compressors, provided the nozzle plug can be inserted in the air line at a point where the flow is not periodically intermittent.

NOTE: The data in this publication are for the convenience of customers, and every effort is made to avoid error, but this Company does not guarantee their correctness, nor does it hold itself responsible for any errors or omissions in this publication. Subject to change without notice.

UNITS OF CALIBRATION

The G.E. air flow meters are calibrated to read in cubic feet of free air per minute at a temperature of 70 deg. F.

INSTALLATION

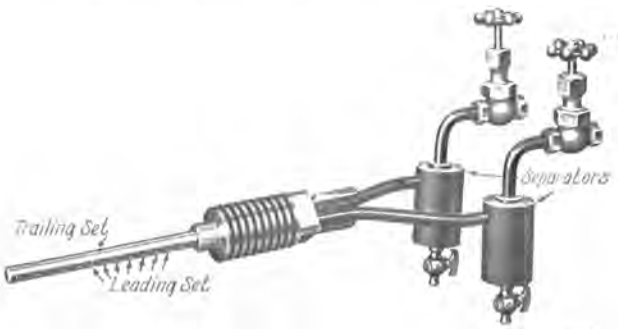
To install the meters under normal conditions, there is no interference with the main piping; all that is necessary being to drill and tap a hole for inserting the nozzle plug

Recording the amount of air delivered to blast furnaces.

Recording the amount of air delivered to mines for ventilation or operation of machinery.

Determining the efficiency of compressors and different kinds of compressed air machinery.

Discovering losses originating from leaks between compressors and points of consumption due to defective valves, gaskets or piping.



NOZZLE PLUG FOR AIR FLOW METER

in a straight vertical or horizontal run of pipe twelve pipe diameters in length.

The meters may be placed in any desired position above or below the nozzle plug to which they are connected by ¼ in. iron pipe.

THE G.E. RECORDING AIR FLOW METER

TYPE RA

The G.E. recording flow meter Type RA, is a curve drawing instrument giving an accurate record of the total rate of flow of air in cubic feet of free air per minute at 70 deg. F.

SERVICE FOR WHICH METER IS ADAPTED

Recording the total amount of air delivered to any department of a manufacturing plant.

DESCRIPTION

The meter consists of two hollow cylindrical cups filled to about half their height with mercury and joined at the bottom by a hollow tube. The arrangement of cups and connecting tube forms a "U" tube, which is supported on, and free to move as a balance about a set of knife edges.

A difference of pressure in the nozzle plug is communicated to the cups by flexible steel tubing placed inside the case. This difference of pressure causes the mercury to rise in the left-hand cup and fall the same amount in the right-hand cup until the unbalanced columns of mercury exactly balance the difference in pressure.

By the displacement of the mercury, the beam carrying the cups moves downward on the left-hand side of the knife edges. This side will descend until the moment of the weights on the right of the knife edges exactly balances the moment caused by the displacement of the mercury into the left-hand cup. The motion of the beam is multiplied by levers and actuates the pen which moves in proportion to the amount of mercury displaced.

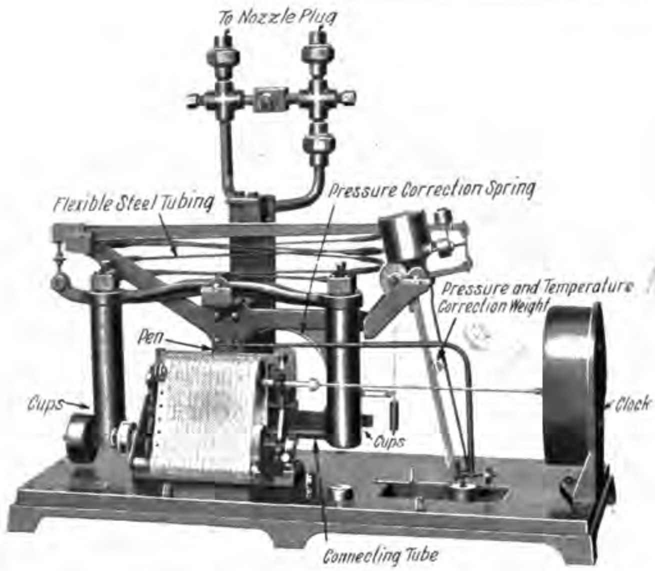
The time element of the meter consists of an eight-day clock which drives the drum feeding the paper. The paper on which the record is made is so calibrated that the rate of flow in cubic feet of free air per minute may be read at any instant or the average rate calculated for a given time.

Meters are equipped with a reroll device of sufficient capacity to accommodate one complete roll of paper.

COMPENSATING DEVICE FOR PRESSURE AND TEMPERATURE VARIATION

The velocity of the air being measured may remain practically constant while the pressure and temperature vary over a considerable range. Therefore, to obtain the actual rate of flow it is necessary to compensate for pressure and temperature fluctuations.

Compensation is made automatically in the case of the pressure variations. A hollow spring, similar to the pressure spring in a steam gauge is connected so as to be influenced by the static pressure at the point where the flow is being measured. Any variation of the static pressure causes the spring to expand or contract, and this movement actuates a small correction weight in such a manner as to affect the deflection of the pen, so that the indicated rate of flow recorded by the pen is correct for the pressure existing in the air main at the point where the flow is being measured.



RECORDING AIR FLOW METER WITH AUTOMATIC PRESSURE CORRECTION—TYPE RA

Compensation for temperature variations is made by an independent hand adjustment of the same correction weight which corrects the reading for pressure fluctuations. This adjustment is made by increasing or decreasing the distance of the correction weight from its point of suspension and this distance is determined from a curve sent out with each meter.

Meters Suitable for Measuring Flow at Constant Temperature and Pressure

In many plants, the temperature and pressure at which air is delivered are held practically constant. To meet this condition, the recording flow meter will be furnished without the automatic pressure compensating device.

The meters can be adjusted by the attendant to give the true rate of flow at the existing pressure and temperature. If it is desired to measure the flow at any other temperature or pressure, the meter must be readjusted by hand for these conditions. This adjustment is readily made by properly setting the compensating weight.

FINISH

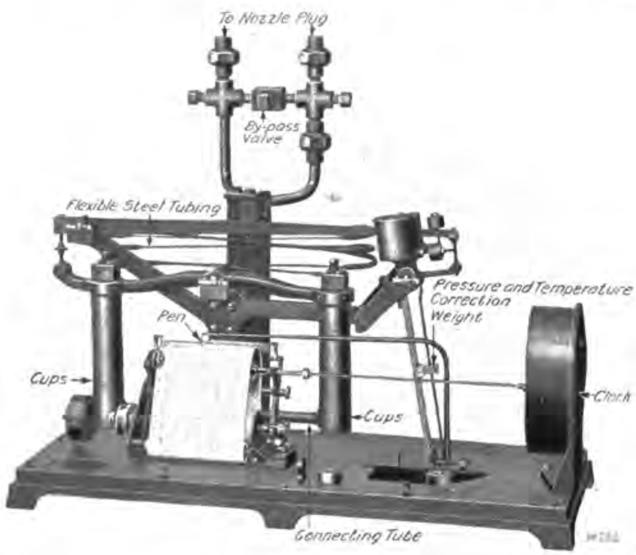
The interior and working parts of the meter are finished in dull black and nickel. The case is finished in dull black with glass front.

WEIGHT

The meter weighs complete 55 lb.

DIMENSIONS

23 in. by 9 in. by 13 in.



RECORDING AIR FLOW METER WITHOUT AUTOMATIC PRESSURE CORRECTION—TYPE RA

FLEXIBILITY OF OPERATION

The Type RA meter may be used to measure the flow under normal conditions in any number of different pipe lines; since it is necessary only to provide the pipe with a nozzle plug of the proper length to which the meter can be connected, and to place on the meter a record roll of the proper range.

PAPER FEEDS

Meters are furnished with standard paper feed of 3 inches per hour, though 1 inch or 6 inches per hour feed can be supplied.

G.E. RECORDING AIR FLOW METER
TYPE RA

Pressure range, 15 to 140 lb. absolute.

Temperature range, 0 deg. to 520 deg. F.

With Automatic Pressure Correction Device		Without Automatic Pressure Correction Device	
Cat. No.	Pipe Diam. in In.	Cat. No.	Pipe Diam. in In.
116167	2	116178	2
116168	3	116179	3
116169	4	116180	4
116170	6	116181	6
116171	8	116182	8
116172	10	116183	10
116173	12	116184	12
116174	14	116185	14
116175	16	116186	16
116176	18	116187	18
116177	20	116188	20

Cat. Nos. include meter complete with nozzle plug.

Meters can be furnished for pipes larger than 20 inches if desired.

Shipping weight, 85 lb.

ADDITIONAL NOZZLE PLUGS FOR USE WITH THE RECORDING AIR FLOW METER

TYPE RA

Cat. No.	Pipe Diam. in In.	Cat. No.	Pipe Diam. in In.
103557	2	103563	12
103558	3	103564	14
103559	4	116266	16
103560	6	116267	18
103561	8	116268	20
103562	10		

Cat. Nos. include two valves, two pet cocks, two separators and piping between nozzle plug and separators.

Nozzle plugs can be furnished for pipes larger than 20 inches if desired.

Shipping weight, 15 lb.

FLOW RANGE

The following table gives the maximum and minimum rates of flow in cubic feet of free air per minute at 70 deg. F. which can be accurately measured with different charts and at different pressures, temperatures and in pipes of various diameters. If the existing air pressure is other than that given in the table, the values for the maximum and minimum flows can be closely approximated by interpolation.

If the actual rate of flow of air to be metered is more or less than can be accurately measured under the existing conditions of pressure, temperature and pipe diameter, accurate results can be obtained by inserting in the air line a section of pipe of greater or less diameter in which section the nozzle plug is installed. This section of pipe should be twelve pipe diameters or more in length.

FLOW RANGE TABLE

TEMPERATURE RANGE 32 DEG. TO 200 DEG. F.

Pipe Diam. in Inches	PRESSURE — Flow in Cubic Feet											
	25 Lb. Abs.		40 Lb. Abs.		60 Lb. Abs.		80 Lb. Abs.		100 Lb. Abs.		130 Lb. Abs.	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
2	500*	135*	500*	150*	500	164	500	180	500 800	212 212	500 800	246 246
3	800 1000	270 270	800 1000	350 350	1000 1600	432 432	1600	476	1600 2000	560 560	1600 2000	650 650
4	1600	500	1600 2000	640 640	2000 3000	793 793	2000 3000	875 875	3000	1030	3000 4000	1190 1190
6	3000 4000	1080 1080	4000 5000	1380 1380	4000 5000 6000	1720 1720 1720	5000 6000	1900 1900	6000 8000	2230 2230	6000 8000 10000	2580 2580 2580
8	5000 6000 8000*	2160 2160 2160	6000 8000	2580 2580	8000 10000 12000	3200 3200 3200	8000 10000 12000	3680 3680 3680	10000 12000 16000	4140 4140 4140	12000 16000	4800 4800
10	8000 10000	3100 3100	10000 12000	3960 3960	12000 16000	4930 4930	16000 20000	5420 5420	16000 20000	6360 6360	20000 24000	7400 7400
12	12000 16000	4400 4400	16000 20000	5650 5650	16000 20000 24000	7000 7000 7000	20000 24000 30000	7720 7720 7720	24000 24000 30000	6360 9070 9070	24000 30000 40000	10560 10560 10560
14	16000 20000	6200 6200	20050 24000 30000	8000 8000 8000	24000 30000	9800 9800	30000 40000	10850 10850	30000 40000	12700 12700	40000 50000	14750 14750
16	24000 30000	8300 8300	24000 30000	11600 11600	30000 40000	13200 13200	40000 50000	14500 14500	40000 50000 60000	17000 17000 17000	50000 60000	19800 19800
18	30000 40000*	10800 10800	40000 50000	13400 13400	40000 50000	16700 16700	50000 60000	18400 18400	50000 60000	21350 21350	60000	25000
20	40000 50000*	13500 13500	40000 50000 60000	16600 16600 16600	50000 60000	20600 20600	60000	22700	60000	26700	60000	31000

FLOW RANGE TABLE (Cont'd)

TEMPERATURE RANGE 200 DEG. TO 520 DEG. F.

Pipe Diam. in Inches	PRESSURE — 25 Lb. Abs. Max.	25 Lb. Abs. Min.	40 Lb. Abs. Max.	40 Lb. Abs. Min.	60 Lb. Abs. Max.	60 Lb. Abs. Min.	80 Lb. Abs. Max.	80 Lb. Abs. Min.	100 Lb. Abs. Max.	100 Lb. Abs. Min.	130 Lb. Abs. Max.	130 Lb. Abs. Min.
	Flow in Cubic Feet											
2	350*	135*	450*	150*	500	135	500	155	500	174	500	202
3	800*	270	800 1000	285 285	800 1000	354 354	1000	408	1000 1600	458 458	1600 2000	532 532
4	1600*	500	1600	523	1600 2000	650 650	2000	750	2000 3000	840 840	2000 3000	975 975
6	3000*	1080	3000 4000	1135 1135	3000 4000 5000	1410 1410 1410	4000 5000 6000	1630 1630 1630	5000 6000	1830 1830	5000 6000 8000	2120 2120 2120
8	5000 6000*	1620 1620	5000 6000	2110 2110	6000 8000	2620 2620	8000 10000	3020 3020	8000 10000 12000	3390 3390 3390	10000 12000	3960 3960
10	8000 10000*	3240 3240	8000 10000 12000	3340 3340 3340	10000 12000	4040 4040	12000 16000	4650 4650	12000 16000 20000	5230 5230 5230	16000 20000	6050 6050
12	12000*	4320	12000 16000	4630 4630	16000 20000	5750 5750	16000 20000 24000	6680 6680 6680	20000 24000	7450 7450	20000 24000 30000	8640 8640 8640
14	16000 20000	5400 5400	16000 20000 24000	6500 6500 6500	20000 24000 30000	8060 8060 8060	20000 24000 30000	9300 9300 9300	24000 30000 40000	10430 10430 10430	30000 40000	12100 12100
16	24000 30000*	8100 8100	20000 24000 30000	8700 8700 8700	24000 30000 40000	10800 10800 10800	30000 40000	12500 12500	30000 40000 50000	14000 14000 14000	40000 50000	16200 16200
18	30000 40000*	10800 10800	30000 40000	11000 11000	30000 40000 50000	13700 13700 13700	40000 50000	15800 15800	40000 50000 60000	17700 17700 17700	50000 60000	20500 20500
20	40000 50000*	13500 13500	40000 50000	13600 13600	40000 50000 60000	16900 16900 16900	50000 60000	19500 19500	50000 60000	21900 21900	60000	25400

* Special compensating weight necessary.

NOTE.—By using a special compensating weight all the maximum flow ranges given in this table, excepting those for 2 inch pipe 520 deg. F. temperature, may be increased from 5 to 22 per cent. without changing the air piping.

G.E. INDICATING AIR FLOW METER, TYPE FA

The Type FA meter will meet general commercial requirements where an indicating rather than a recording instrument is required. Owing to its light weight and simple construction, it will be found especially useful for testing work, locating troubles, etc.

This meter will indicate the instantaneous rate of flow of air in cubic feet of free air per minute at 70 deg. F. in any pipe of any diameter at any condition of temperature or pressure within the range of the meter.

SERVICE FOR WHICH THE METER IS ADAPTED

Indicating the total amount of air delivered to any department of a manufacturing plant.

Indicating the amount of air delivered to blast furnaces.

Indicating the amount of air delivered to mines for ventilation or operation of machinery.

Determining the efficiency of compressors and different kinds of compressed air machinery.

INDICATING AIR FLOW METER—TYPE FA

Discovering losses originating from leaks between compressors and points of consumption due to defective valves, gaskets or piping.

DESCRIPTION

The meter consists of an iron casting which is cored out to form a "U" tube. This is filled for part of its height with water. (See Fig. 1.) A difference of pressure in the nozzles of the plug causes a difference in level of the water in the "U" tube. A small float suspended by a silk cord actuates a pulley over which the cord passes. The pulley in turn moves a small magnet on the end of the shaft next to the dial in proportion to the change in level of the water in the "U" tube. (See Fig. 1.) The indicating needle is mounted in a separate cylindrical casing. This needle carries another magnet which is free to turn in the same plane as the magnet on the inside of the meter. The mutual attraction of these two magnets keeps them always parallel and the necessity of a packed joint in transmitting the motion of the pulley to the indicating needle is thus eliminated.

The piping, reservoirs and nozzle plugs are of the same general design as those used with the recording meter.

METHOD OF MAKING OBSERVATIONS

The proper adjustments for pipe diameters, temperature and pressure are readily made by setting the graduated cylinders (see Fig. 1) which actuate the rack carrying the pointer. When these settings are made, the rack is rotated by hand until the pointer coincides with the indicating needle. The point on the graduated scale at the intersection of the needle and pointer gives the true instantaneous rate of flow in cubic feet of free air per minute at 70 deg. F.

If the temperature and pressure of the air remain practically constant, only a single adjustment of the graduated cylinders is necessary for making observations.

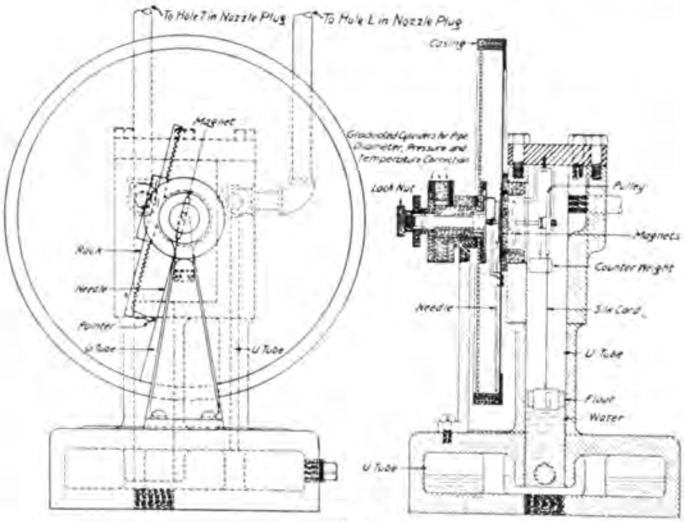


FIG. 1

FLEXIBILITY OF OPERATION

The Type FA meter may be used to measure the flow under normal conditions in any number of pipe lines in the plant; since all that is necessary is to provide the pipe with a nozzle plug of the proper length to which the meter can be connected. Since the meter is light and compact, it can be easily carried about and used as a portable instrument.

FINISH

The meter is finished in black japan and nickel.

WEIGHT

The meter weighs complete 25 lb.

G.E. INDICATING AIR FLOW METERS

TYPE FA

LOW PRESSURE Pressure Range, 12 to 35 Lb. Abs. Temperature Range, 30 Deg. to 210 Deg. F. Cat. No.	HIGH PRESSURE Pressure Range, 10 to 120 Lb. Gauge. Temperature Range, 30 Deg. to 210 Deg. F. Cat. No.	Pipe Diameter in In.
116244	116255	2
116245	116256	3
116246	116257	4
116247	116258	6
116248	116259	8
116249	116260	10
116250	116261	12
116251	116262	14
116252	116263	16
116253	116264	18
116254	116265	20

Cat. Nos. include meter complete with nozzle plug.

Meters can be furnished for pipes larger than 20 inches if desired.

Shipping weight, 40 lb.

ADDITIONAL NOZZLE PLUGS FOR USE WITH INDICATING AIR FLOW METER

TYPE FA

Cat. No.	Pipe Diam. in In.
103557	2
103558	3
103559	4
103560	6
103561	8
103562	10
103563	12
103564	14
116266	16
116267	18
116268	20

Cat. Nos. include two valves, two pet cocks, two separators and piping between the nozzle plug and separators.

Nozzle plugs can be furnished for pipes larger than 20 inches if desired.

Shipping weight, 15 lb.

FLOW RANGE

The following table gives the maximum and minimum rate of flow in cubic feet of free air per minute at 70 deg. F. which can be accurately measured at different pressures and temperatures, and in pipes of various diameters. If the existing air pressure be other than that given in the table, the values for the maximum and minimum flows can be closely approximated by interpolation.

If the actual rate of flow of air to be metered be more or less than can be accurately measured under the existing conditions of pressure, temperature and pipe diameter, accurate results can be obtained by inserting in the air line a section of pipe of greater or less diameter in which section the nozzle plug is installed. This section of pipe should be twelve pipe diameters or more in length.

FLOW RANGE TABLE

LOW PRESSURE

TEMPERATURE 30 DEG. TO 120 DEG. F.

Pipe Diam. in Inches	PRESSURE 15 Lb. Abs.		20 Lb. Abs.		25 Lb. Abs.		30 Lb. Abs.		35 Lb. Abs.	
	Flow in Cubic Feet									
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
2	98*	35*	115	42.4	130	47	141	52	155	56.5
3	265	95.5	302	106	340	117	378	138	414	149
4	470	169	545	195	616	218	677	244	736	264
6	1060	382	1230	467	1400	510	1530	555	1680	595
8	1890	680	2190	830	2490	910	2720	980	3000	1060
10	2950	1060	3420	1300	3900	1415	4250	1530	4670	1650
12	4250	1525	4910	1865	5600	2030	6100	2200	6700	2380
14	5770	2080	6700	2540	7600	2770	8300	3000	9150	3240
16	5750	2710	8750	3310	9950	3610	10840	3910	11900	4220
18	9550	3430	11100	4200	12600	4580	13700	4950	15100	5350
20	11800	4250	13650	5170	15500	5650	16950	6100	18800	6600

TEMPERATURE 120 DEG. TO 210 DEG. F.

2	90*	32*	105*	37*	120	42.5	132	47	144	52
3	240*	87*	282	95.5	318	116	350	127	382	137.5
4	425*	155*	508	188	565	206	620	225	675	244
6	960*	350*	1150	425	1275	467	1440	510	1570	555
8	1700*	625*	2040	755	2260	830	2560	910	2800	980
10	2740*	980*	3180	1180	3540	1300	4000	1415	4360	1530
12	3850*	1410*	4580	1700	5100	1865	5750	2030	6260	2200
14	5200*	1910*	6250	2310	6940	2540	7850	2770	8550	3000
16	6820*	2500*	8150	3010	9050	3310	10250	3610	11150	3910
18	8630*	3170*	10600	3820	11450	4200	13000	4580	14100	4950
20	10650*	3900*	12700	4700	14100	5170	16000	5650	17400	6100

*Values are obtained by applying to the meter readings a constant derived from a correction curve.

FLOW RANGE TABLE (Cont'd)

HIGH PRESSURE

TEMPERATURE 30 DEG. TO 120 DEG. F.

Pipe Diam. in Inches	PRESSURE — Flow in Cubic Feet									
	20 Lb. Gauge		40 Lb. Gauge		75 Lb. Gauge		100 Lb. Gauge		120 Lb. Gauge	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
2	144*	53*	195	72	254	94	290	107	314	116
3	400	148	500	184	670	247	750	282	835	300
4	730	264	930	339	1200	440	1380	500	1500	550
6	1640	594	2090	765	2740	1020	3140	1130	3420	1240
8	2910	1050	3770	1360	4920	1810	5580	2010	6080	2210
10	4550	1650	5900	2120	7700	2830	8720	3140	9500	3460
12	6570	2380	8500	3060	11100	4080	12700	4650	13700	5000
14	8940	3230	11500	4150	15100	5550	17200	6300	18600	6770
16	11650	4220	15100	5420	19700	7250	22500	8250	24300	8850
18	15000	5600	19000	6880	25200	9150	28500	10400	30800	11200
20	18500	6920	23600	8500	31200	11300	35200	12900	36600*	13200*

TEMPERATURE 120 DEG. TO 210 DEG. F.

2	133*	48*	182	66	236	85	270	97	296	107
3	375	140	480	176	620	226	715	260	780	282
4	680	250	865	314	1130	415	1280	475	1400	515
6	1525	565	1950	706	2570	934	2910	1070	3160	1160
8	2710	1010	3460	1260	4570	1660	5170	1910	5620	2060
10	4250	1570	5400	1960	7150	2600	8100	2980	8800	3220
12	6100	2260	7920	2940	10300	3740	11800	4300	12800	4750
14	8300	3080	10800	4000	14000	5070	16000	5850	17400	6460
16	10800	4000	14000	5220	18300	6620	20900	7630	22700	8450
18	13700	5100	17800	6600	23200	8400	26400	9680	28800	10700
20	17000	6300	20000	8200	28600	10350	32700	11950	35500	13200

* Values are obtained by applying to the meter readings a constant derived from a correction curve.

When Ordering Recording or Indicating Air Flow Meters Always Give the Following Information:

Cat. Nos. of meters desired.

Cat. Nos. of additional nozzle plugs desired.

Approximate maximum air flow through each pipe to be metered in cubic feet of free air per minute at 70 deg. F.

For what purpose is air in each pipe metered to be used?

What is the maximum and minimum pressure in pounds gauge?

Can the nozzle plug be placed in a straight vertical or horizontal run of pipe at least twelve pipe diameters in length?

GENERAL ELECTRIC COMPANY

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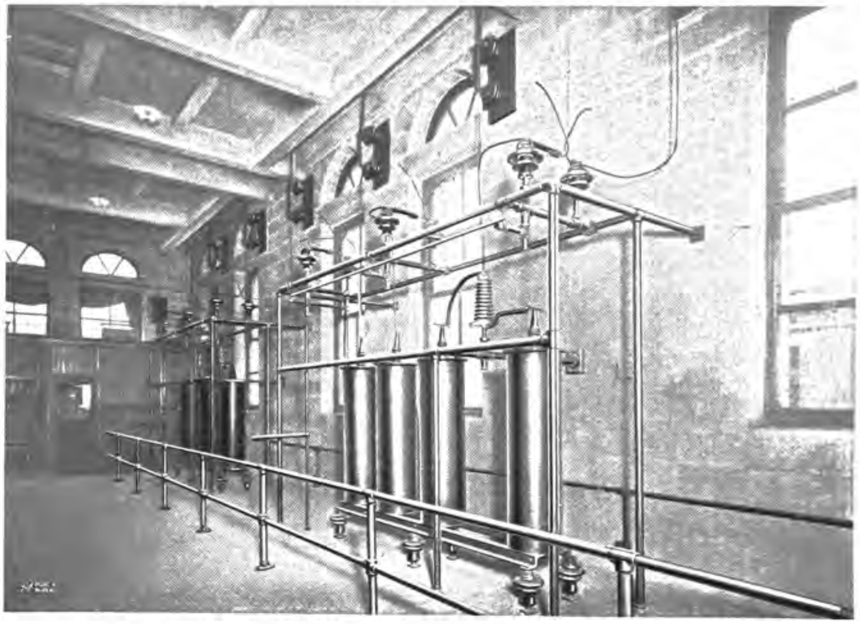
ALUMINUM LIGHTNING ARRESTERS FOR ALTERNATING CURRENT CIRCUITS

The successful operation of the General Electric aluminum arresters continues to bear out the prophecy that the aluminum cell type of arrester was destined to create a revolution in protection against lightning and similar disturbances. The aluminum arresters have not been changed in their essentials since they were first placed on the market, but from time to time changes have been made which experience with hundreds of installations under all sorts of conditions and in all parts of the world, has shown to be advisable. The arresters described herein embody improvements which will easily enable them to retain their leadership.

They are designed to protect alternating current electrical systems from all surges and lightning disturbances.

They have an enormous discharge capacity and their design and construction enable them not only to discharge large quantities of lightning but also to safely take care of both continuous and recurrent discharges lasting for long periods. They can be adjusted to discharge at only a small percentage above the normal operating voltage of a system.



44,000 VOLT, THREE-PHASE ALUMINUM LIGHTNING ARRESTERS

The design of the aluminum arrester is based on the characteristics of the aluminum cell consisting of two aluminum plates, on

*Supersedes No. 4759.

which has been formed a film of hydroxide of aluminum, immersed in a suitable electrolyte.

FORMATION OF FILM

The most important characteristic of the aluminum cell is its critical* voltage, which

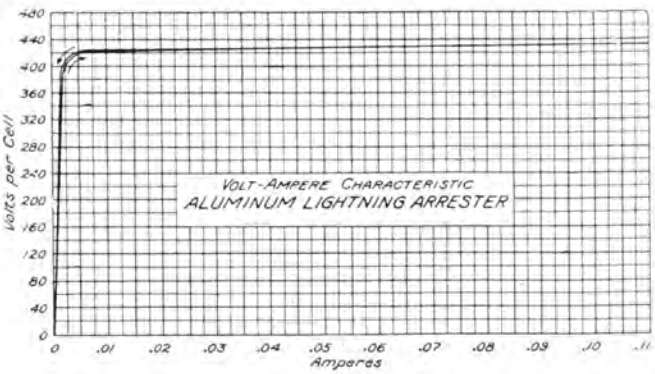


Fig. 2

VOLT-AMPERE CHARACTERISTIC CURVE OF AN ALUMINUM CELL ON DIRECT CURRENT

depends upon the hydroxide film of aluminum formed on the surface of the aluminum plates by putting them through chemical and electro-chemical treatments. Up to a certain voltage the cell allows an exceedingly low current to flow, but at a higher voltage the current flow is limited only by the internal resistance of the cell, which is very low. A close analogy to this action is found in the well-known safety valve of the steam boiler, by which the steam is confined until the pressure rises above a given value, when it is released.

On the aluminum plates there are myriads of minute safety valves, so that, if the electric pressure rises above the critical voltage, the discharge takes place equally over the entire surface. It is important to distinguish between the valve action of this hydroxide film and the failure of any di-electric substance such as mica, for example. The internal action of the cell closely resembles that of a storage battery on direct current, in which up to about 2 volts per cell impressed the storage battery gives an equal counter e.m.f., but above this value the current that flows is limited only by the internal resistance of the cell.

The volt-ampere-characteristic-curve of the aluminum cell will vary somewhat according to whether direct currents or alternating currents are used. If direct current is used, there will be no current passing through the circuit except the small leakage current through the film; whereas, if alternating current is used, the aluminum cell acts as a fairly good condenser, and there is not only the leakage through the film, but also a capacity current flowing into the cell. The phase of this current, then, is nearly 90 degrees ahead of the potential and represents a very low energy factor.

A volt-ampere-characteristic-curve of the aluminum cell on direct current is shown in Fig. 2 in which the permanent critical voltage is 420. This voltage will, however, vary considerably with the nature of the electrolyte. A curve of the current discharging above the

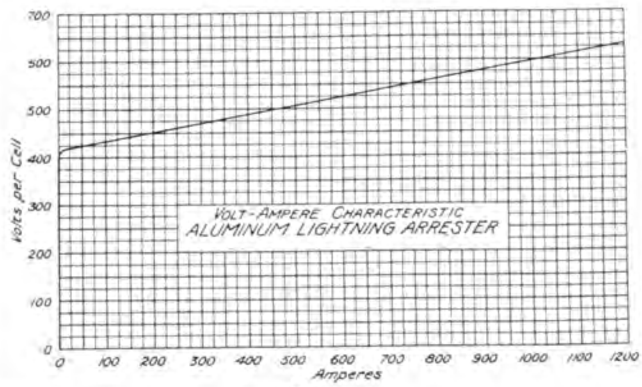


Fig. 3

VOLT-AMPERE CHARACTERISTIC CURVE OF AN ALUMINUM CELL ON DIRECT CURRENT SHOWING THE RATE OF DISCHARGE ABOVE THE CRITICAL FILM VOLTAGE

critical voltage is shown in Fig. 3. The data for this curve were taken from oscillograph records.

* The particular voltage at which the current begins to flow freely is known as the critical voltage of the cell.

The volt-ampere-characteristics of an aluminum cell on alternating current are shown in Fig. 4. The permanent critical voltage is between 335 and 360 volts, and indicates a less definite value of the critical voltage than the direct current curve.

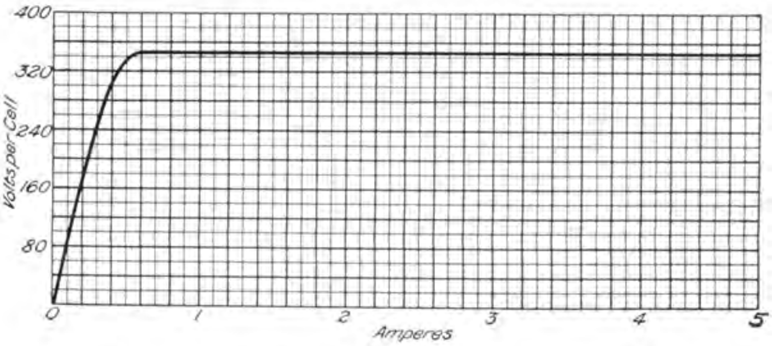


Fig. 4
VOLT-AMPERE CHARACTERISTIC CURVE OF AN ALUMINUM CELL ON ALTERNATING CURRENT

When a cell is connected *permanently* to the circuit, two conditions are involved which may be distinguished as the temporary critical voltage, and the permanent critical voltage. For example, if the cell has 300 volts applied to it constantly, and the voltage is suddenly increased to, say 325 volts, there will be a considerable rush of current until the film thickness has been increased to withstand the extra 25 volts; this usually requires several seconds. In this case 325 volts is the temporary critical value of the cell. Similar action will occur at any potential up to about the permanent critical voltage, or the voltage at which the film cannot further thicken and therefore allows a free flow of current.

If the voltage is again reduced to 300 the excess thickness of film will be gradually dissolved, and if it varies periodically between two values, each of which is less than the permanent critical value, the temporary critical voltage will be the higher value. This feature is of great importance as it provides a means of discharging abnormal surges, the instant the pressure rises above the impressed value.

The number of cells for a circuit is so chosen that the average dynamic voltage per cell will be approximately 300 volts, or always less than the permanent critical voltage.

The foregoing shows that the arrester will discharge a large amount of dynamic current for a brief interval, and lightning, being of a similar nature, will be discharged with equal facility.

FILM DISSOLUTION

Another characteristic of the aluminum cell is the dissolution of a part of the film when the plates stand in the electrolyte and the cell is disconnected from the circuit. The film is composed of two parts: one part is hard and insoluble, and apparently acts as a skeleton to hold the more soluble part. The action of the cell seems to indicate that the soluble part of the film is composed of gases

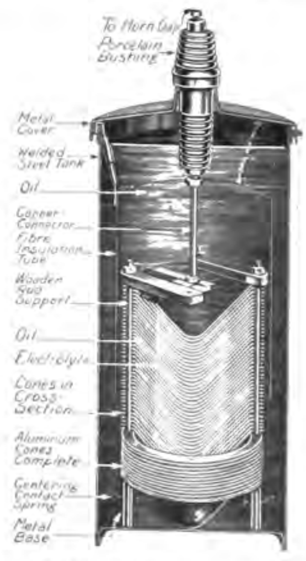


Fig. 5. CROSS SECTION OF ALUMINUM LIGHTNING ARRESTER

in a liquid form. When a cell which has stood for some time disconnected is reconnected to the circuit, there is a momentary rush of current which reforms the part of the film which has dissolved. This current rush will have increasing values as the intervals of rest of the cell are made greater. Many electrolytes have been studied, but none has been found which does not show this dissolution effect to a greater or less extent. If the cell has stood disconnected from the circuit for some time, especially in a warm climate, there is a possibility that the initial current rush will be sufficient to open the circuit breakers or oil switches. This current rush also raises the temperature of the cell, and if this temperature rise is great it is objectionable. When the cells do not stand for more than a day, however, the film dissolution and initial current rush are negligible. Suitable means are provided with the arresters for throwing them directly on the line by a very simple operation, and thus the film may be always kept in good condition.

Fig. 6
ELEMENTS, LESS HORN GAPS, ETC., OF 6600 VOLT, THREE-PHASE ALUMINUM LIGHTNING ARRESTER FOR NON-GROUNDED NEUTRAL CIRCUIT

CONSTRUCTION OF ARRESTERS

In the following pages, arresters for three-phase circuits will be described, but arresters for other circuits of 1000 or more volts have the same general construction. Further information on arresters for other than three-phase circuits will be furnished upon request, as, for example, on arresters for single-phase and two-phase circuits, and on arresters for voltages less than 1000.

The form of the arrester varies somewhat according to the voltage, and according to whether the circuit has or has not a grounded neutral.

Arresters for cable systems differ in some particulars from arresters for overhead circuits. Considering the latter only, the arresters vary in the construction of the series gaps and in the grouping and spacing of the cells.

The differences in the arrangement of the cells will be described first; then the differences in the construction of the horn gaps.

CELLS

The arresters consist of a series of concentric inverted cones placed one above the other with a vertical spacing of about 0.3 inch in arresters up to and including 27,000 volts and 0.42 inch in arresters above that voltage.

The electrolyte is poured into the cones and partly fills the space between adjacent ones. The stack of cones with the electrolyte between them is then immersed in a tank of oil. The tanks are steel with welded seams and are provided with metal covers. (Fig. 5.)

The cones are insulated from each other except for the electrolyte. The oil improves this insulation as well as prevents the evaporation of the solution.

A cylinder of insulating material concentric with the cone stack is placed between the latter and the steel tank. This improves the circulation of the oil and increases the insulation between the tank and the cone stack.

without a sacrifice in the features of endurance and insulation. (Fig. 6.)

Above 7250 Volts each stack of cones is placed in a separate tank. (Fig. 7.)

A larger spacing between cones has been adopted for the arresters above 27,000 volts because in general they are used on long distance transmission lines where rises in voltage at substations when load is suddenly removed from the line at the power house are especially severe on the arresters. The larger spacing increases the factor of safety and the length of time the arrester can take a discharge without overheating due to the larger amount of electrolyte to be heated

Fig. 7
ONE LEG, LESS HORN GAPS, ETC., OF 15,000 VOLT ALUMINUM LIGHTNING ARRESTER

The utilization of the heat-absorbing capacity of the oil is an original feature in General Electric aluminum arresters and is of great value, since it enables the arrester to discharge continuously for long periods.

There is a stack of cones for each phase, and for non-grounded neutral circuits and for circuits grounded through resistance there is an additional stack for the ground leg. The necessity of the fourth stack is given under "Differences in Arresters for Grounded and Non-Grounded Circuits." (Page 7.)

1000 to 7250 Volts. In these arresters the radiating and insulating qualities are such that all of the cones may be placed in a single tank. This effects a saving in space

and the larger radiating surface of electrolyte in contact with the oil. The size of the tanks and amount of oil have also been made larger, thus adding to the heat storage and radiating surface of the arresters. On account of the increased height of tanks, on the 60,000 and 70,000 volt arresters tie rods are provided from the tops of the tanks to the supporting racks. These hold the tanks securely in place and avoid the danger of overturned tanks should they be subjected to an external force or blow.

HORN GAPS

The arresters are not designed to be connected permanently between the line and the ground. A gap set at a suitable value above the line potential is inserted in series, and prevents the arrester from being subjected continuously to the line voltage. In this way leakage is prevented at normal voltage and longer life is insured for the aluminum cones.

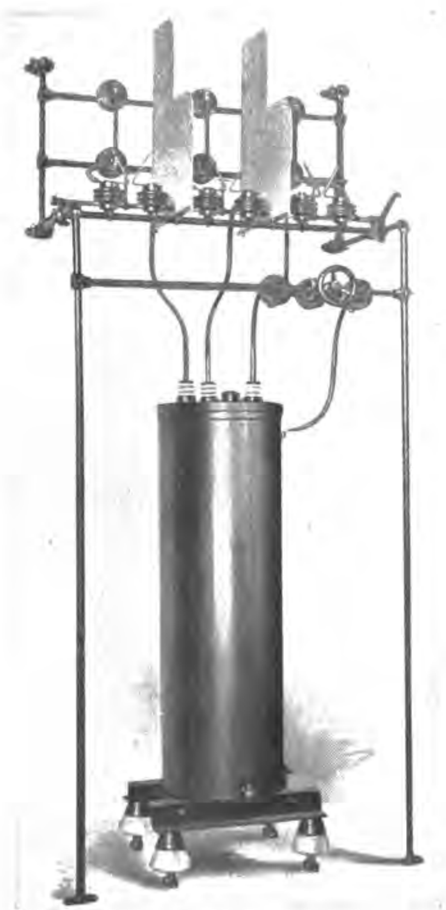


Fig. 8
INSTALLATION OF ALUMINUM LIGHTNING ARRESTER FOR 6600 VOLT, THREE-PHASE NON-GROUNDED NEUTRAL CIRCUIT

The horn gaps placed between the aluminum cells and the line serve a triple function.

1st. As fixed gaps in series with the cells, they prevent the arresters from being subjected continually to the normal line voltage which would result ultimately in overheating the cells.

2nd. They act as a disconnecting switch to disconnect the arrester from the line for repairs, inspection, etc.

3rd. They can be used as a connecting switch for daily testing. As described above, the film, if allowed to stand in the electrolyte without any current flowing, gradually dissolves, so that after a period of inactivity there might be a considerable flow of dynamic current following a lightning discharge. For this reason the gaps are designed so that they may be closed for a few seconds and thus keep the film in normal condition.

In arresters up to 7250 volts, the type of horn gaps used is shown in Fig. 8.

The closing of the horn gaps for charging is effected by a rotating shaft of insulating material carrying three metallic projectors, which, when the shaft is rotated, bridge the three gaps and allow the necessary charging current to flow through the cells. The disconnecting feature is provided by separate detachable fuses. The horn gaps, fuses and transfer device are mounted on a pipe framework.

Above 7250 Volts, the horn gaps consist of three sets of horns mounted on a common framework of iron pipe. Each pair of horns is clamped firmly to petticoat insulators, one insulator being fixed rigidly to the frame while the insulator carrying the other side of the horn can be turned, using its pin as an axis. There is a gap for each phase and all three of the movable insulators are joined by a connecting rod so that they move simultaneously. In the normal position of the gap the movable horn is turned sufficiently to give the required spark gap. When the horn gaps are in normal position they are held firmly by a latch.

The type used from 7250 to 27,000 volts inclusive is shown in Figs. 9 and 10. In this type the movable insulators are held in position against the latch by heavy coiled springs. The short-circuiting operation is performed by pulling rope No. 1 until the horn gaps are closed. When this rope is released, coiled springs return the horn gaps

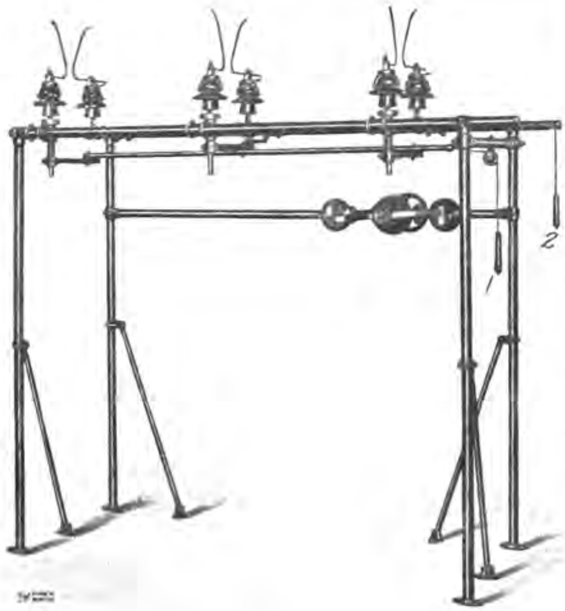


Fig. 9
HORN GAPS AND TRANSFER DEVICE OF ALUMINUM LIGHTNING ARRESTER FOR 12,500 VOLT NON-GROUNDED NEUTRAL CIRCUIT

to the normal position. Disconnecting is accomplished by pulling rope No. 2, which releases the latch, thus allowing the coiled springs to turn the movable horns through a large and amply safe angle. The gaps are put in the normal position by pulling rope No. 1, until the latch resets.

To facilitate the setting of the horn gaps an adjustable latch block is provided by which all the gap spaces may be changed uniformly and simultaneously without taking the voltage off the horns.

In the type used with arresters above 27,000 volts, one of the supporting pins of one of the revolving insulators is extended to a point within easy reach of the operator, and is fitted with an operating lever and latch. It will be remembered that the movable insulators are joined, so that by turning this lever all three horns are moved. When the latch has been released, the operator can turn the movable horn into either the short-circuiting or the disconnecting position. (Fig. 12.)

Provision is made for locking the horn gaps in either the normal or the disconnecting position and for adjusting the horn gap setting.

DIFFERENCE BETWEEN ARRESTERS FOR GROUNDED AND NON-GROUNDED NEUTRAL CIRCUITS

It is important to avoid the mistake of choosing an arrester for a thoroughly grounded neutral when the neutral is only partly grounded, that is to say, grounded through an appreciable resistance. Careful consideration of this condition will make the above statement clear. In an arrester for a grounded neutral circuit, each stack of cones normally receives the neutral potential when the arrester discharges; but if a phase becomes accidentally grounded the line voltage is thrown across each of the other stacks of cones until the circuit breaker opens the

Fig. 10
INSTALLATION OF ALUMINUM LIGHTNING ARRESTER FOR 12,500 VOLT, THREE-PHASE NON-GROUNDED NEUTRAL CIRCUIT

circuit. Line voltage is 173 per cent. of the neutral or normal operating voltage of the cells and therefore about 150 per cent. of the permanent critical voltage of each cell. This means that when a grounded phase occurs this 50 per cent. excess dynamic potential is short-circuited through the cells until the circuit breaker opens. The amount of energy to be dissipated in the arrester depends upon the kilowatt capacity of the generator, the internal resistance of the cells, and the time required to operate the circuit breakers. It is evident that the greater the amount of resistance in the neutral, the longer will be the time required for the circuit breakers to operate. *Therefore, in cases when the earthing resistance in the neutral is great enough to prevent the automatic circuit breakers from opening practically instantaneously, an arrester for a non-grounded neutral system should be installed.*

It is difficult to determine these factors of ground resistance and time elements in the operation of switches and therefore no mistake can be made by adopting the four tank arrester even on grounded Y circuits.

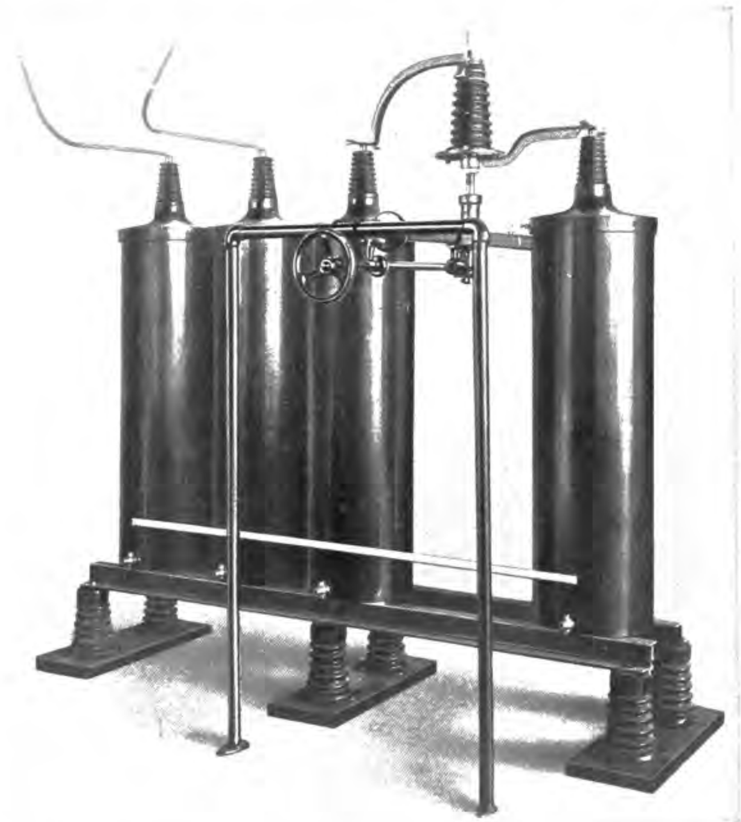


Fig. 11
TANKS, TRANSFER DEVICE AND RACK OF 35,000 VOLT ALUMINUM LIGHTNING ARRESTER FOR NON-GROUNDED NEUTRAL CIRCUIT

Arresters for circuits with thoroughly grounded neutrals have three stacks of cones. The bases of the stacks of cones are connected to the tanks and grounded. For arresters up to 7250 volts, inclusive, all the cones are mounted in a single tank, but for higher voltages each stack is mounted in a separate tank. (Fig. 7.) The top cone of each stack is connected to the line through a horn gap. Insulating supporting racks are not necessary with arresters for grounded neutral circuits.

For non-grounded circuits the arresters have four stacks of cones, the bases of which are connected together by the well-known General Electric multiplex connection. The fourth stack is thus between the multiplex connection and the ground, the object being to give the same protection between the line and line as between line and ground. This insures proper distribution of voltage in the cells during the conditions incident to an accidentally grounded phase. The fourth stack is called the ground leg of the arrester. Below 7250 volts all of the cones are installed in a single tank, but for higher voltages each stack is installed in its own tank. The tanks are mounted on insulating racks. Two of the stacks are connected directly to the line, each through a horn gap; the third is connected to the line through the transfer device and a horn gap. The fourth stack is connected to the ground through the transfer device.

TRANSFER DEVICE

The object of the transfer device is to provide a means for interchanging the ground stacks with one of the line stacks of cones during the charging operation so that the films of all the cells will be formed to the same value.

This transfer device consists of a rotating switch which may be turned 180 degrees, thus interchanging the connections of the ground stack and one of the line stacks. For arresters up to 27,000 volts the device is mounted with three insulators on the pipe framework, and is operated by a handwheel. (Fig. 9.) For arresters of higher voltage the transfer device is mounted directly over the tanks (Fig. 11), and is operated by bevel gears and handwheel.

CHARGING OPERATION

The dissolution of the films on the aluminum cones when they are left in the electrolyte is brought out in the discussion of the theory of the arrester. (See Film Dissolution.) This fact was perceived early in the preliminary investigations into the subject and it was realized that in order to use the general principle successfully in an arrester, it would be necessary to provide means for easily and

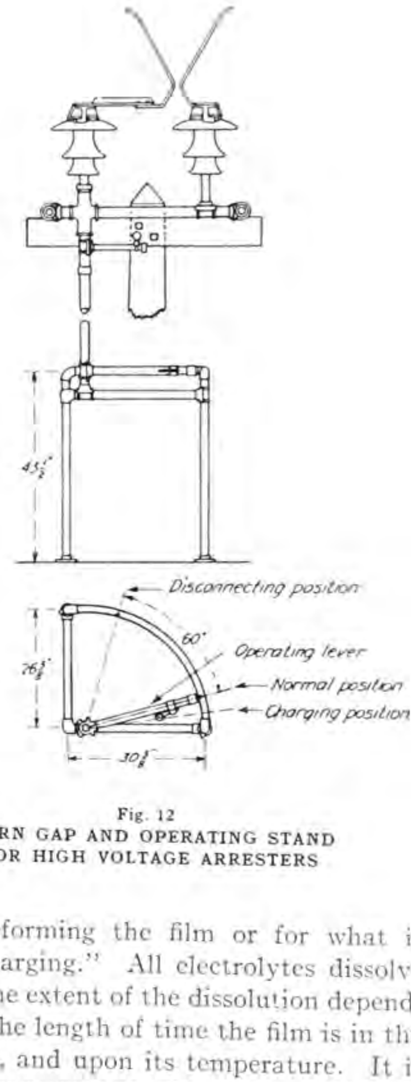


Fig. 12
HORN GAP AND OPERATING STAND
FOR HIGH VOLTAGE ARRESTERS

quickly reforming the film or for what is called "charging." All electrolytes dissolve the film, the extent of the dissolution depending upon the length of time the film is in the electrolyte, and upon its temperature. It is therefore necessary to charge the cells from time to time and thus prevent the dissolution and consequent rush of dynamic current which would otherwise occur when the arrester discharges.

In developing the aluminum arrester, the intention was to provide apparatus which would be capable of discharging surges and line disturbances lasting for a considerable length of time. The problem was therefore that which is met in the designing of all electrical apparatus, namely, to design against overheating. The current passing through the arrester heats it and thus its capacity to take care of discharges lasting for any considerable length of time depends on the quantity of the current allowed to flow and the heat-absorbing and radiating qualities of the arrester. The arrester is designed so that the current it will discharge is ample to lower dangerously high potentials to a safe value. However, the length of time an arrester can discharge, is reduced if any unnecessary current passes through it. This unnecessary current is the dynamic rush which would flow at the beginning of a discharge, if the films were not properly formed. By keeping the films formed at all times, this initial rush of current is prevented and the ultimate temperature rise of the arrester is minimized. In very warm climates it is necessary to take special precaution to keep the cells normally cool.

The charging operation in the case of arresters for grounded circuits consists merely in simultaneously closing the three horn gaps so that the full potential across the cells causes a small charging current to flow and form the films to their normal condition.

In the case of arresters for non-grounded circuits, the charging operation is as follows: First, the horn gaps of the arresters are closed for five seconds and opened again to normal position, thus charging the cells of the three line stacks. Second, with the horn gaps still in normal position, the position of the transfer device is reversed and the horn gaps are again closed for five seconds and returned to the normal position. The complete charging operation takes but a few moments and should be performed daily. The operation is valuable, not only in keeping the films in good condition, but also in giving the operator some idea of the condition of the arrester by enabling him to observe the size and color of the charging spark.

INSTALLATION

Below 7250 volts the standard horn gaps are for indoor installation only; above that voltage they may be installed out-of-doors but the station layout is often such as to require modifications of standard equipments as described herein.

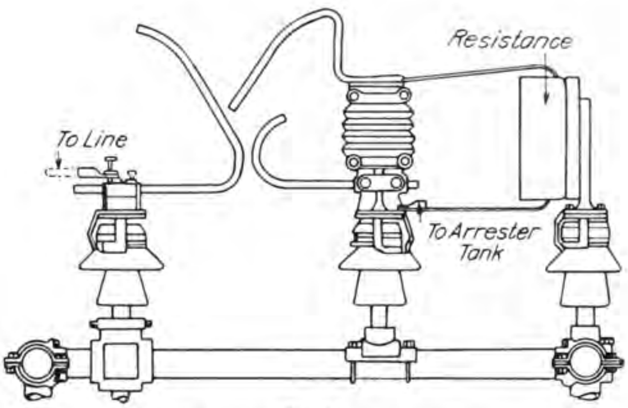


Fig. 13
HORN GAP WITH CHARGING RESISTANCE FOR CABLE SYSTEM

For voltages above 27,000 there is usually insufficient overhead space to install the horn gaps inside the building, therefore it is generally recommended that they be installed out-of-doors, and that the tanks be installed inside the station. The material supplied with all arresters is tabulated on page 17. The lines through the horn gaps to the arresters and ground should be as short as possible. For recommendation on wiring see page 12.

Proper entrance bushings can be supplied where the tanks are installed inside the station, and the horn gaps outside.

The aluminum arresters listed are designed for indoor use. While the arresters may be adapted for outdoor use, they are not recommended for this service, where there is liability of the electrolyte's freezing. The electrolyte freezes at about 20 degrees F., and when frozen, its resistance is greatly increased, thus rendering the arresters less efficient. There is also further liability of mechanical injury if they are installed out-of-doors. Since the aluminum arresters will continue to discharge until the trouble is removed from a circuit, they should be installed where there is an attendant to note the discharge and take steps to locate the trouble and remove it.

This consists of an auxiliary horn mounted above and insulated from the regular horn in such a manner as to intercept the arc if it arises on the regular horns. (Fig. 13.) Enough resistance is connected in series with this auxiliary horn so that the current flow and arc across this gap are always limited to a moderate value. Such a device has several advantages. Since the mechanism is so arranged that the charging is always done through the auxiliary horn the current rush is limited during the charging and thus troubles from carelessness or ignorance are avoided. It also gives a more uniform charging current.

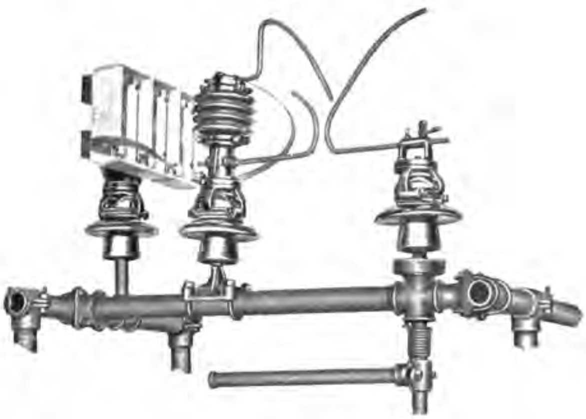


Fig. 14
HORN GAP WITH CHARGING RESISTANCE FOR 15,000 VOLT ALUMINUM ARRESTER

ARRESTERS FOR CABLE SYSTEMS

Arresters for cable systems differ from arresters for overhead circuits only in the construction of the horn gaps. The necessity for this difference is due to the fact that a cable system has a very much higher electrostatic capacity and much less inductance than an overhead system. In consequence, the currents which flow into the arrester during charging are somewhat higher. It is desirable to avoid these heavier currents, especially during the time of breaking the arc at the horn gap. This is accomplished by using a special horn gap and resistance.

In the use of this auxiliary horn gap and resistance there are three successive stages which will be described in their order as follows:

1st. Light discharges will pass across the smaller gaps to the auxiliary horn and through the series resistance to the cells.

2nd. If the discharge is heavy, the resistance offers sufficient impedance to cause the spark to pass to the main horn. This is accomplished with only a slight increase in potential because the gap is already ionized.

If the cells are in normal condition the spark at the gap is immediately extinguished without any flow of dynamic current.

3rd. If the cells through either negligence or some untoward condition are in poor form, the dynamic current may follow the discharge across the main gap and the arc will rise to the safety horn and be extinguished through a resistance.

In the case of mixed overhead and cable systems the choice of arresters will be a matter of judgment. If there is a comparatively short length of cable in the circuit the usual practice for overhead systems may be adopted.

For direct connection to busbars arresters with charging resistance should be used.

COPPER TUBING FOR WIRING ARRESTERS

For wiring aluminum arresters, the use of copper tubing is strongly recommended. There are several reasons which make its use advisable:

In all lightning arrester installations it is necessary to provide a path to the lightning arrester and ground with as little impedance as possible. In order to accomplish this purpose, rather large wires with long bends and turns would have to be used. It is well known that high frequency lightning disturbances are confined largely to the outside surfaces of the conductors, penetrating but little towards the center, hence, by using either flat strip or tubing, we are able to secure the advantage of a large conductor, namely, a large surface, but at a much lower cost. Copper tubing has the advantage over either strip or solid conductors, in that it is easily supported, requires fewer insulators, and is therefore the cheapest to install. It also presents a very neat appearance, since when the wiring is complete, all joints are flush, all sharp bends are eliminated, and there are no points where corona or brush discharges can take place.

As installations vary so much in their details, it is impossible to provide copper tubing for wiring the arresters completely; parts are listed which may be selected as soon as the lightning arrester layout has been determined.

The parts consist of straight sections, bends of various angles, tees, terminals, and connectors for joining the various parts together. All of these parts, except the straight tubing, are tinned at the joints and it is only necessary to assemble sections and apply a sufficient heat to the outside to sweat the sections together. The parts are tabulated on page 23.

DISCHARGE ALARMS

One of the severest conditions to which an arrester may be subjected is that of an accidentally grounded phase on a normally non-grounded circuit. A grounded phase may produce continual discharges through the arrester for a long period and, while the aluminum arresters are designed to withstand such discharges for at least half an hour, it is evident that if the discharge lasts too long, the arrester will gradually heat up and may be damaged internally, owing to the increase in the leakage current due to the warming of the electrolyte. To prevent this, a discharge alarm is supplied with each arrester for non-grounded neutral circuits. This discharge alarm consists of a single aluminum cell placed in the ground connection of the arrester, and an electric bell or auxiliary relay in shunt with the cell.

Whenever current passes through the ground circuit, the bell rings or the relay closes a signal circuit, and the operator's attention is thus called to the discharge of the arrester.

DISCHARGE RECORDERS

Ever since the aluminum arrester was placed on the market there has been a demand for an instrument which would indicate and record discharges through the arresters.

Fig. 15
DISCHARGE RECORDER

The discharge alarms described above indicate the existence of a grounded phase on non-grounded neutral circuits, but do not give a record of the discharges nor do they operate for discharges not due to grounded phases. A knowledge of all discharges is of an immense value to operating engineers in studying conditions of abnormal voltage on transmission and cable systems, but heretofore the only way of observing the discharges was to watch for them at times when they might be expected. It is, however, impossible to watch the arrester all of the time and there are, furthermore, a large number of discharges which can hardly be detected even by watching the horn gaps.

To meet this demand the General Electric Company has developed the discharge recorder which registers the time and nature of discharges through an arrester.

This discharge recorder (Fig. 15) consists of four spark gaps so arranged that the discharges between lines or between lines and ground pass through the gaps.

The spark gaps are assembled with a clock-operated drum in such a manner that a continuous record is obtained, showing all discharges by means of punctures in a moving roll of paper. This paper passes through the gaps at a rate of about 3 in. per hour which gives a very accurate record

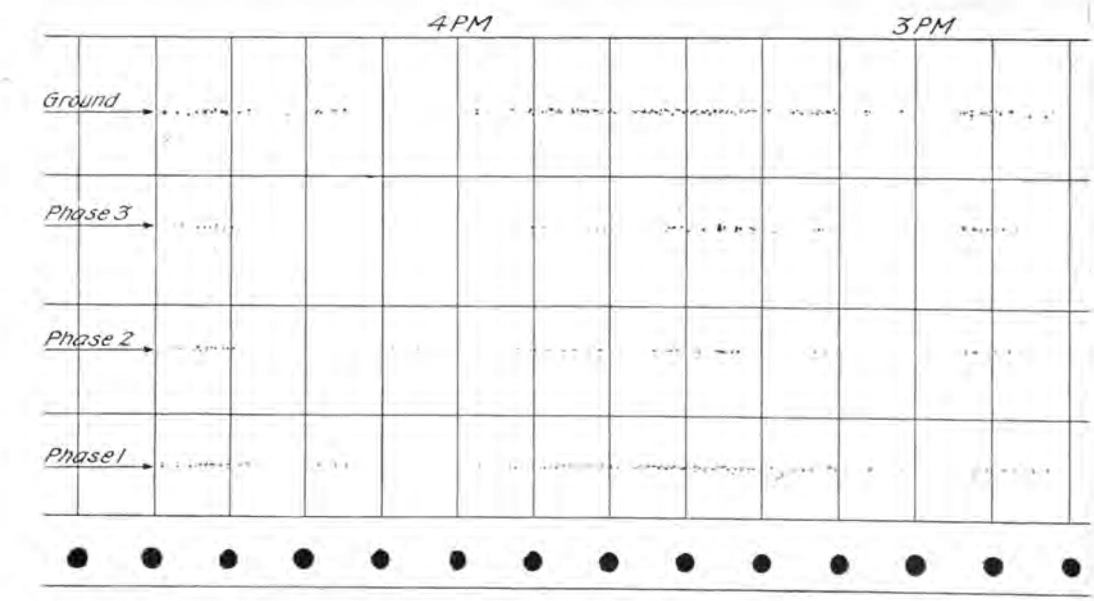


Fig. 16
SECTION OF RECORD FROM DISCHARGE RECORDER

of the time and duration of each discharge. The clock mechanism is a seven day movement, and each roll of paper is of sufficient

Fig. 17
HOUR GLASS CHOKE COILS, 110,000 VOLTS

length to record ten days' run. The device is supplied with brackets and connections so that it may be readily attached to any standard arrester. It can be supplied either with or without reroll attachment.

Besides being valuable in recording discharges due to abnormal voltages on a system, the discharge recorder is of value in indicating and recording the daily charging of the arrester. With such a recorder it can be told whether the arresters are or are not being properly charged by the station operator; and besides, the puncture gives some indication of the condition of the arrester. If the record shows that the charging current is abnormally large, steps can be taken to examine the arrester for damage due to neglect or carelessness.

Fig. 16 reproduces an interesting record of discharges due to grounded phase conditions. The large number of discharges occurring in the short period of time covered by the record is proof of the value of an aluminum arrester in taking care of such conditions.

CHOKE COILS

Opinions on the design of choke coils for use with lightning arresters vary considerably. Some engineers recommend the use of very large choke coils, but while large choke coils of high inductance do choke back the high frequency currents better than smaller coils of less inductance, they cost more, and under many conditions they are a menace to the insulation unless the lightning arresters are installed on both sides of them. Part of the functions of the choke coil are performed by the end turns of a transformer and extra insulation is invariably installed in all power transformers built in recent years. The choice of choke coils must be influenced by the condition of insulation in the transformers as

Fig. 18
HOUR GLASS CHOKE COILS, 45,000 VOLTS

well as by the cost, potential regulation, and nature of the lightning protection required.

The primary objects of the choke coil should be:

4600 Volts

6600 Volts

Fig. 19
LOW VOLTAGE CHOKE COILS

(a) To hold back the lightning disturbance from the transformer or generator until the lightning arrester discharges to earth. If there is no lightning arrester the choke coil evidently cannot perform this function.

(b) To lower the frequency of the oscillation so that whatever charge gets through the choke coil will be of a frequency too low to cause a serious drop of potential around the first turns of the end coil in either generator or transformer. Another way of expressing this is from the standpoint of wave-front; a steep wave-front piles up the potential when it meets an inductance. The second function of the choke coil is, then, to smooth out the wave-front of the surge.

It seems best to consider the choke coil as an auxiliary to the lightning arrester. There seems to be no justification for the expense of a very large choke coil. If it has an inductance equal to that of several end turns it will reduce the wave front of the surge by more than a corresponding value. For example, if there is no choke coil at all, the full strain of a steep wave front will fall on the end turn. If a choke coil of inductance equal to the end turn is placed in series, this strain will be reduced to one-half. If the choke coil has an inductance equal to six turns, the strain on the end turn will be reduced to about one-seventh. Since the value of such an inductance in a choke coil will make its time constant greater than the dielectric spark-lag of a modern arrester, the arrester will be in full operation to relieve the strain before the charge can get through the choke coil.

In the case of a choke coil the principal electrical condition to be avoided is that of resonance. The coil should be so arranged that if continual surges are set up in the circuit, a resonant voltage due to the presence of the choke coil cannot build up at the transformer or generator terminals. This factor is the menace to the insulation mentioned above. Another way of stating the condition is as follows: Arrange the choke coil in such a way as not to prevent surges originating in a transformer from passing to the lightning arrester.

Another electrical condition to be avoided in a choke coil is internal static capacity between adjacent turns, since this lowers the effectiveness of the coil.

In General Electric choke coils recommended with lightning arresters these features have been given careful consideration. Two types of choke coils, depending upon the voltage, are shown in the illustrations on page 14. Those for use on circuits not exceeding 6600 volts are made of several turns of insulated wire, while for voltages above 6600 the hour glass type with air insulated turns is used and the coil is mounted on a steel, slate or marble base. The hourglass type has the following advantages on high voltages:

1st. Should there be any arcing between adjacent turns the coils will reinsulate themselves.

2nd. They are mechanically strong, and sagging is prevented by tapering the coils toward the center turns.

3rd. The insulating supports can be best designed for the strains which they have to withstand.

GROUND CONNECTIONS

In all lightning arrester installations it is of the utmost importance to make proper ground connections, as many lightning arrester troubles can be traced to bad grounds. It has been customary to ground a lightning arrester by means of a large metal plate buried in a bed of charcoal at a depth of six or eight feet in the earth.

A more satisfactory method of making a ground is to drive a number of 1 inch iron pipes six or eight feet into the earth surrounding the station, connecting all these pipes together by means of a copper wire or, preferably, by a thin copper strip. A quantity of salt should be placed around each pipe at the surface of the ground and the ground should be thoroughly moistened with water. It is advisable to connect these pipes to the iron framework of the station, and also to any water mains, metal flumes, or trolley rails which are available. For the usual-sized station the following recommendation is made. Place three pipes equally spaced near each outside wall, making twelve altogether, and place three extra pipes spaced about six feet apart at a point nearest the arrester.

Where plates are placed in streams of running water, they should be buried in the mud along the bank in preference to being laid in the stream. Streams with rocky bottoms are to be avoided.

Whenever plates are placed at any distance from the arrester, it is necessary also to drive a pipe into the earth directly beneath the arrester, thus making the ground connection as short as possible. Earth plates at a distance cannot be depended upon. Long ground wires in a station cannot be depended upon unless a lead is carried to the multiple grounding pipes installed as described above.

As it is advisable occasionally to examine the underground connections to see that they are in proper condition, it is well to keep on file exact plans of the location of ground plates, ground wires and pipes, with a brief description, so that the data can be readily referred to.

From time to time the resistance of these ground connections should be measured to determine their condition. The resistance of a single pipe ground in good condition has an average value of about 15 ohms. A simple and satisfactory method of keeping account of the condition of the earth connections is to divide the grounding pipes into two groups and connect each group to the 110 volt lighting circuit with an ammeter in series.

THE SUPERIOR FEATURES OF G.E. ALUMINUM LIGHTNING ARRESTERS

1st. They have an enormous discharge capacity.

2nd. The arresters prevent abnormal potentials from rising to dangerous values as they can be adjusted to discharge at a rise of 25 per cent. in voltage.

3rd. They are designed to discharge continuously for a half-hour.

4th. The entire stack of cones is surrounded by oil to absorb the heat generated during a discharge. A cylinder of insulating material between the cone stack and tank induces good circulation of the oil and augments the insulation between the tank and cone stack.

5th. They are mechanically strong. The aluminum cones are placed in steel tanks with metal covers, which are not liable to be broken in transportation, installation or operation. The use of iron supporting racks and iron pipe work for the horn gap supports gives the most substantial construction which could be used.

6th. The aluminum parts are cone shaped so that the gases which form during the discharge will not stick to the aluminum and destroy the film, but will rise harmlessly to the top of the tank.

7th. It is an inherent feature of arresters embodying the aluminum cell that the cells need frequent charging. The ease with which this is accomplished in the case of General Electric arresters will appeal to every practical operating man.

8th. Every possible means has been employed to provide safety for an operator of these arresters.

ALTERNATING CURRENT ALUMINUM LIGHTNING ARRESTERS

WITH HORN GAP DISCONNECTING SWITCHES FOR * THREE-PHASE CIRCUITS NOT FOR USE ON CABLE SYSTEMS

ARRESTERS SHOULD BE SELECTED FOR THE MAXIMUM VOLTAGE OF THE SYSTEM REGARDLESS OF THE LINE DROP

Minimum and Maximum Voltage of Circuits on which Arresters Should be Installed	For Non-Grounded Neutral Systems		For Grounded Neutral Systems	
	† Cat. No.	Approx. Ship. Wt. in Lb.	† Cat. No.	Approx. Ship. Wt. in Lb.
1000– 2550	78482	930	78481	650
2551– 3600	78484	1000	78483	720
3601– 4680	78486	1090	78485	850
4681– 7250	78488	1350	78487	1100
7251–11900	76710	1875	76709	1300
11901–14000	76712	2065	76711	1400
14001–16100	76714	2230	76713	1500
16101–18700	76716	2400	76715	1600
18701–21800	76718	2520	76717	1700
21801–27000	76720	2780	76719	1950
27001–32200	78886	4000	78885	2700
32201–37900	78888	4400	78887	3000
37901–43000	78890	5300	78889	3500
43001–48250	78892	5900	78891	4000
48251–53500	78894	7000	78893	4800
53501–64250	78896	9100	78895	6600
64251–75000	78898	11000	78897	8100

FOR USE ON CABLE SYSTEMS

1000– 2550	78604	1020	78603	740
2551– 3600	78606	1100	78605	800
3601– 4680	78608	1200	78607	940
4681– 7250	78610	1440	78609	1200
7251–11400	78612	1970	78611	1400
11901–14000	78614	2160	78613	1500
14001–16100	78616	2320	78615	1600
16101–18700	78618	2500	78617	1700
18701–21800	78620	2600	78619	1800
21801–27000	78622	2870	78621	2050

MATERIAL SUPPLIED WITH ARRESTERS

* Information on three-phase arresters for other voltages and on single- and quarter-phase arresters for any voltage will be furnished upon request.

† Arresters, Cat. Nos. 78481–78488 inc. and Cat. Nos. 78603–78610 inc., are for indoor installation only. The horn gaps of these arresters are not arranged for disconnecting the arresters but detachable fuses are provided for that purpose.

Arresters, Cat. Nos. 76709–76720 inc. and Cat. Nos. 78611–78622 inc. have horn gaps which may be used out-of-doors.

Arresters, Cat. Nos. 78481–78488 inc. and 76709–76720 inc. and Cat. Nos. 78603–78610 inc. are supplied complete for installation except the material for wiring.

Arresters, Cat. Nos. 78885–78898 inc. should preferably have the horn gaps installed out-of-doors. All parts are supplied except the material for wiring and the vertical supports for the horn gaps.

Except under special conditions the arrester tanks should always be installed in the station. Modifications of the standard arresters, in the bushings, etc., are necessary for out-of-door installation. See "Installation," page 10.

A discharge alarm with bell, Cat. No. 75486, is supplied with each arrester for non-grounded neutral circuits.

CHOKE COILS

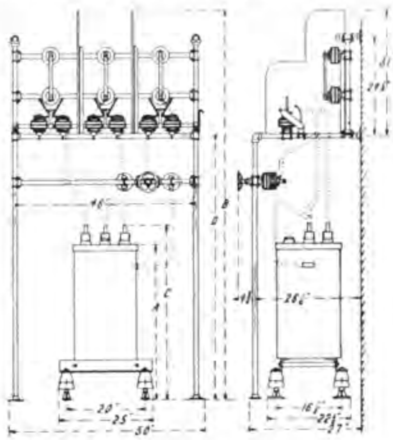
FOR INDOOR* USE

Cat. No.	Maximum Volts	Amperes	Base	Approx. Wt. in Lb. Ship.	Net
76339	4600	25	Steel Bracket	15	6
76340	4600	50	Steel Bracket	25	10
25401	6600	25	Marble	30	14
3416	6600	100	Marble	50	37
36882	6600	200	Marble	40	30
78802	7500	200	Steel	100	75
78801	7500	200	Slate	150	111
78800	7500	200	Marble	150	111
78803	7500	400	Steel	145	109
78804	7500	650	Steel	210	154
78805	7500	1000	Steel	270	200
78806	15000	200	Steel	105	77
77699	15000	200	Slate	150	113
77704	15000	200	Marble	150	113
78807	15000	400	Steel	150	113
78808	15000	650	Steel	215	160
78809	15000	1000	Steel	280	206
78810	25000	200	Steel	145	108
77700	25000	200	Slate	220	162
77705	25000	200	Marble	220	162
78814	25000	400	Steel	190	142
78812	25000	400	Slate	250	183
78813	25000	400	Marble	250	183
78815	35000	200	Steel	160	120
77701	35000	200	Slate	235	174
77706	35000	200	Marble	235	174
78819	35000	400	Steel	210	154
78817	35000	400	Slate	260	195
78818	35000	400	Marble	260	195
78820	45000	200	Steel	190	141
77702	45000	200	Slate	260	193
77707	45000	200	Marble	260	193
78824	45000	400	Steel	235	174
78822	45000	400	Slate	290	216
78823	45000	400	Marble	290	216
78825	60000	200	Steel	220	164
77703	60000	200	Slate	295	215
77708	60000	200	Marble	295	215
78829	60000	400	Steel	270	197
78827	60000	400	Slate	325	241
78828	60000	400	Marble	325	241
78830	70000	200	Steel	380	279
78831	90000	200	Steel	460	342
78832	110000	200	Steel	600	443

* Information on choke coils mounted on petticoat insulators for out-of-door use furnished upon request.

DIMENSIONS OF ALUMINUM LIGHTNING ARRESTERS

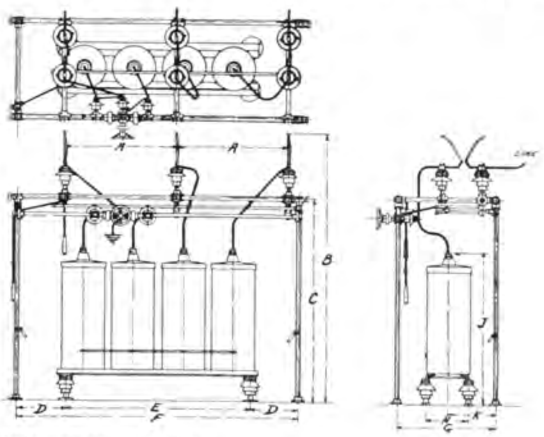
FOR NON-GROUNDED NEUTRAL SYSTEMS, 2500 TO 6600 VOLTS



Catalogue numbers do not include parts shown in dotted lines.

Cat. No.	Volts	A	B	C	D
78482	2500	38⅞	103	43⅝	72
78484	3300	44⅜	103	49⅛	72
78486	4600	49¾	115	54⅛	84
78488	6600	58⅞	115	63⅝	84

FOR NON-GROUNDED NEUTRAL SYSTEMS, 10,000 TO 25,000 VOLTS

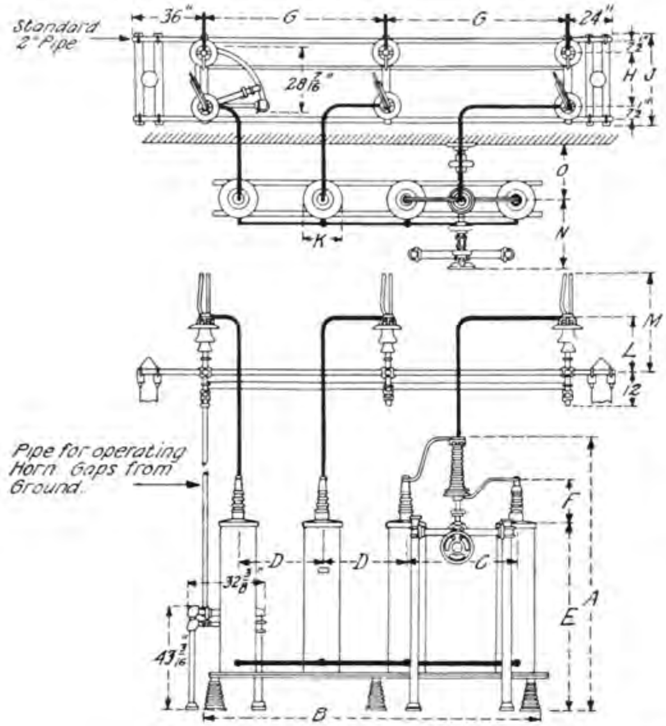


Catalogue numbers do not include material for wiring.

Cat. No.	Volts	A	B	C	D	E	F	G	H	J	K
76710	10000	30	91¾	72	6	69	81	32	16½	42½	16
76712	12500	30	91¾	72	6	69	81	32	16½	45½	16
76714	15000	30	91¾	72	6	69	81	32	16½	48½	16
76716	17500	42	97¼	76	18	69	105	36	16½	51¼	18
76718	20000	42	97¼	76	18	69	105	36	16½	51¼	18
76720	25000	42	97¼	76	18	69	105	36	16½	59¼	18

DIMENSIONS OF ALUMINUM LIGHTNING ARRESTERS

FOR NON-GROUNDED NEUTRAL SYSTEMS—30,000 TO 50,000 VOLTS

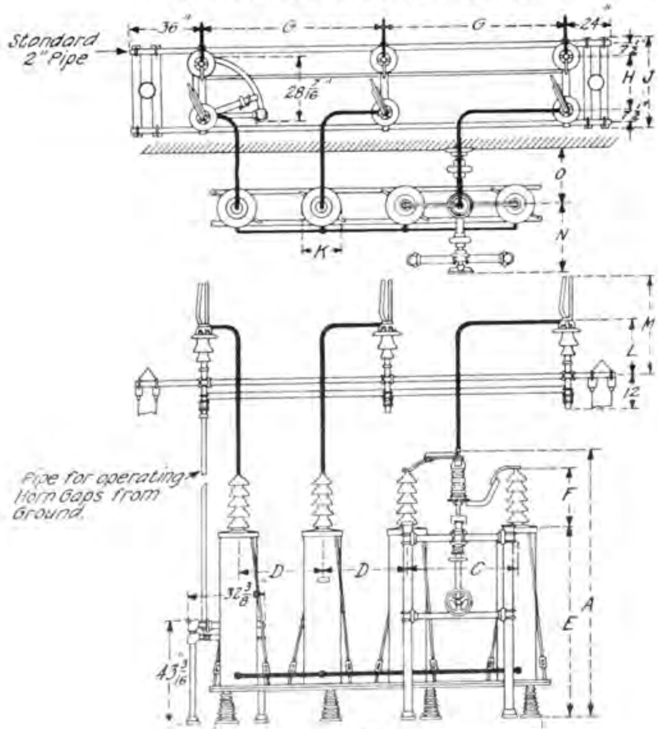


* Cat. No.	Voltage	DIMENSIONS IN INCHES					
		A	B	C	D	E	F
78886	30000	88 3/4	102	38	20	69 3/4	8 3/4
78888	35000	96 1/4	102	38	20	74 1/4	11 3/4
78890	40000	108 1/8	133	47	30 1/2	82 1/2	11 1/8
78892	45000	120 3/4	133	47	30 1/2	90	16 1/4
78894	50000	132 1/2	171	57	43 1/2	99	16 3/4

* Cat. No.	DIMENSIONS IN INCHES (Continued)							
	G	H	J	K	L	M	N	O
78886	48	22	39 3/8	18 11/16	17 3/4	35 5/8	35 7/8	22
78888	48	22	39 3/8	18 11/16	17 3/4	35 5/8	35 7/8	22
78890	60	22	39 3/8	19 11/16	17 3/4	35 5/8	36 7/8	27
78892	72	26	43 3/8	19 11/16	23 3/16	42 3/4	36 7/8	27
78894	72	26	43 3/8	21 7/16	23 3/16	42 3/4	41 7/8	32

* Cat. Nos. do not include material for wiring.

FOR NON-GROUNDED NEUTRAL SYSTEMS—60,000 TO 70,000 VOLTS

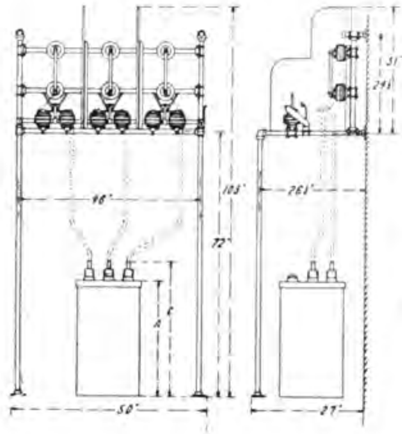


* Cat. No.	Voltage	DIMENSIONS IN INCHES					
		A	B	C	D	E	F
78896	60000	142 3/4	171	57	43 1/2	110 1/2	28 5/8
78898	70000	151 1/2	191 1/2	66	54	125 1/2	28 5/8

* Cat. No.	DIMENSIONS IN INCHES (Continued)							
	G	H	J	K	L	M	N	O
78896	96	41	58 3/8	23 1/2	29 1/2	54 11/16	41 3/8	32
78898	96	41	58 3/8	25 5/8	29 1/2	54 11/16	46 7/8	36

* Cat. Nos. do not include material for wiring.

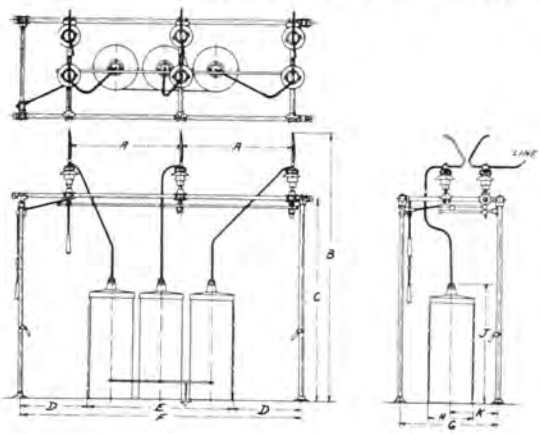
FOR GROUNDED NEUTRAL SYSTEMS, 2500 TO 6600 VOLTS



Catalogue numbers do not include parts shown in dotted lines.

Cat. No.	Volts	A	C
78481	2500	29	33¾
78483	3300	34½	39¼
78485	4600	39½	44¼
78487	6600	43½	48¼

FOR GROUNDED NEUTRAL SYSTEMS, 10,000 TO 25,000 VOLTS

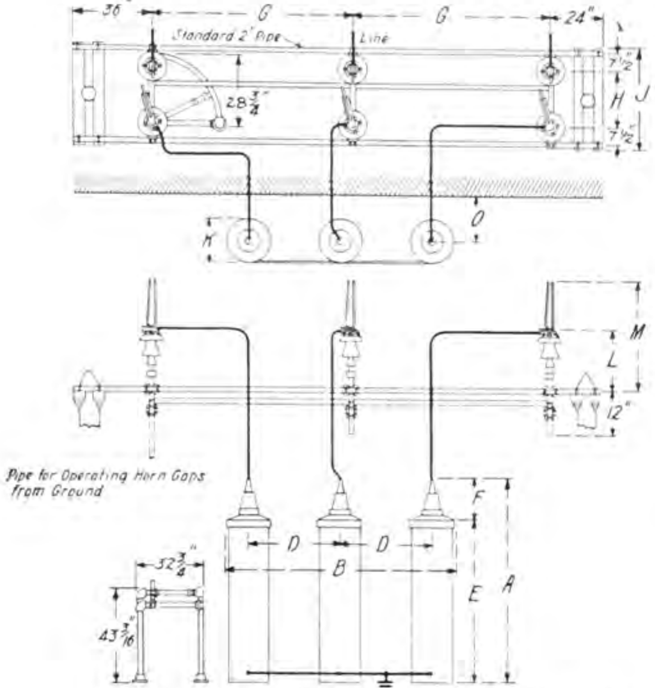


Catalogue numbers do not include material for wiring.

Cat. No.	Volts	A	B	C	D	E	F	G	H	J	K
76709	10000	30	91¾	72	14¾	51½	81	32	16½	31¼	16
76711	12500	30	91¾	72	14¾	51½	81	32	16½	34¼	16
76713	15000	30	91¾	72	14¾	51½	81	32	16½	37¼	16
76715	17500	42	97¼	76	25¼	54½	105	36	17½	39¾	18
76717	20000	42	97¼	76	25¼	54½	105	36	17½	39¾	18
76719	25000	42	97¼	76	25¼	54½	105	36	17½	47⅞	18

DIMENSIONS OF ALUMINUM LIGHTNING ARRESTERS

FOR GROUNDED NEUTRAL SYSTEMS—30,000 TO 50,000 VOLTS

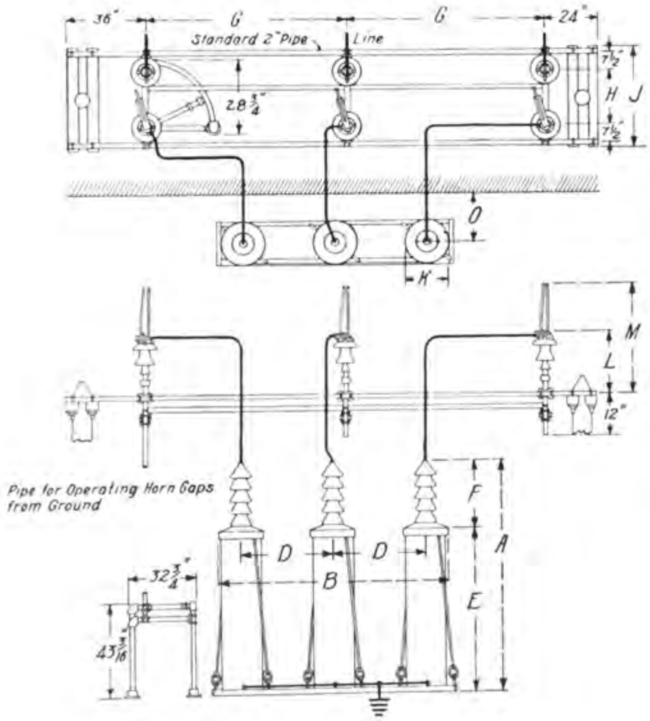


* Cat. No.	Voltage	DIMENSIONS IN INCHES				
		A	B	D	E	F
78885	30000	$63\frac{1}{16}$	$58\frac{3}{4}$	20	$51\frac{1}{2}$	$8\frac{3}{16}$
78887	35000	$70\frac{3}{16}$	$58\frac{3}{4}$	20	59	$11\frac{3}{16}$
78889	40000	$75\frac{7}{16}$	$80\frac{3}{4}$	$30\frac{1}{2}$	$64\frac{1}{2}$	$10\frac{15}{16}$
78891	45000	$88\frac{1}{16}$	$80\frac{3}{4}$	$30\frac{1}{2}$	72	$16\frac{1}{16}$
78893	50000	$97\frac{1}{16}$	$108\frac{1}{2}$	$43\frac{1}{2}$	81	$16\frac{1}{16}$

* Cat. No.	DIMENSIONS IN INCHES (Continued)						
	G	H	J	K	L	M	O
78885	48	22	$39\frac{7}{8}$	$18\frac{3}{4}$	$17\frac{3}{4}$	$35\frac{5}{8}$	12
78887	48	22	$39\frac{7}{8}$	$18\frac{3}{4}$	$17\frac{3}{4}$	$35\frac{5}{8}$	12
78889	60	22	$39\frac{7}{8}$	$19\frac{3}{4}$	$17\frac{3}{4}$	$35\frac{5}{8}$	13
78891	72	26	$43\frac{7}{8}$	$19\frac{3}{4}$	$23\frac{9}{16}$	$42\frac{3}{4}$	15
78893	72	26	$43\frac{7}{8}$	$21\frac{1}{2}$	$23\frac{9}{16}$	$42\frac{3}{4}$	16

* Cat. Nos. do not include material for wiring.

FOR GROUNDED NEUTRAL SYSTEMS—60,000 TO 70,000 VOLTS



* Cat. No.	Voltage	DIMENSIONS IN INCHES				
		A	B	D	E	F
78895	60000	$122\frac{9}{16}$	$110\frac{3}{4}$	$43\frac{1}{2}$	94	$28\frac{3}{16}$
78897	70000	$132\frac{1}{16}$	$133\frac{3}{4}$	54	$103\frac{1}{2}$	$28\frac{3}{16}$

* Cat. No.	DIMENSIONS IN INCHES (Continued)						
	G	H	J	K	L	M	O
78895	96	41	59	$23\frac{5}{8}$	$29\frac{1}{2}$	$54\frac{11}{16}$	22
78897	96	41	59	$25\frac{3}{4}$	$29\frac{1}{2}$	$54\frac{11}{16}$	25

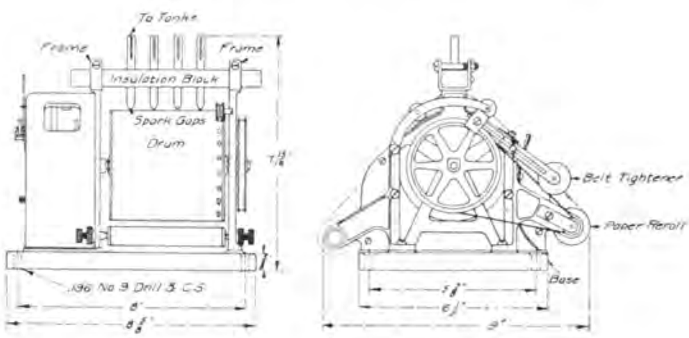
* Cat. Nos. do not include material for wiring.

DIMENSIONS OF ALUMINUM ARRESTERS

FOR USE ON CABLE SYSTEMS

Arresters for three-phase cable systems, Cat. Nos. 78603-78622 inclusive differ from arresters for overhead circuits only in the horn gaps as illustrated, for the higher voltages, in Fig. 14. The dimensions of all other parts of the cable arrester are therefore the same as of an overhead arrester of corresponding voltage. The overall dimensions of both kind of arresters are the same.

DIMENSIONS OF DISCHARGE RECORDER

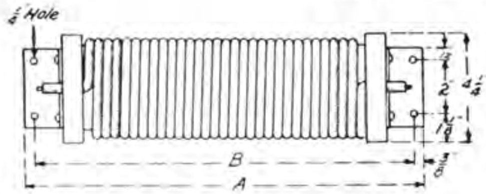


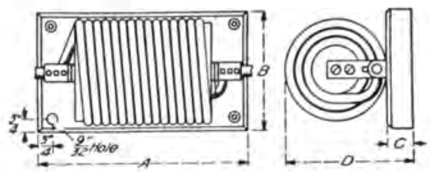
COPPER TUBING AND PARTS FOR WIRING LIGHTNING ARRESTERS

Cat. No.	Description	Outside Diameter in In.	Inside Diameter in In.
76689	Bend 90 deg. 6 in. radius	3/4	11/16
76690	Bend 60 deg. 6 in. radius	3/4	11/16
76691	Bend 45 deg. 6 in. radius	3/4	11/16
76692	Bend 30 deg. 6 in. radius	3/4	11/16
76693	T connector	3/4	11/16
76695	Terminal connector (round end)	3/4	11/16
76696	Terminal connector (square end)	3/4	11/16
76694	Connector 2 in. long	11/16	5/8
Tubing	Any length up to 10 ft.	3/4	11/16

4828-24 Aluminum Lightning Arresters for Alternating Current Circuits

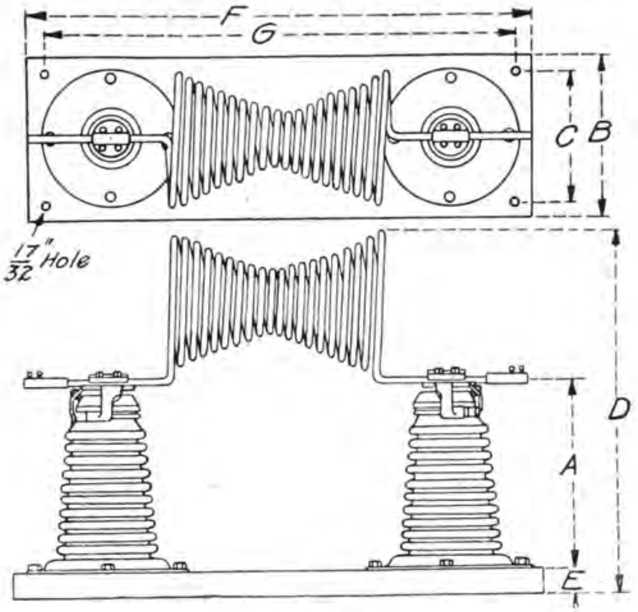
DIMENSIONS OF CHOKE COILS





Cat. No.	Volts	Amp.	A	B	Cat. No.	Volts	Amp.	A	B	C	D
76339	4600	25	15 3/8	14 5/8	25401	6600	25	10 1/2	5 1/2	1 1/4	5 13/16
76340	4600	50	17 5/8	16 7/8	3416	6600	100	12 1/2	7	1 1/2	7 3/4
					36882	6600	200	12 1/2	7	1 1/8	7

200 AMPERES—7500 TO 60,000 VOLTS INCLUSIVE



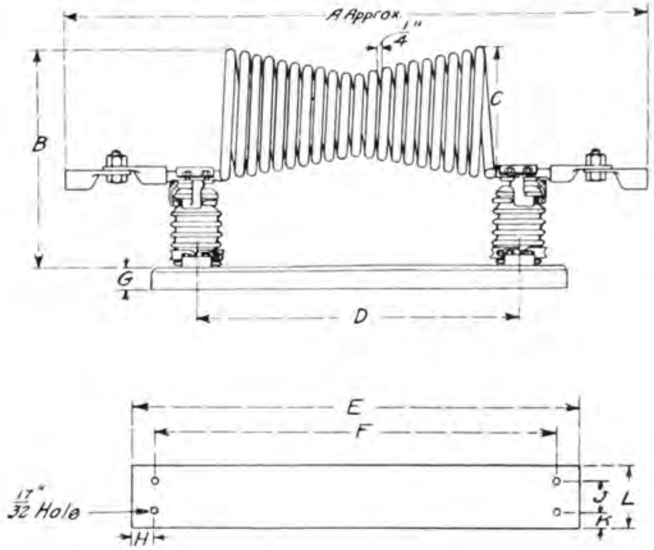
STEEL BASE

CAT. NO. Steel Base	Volts	DIMENSIONS IN INCHES A	B	C	D	E	F	G
78802	7500	6 7/8	8	6	17 1/8	3/8	28 3/4	26 3/4
78806	15000	8	8	6	18 1/4	3/8	28 3/8	26 3/4
78810	25000	10 1/2	12	9	20 3/4	3/8	30 3/4	27 3/4
78815	35000	13 1/4	12	9	20 3/4	3/8	30 3/4	27 3/4
78820	45000	17 3/8	12	9	27 5/8	3/8	31 3/4	28 3/4
78825	60000	21 1/2	12	9	31 3/4	3/8	32 3/4	29 3/4

MARBLE BASE AND SLATE BASE

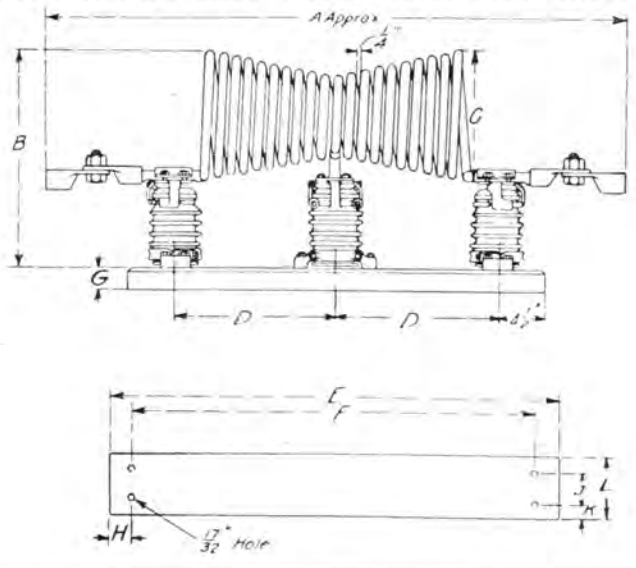
CAT. NO. Marble Base	CAT. NO. Slate Base	Volts	DIMENSIONS IN INCHES A	B	C	D	E	F	G
78800	78801	7500	6 7/8	8 1/2	5 3/4	18 3/4	2	35	32 1/4
77704	77699	15000	8	8 1/2	5 3/4	19 11/16	2	35	32 1/4
77705	77700	25000	10 1/2	13	10 1/4	22 3/8	2	35	32 1/4
77706	77701	35000	13 1/4	13	10 1/4	25 1/8	2	35	32 1/4
77707	77702	45000	17 3/8	13	10 1/4	29 1/16	2	35	32 1/4
77708	77703	60000	21 1/2	13	10 1/4	33 3/8	2	35	32 1/4

400 AMPERES—7500 TO 15,000 VOLTS INCLUSIVE



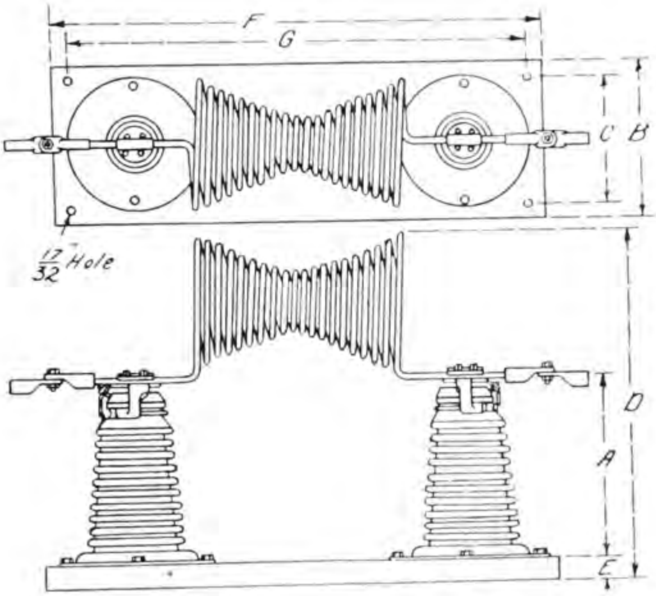
Cat. No.	Amperes	Volts	DIMENSIONS IN INCHES										
			A	B	C	D	E	F	G	H	J	K	L
78803	400	7500	41	17⅛	10$\frac{5}{16}$	24	33	31	⅜	1	6	1	8
78807	400	15000	41	18$\frac{3}{16}$	10$\frac{5}{16}$	24	33	31	⅜	1	6	1	8

650 AND 1000 AMPERES—7500 TO 15,000 VOLTS INCLUSIVE

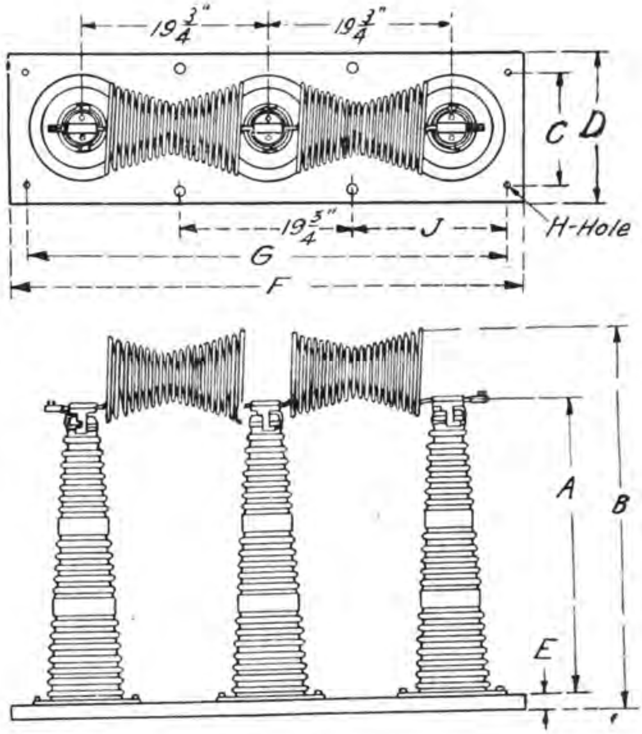


Cat. No.	Amperes	Volts	DIMENSIONS IN INCHES										
			A	B	C	D	E	F	G	H	J	K	L
78804	650	7500	47	17½	10⅝	13½	36	34	⅜	1	6	1	8
78805	1000	7500	53	17¾	11	15½	40	38	⅜	1	6	1	8
78808	650	15000	47	18½	10⅝	13½	36	34	⅜	1	6	1	8
78809	1000	15000	53	18⅞	11	15½	40	38	⅜	1	6	1	8

4828-26 Aluminum Lightning Arresters for Alternating Current Circuits



400 AMPERES—25,000 TO 60,000 VOLTS INCLUSIVE



200 AMPERES—70,000 TO 110,000 VOLTS INCLUSIVE

400 AMPERES—25,000 TO 60,000 VOLTS INCLUSIVE

STEEL BASE

Cat. No. Steel Base	Volts	Dimensions in Inches						
		A	B	C	D	E	F	G
78814	25000	$10\frac{1}{2}$	12	9	$21\frac{1}{16}$	$\frac{3}{8}$	35	32
78819	35000	$13\frac{1}{4}$	12	9	$23\frac{13}{16}$	$\frac{3}{8}$	35	32
78824	45000	$17\frac{3}{8}$	12	9	$27\frac{15}{16}$	$\frac{3}{8}$	36	33
78829	60000	$21\frac{1}{2}$	12	9	$32\frac{1}{16}$	$\frac{3}{8}$	37	34

MARBLE BASE AND SLATE BASE

Cat. No.		Volts	Dimensions in Inches						
Marble Base	Slate Base		A	B	C	D	E	F	G
78813	78812	25000	$10\frac{1}{2}$	12	9	$22\frac{11}{16}$	2	35	32
78818	78817	35000	$13\frac{1}{4}$	12	9	$25\frac{7}{16}$	2	35	32
78823	78822	45000	$17\frac{3}{8}$	12	9	$29\frac{9}{16}$	2	36	33
78828	78827	60000	$21\frac{1}{2}$	12	9	$33\frac{11}{16}$	2	37	34

200 AMPERES—70,000 TO 110,000 VOLTS INCLUSIVE

Cat. No.	Volts	Dimensions in Inches								
		A	B	C	D	E	F	G	H	J
78830	70000	$21\frac{9}{16}$	$30\frac{3}{4}$	9	12	$\frac{3}{8}$	$52\frac{1}{2}$	$49\frac{1}{2}$	$\frac{17}{32}$	$14\frac{7}{8}$
78831	90000	27	$37\frac{1}{8}$	11	14	$\frac{3}{8}$	$53\frac{1}{2}$	$50\frac{1}{2}$	$\frac{17}{32}$	$15\frac{3}{8}$
78832	110000	$36\frac{7}{16}$	$46\frac{1}{2}$	11	14	$\frac{3}{8}$	$54\frac{1}{2}$	$51\frac{1}{2}$	$\frac{17}{32}$	$15\frac{7}{8}$

INDEX

GENERAL ELECTRIC COMPANY

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(Address nearest office)

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New Haven, Conn.	Malley Building
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Schenectady, N.Y.

May, 1911

Bulletin No. 4829

ELECTRIC LOCOMOTIVES FOR INDUSTRIAL RAILWAYS

The transportation of material is an important feature of many industries, and in some instances is a vital factor in the total cost of operation. It is a problem worthy of careful study, and its proper solution will be found to result invariably in economy of both time and money.

The electric locomotive is admirably adapted to fulfill the transportation requirements of all industries and possesses many advantages over steam locomotives, animal haulage, hand trucks, etc. Large factories are usually connected with the nearest railway by a spur track and the movement of freight cars over this spur and about the factory yards, if done by the railway company, involves more or less heavy switching charges. If the manufacturer operates a steam locomotive of his own, the expense is also great, since it requires a high grade operator, consumes coal when standing idle and involves heavy maintenance charges. For this class of work the electric locomotive possesses many advantages, the more important of which are outlined as follows:

EIGHT TON LOCOMOTIVE—EMPIRE BRICK AND SUPPLY CO., WALSHVILLE, N. Y.

It consumes power only when in actual operation.

Can be operated by one man of ordinary intelligence.

Is ready for use at all times.

Has large momentary overload capacity.

Possesses an easy and perfect system of control.

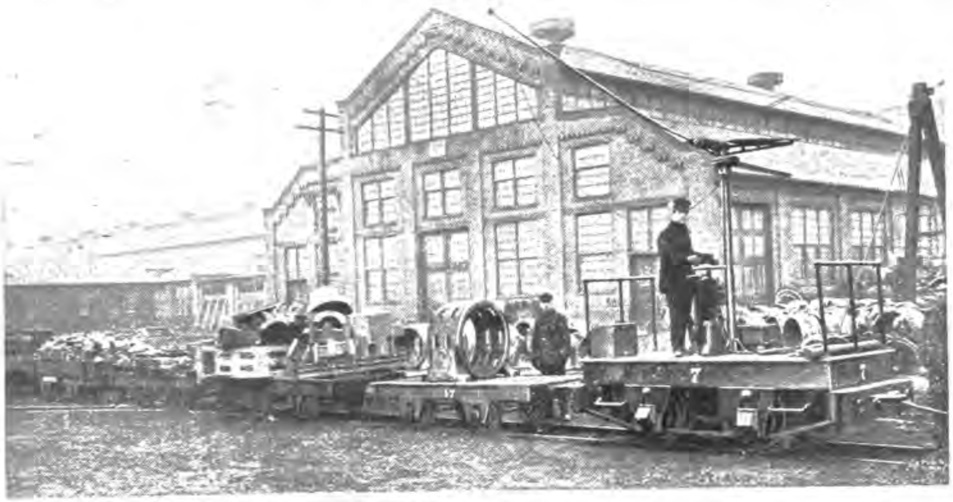
Has comparatively few wearing parts and consequently low maintenance cost.

Requires attention only when actually in use.

Can be run inside a building and in other localities where the smoke and fire risk of a steam locomotive would forbid its use.

The inter-factory transportation of large manufacturing plants, that consist of buildings scattered over considerable areas, can be most satisfacterily and economically handled by small electric locomotives. At the factories of the General Electric Company the transportation of material between the various buildings is practically all accomplished in this manner. In those manufacturing plants that have installed a system of narrow gauge tracks, and transport material on small cars pushed by hand, it is a comparatively simple matter to elaborate the system by the addition of one or more electric locomotives since it is only necessary to string the overhead trolley wire, and if electric power is not already in use, install a suitable generator. In many cases advantageous arrangements can be made with the local lighting or street railway company to furnish power.

Factory transportation service, however, is only one of the many fields in which the electric locomotive can be advantageously used. It is equally well adapted for service in brick yards, stone quarries, cement plants, etc. In getting ore from mines to the stamp mills, hauling log trains to the saw mill, and other similar service, the electric locomotive is well fitted, particularly if heavy grades are encountered; for owing to the fact that all its weight is on the drivers and the tractive effort is continuous instead of pulsating, it will climb grades that for the steam locomotive are prohibitive. They are also employed successfully on large public works where great quantities of earth and rock have to be moved, the high cost and delay of animal haulage more than offsetting the expense of the electric installation. In tunnel driving particularly, the low, mine type of locomotive provides an ideal form of haulage.



SEVEN TON LOCOMOTIVE USED IN YARDS OF THE GENERAL ELECTRIC COMPANY'S SCHENECTADY WORKS

The line of electric industrial locomotives designed and built by the General Electric Company covers a range of sizes and forms wide enough to include any haulage requirement and they incorporate principles of construction which are the result of many years experience in this class of work. Full advantage has also been taken of the experience gained in the manufacture of mine locomotives, which have to be built to withstand unusually severe service and rough handling. In common with all other lines of apparatus manufactured by the General Electric Company, they embody a high quality of material and workmanship and undergo a rigid system of inspection and tests.

It is the purpose of this bulletin to illustrate and briefly describe a few representative types of General Electric industrial locomotives. The locomotives are of the single truck, two motor type and vary in weight from two tons to twenty-five tons; they are built for gauges varying from 18 in. up to 56½ in. and are fitted with motor equipments designed for operation on 250 and 500 volt direct current circuits. Locomotives can also be furnished equipped with three-phase induction motors for operating on alternating current circuits of 25 and 60 cycle frequency. Alternating current operation involves the use of two trolley poles and two overhead trolley wires; the track rails forming the third leg of the three-phase circuit.

Details of frame construction, arrangement of bumpers and coupling, location of control apparatus, cab, etc., vary considerably with the different types of locomotives. The general principles of construction, however, that are common to all types are herein briefly described.

Frames

On the small and medium sizes the frames are, for the most part, built up of structural steel. Channel or I beam sections are used for the side frames and the end frames are channel beams faced off with heavy wooden bumpers. Heavy steel angles and large through bolts hold the side and end frames together and, where necessary, heavy gusset plates are used on the larger sizes. Cast pedestal boxes are securely bolted to the bottom edge of the side frames and in addition are braced with heavy forged stay rods. Coupling devices are mounted on the bumpers and held in position by through bolts passing through bumper and end frame. The particular style of coupling device depends upon the cars that the locomotive is to haul. On the heavier locomotives, from about fifteen tons and above, the frames are made of cast iron. The side frames are cored out to form pedestal jaws for the journal boxes

FIFTEEN TON LOCOMOTIVE—SINGER MANUFACTURING CO.
ST. JOHNS, P. Q.

and across the bottom of the jaws heavy stay plates are bolted. The joint surfaces between the side and end frames are accurately machined and the joints are held by heavy helical springs which are made from a high grade spring steel and are designed to withstand the heavy shocks incidental to this class of service.

SEVEN TON LOCOMOTIVE—YALE & TOWN MANUFACTURING CO., STAMFORD, CONN.

finished bolts driven into reamed holes, thus producing a frame that has the rigidity of a solid casting.

Journal Boxes and Springs

The journal boxes are of the regular railway type with removable brass linings and are lubricated from oil cellars filled with waste; the linings being made of a special

Wheels and Axles

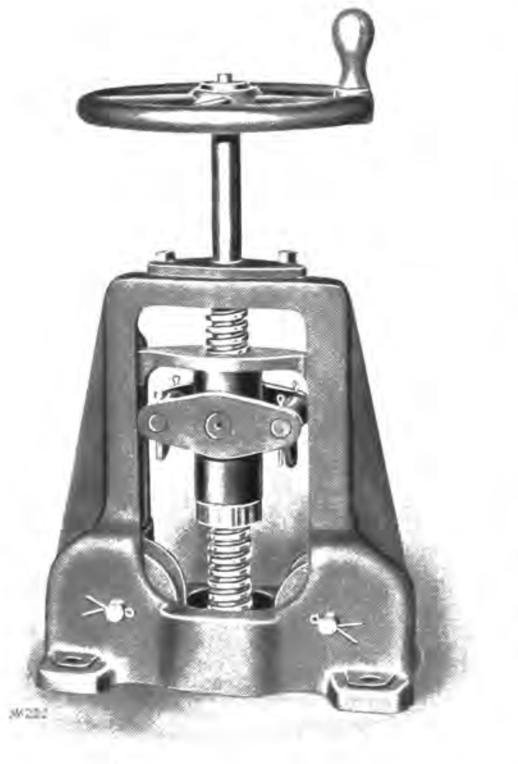
Chilled iron wheels are furnished as a standard equipment, but steel tired or rolled steel wheels can be supplied if desired. The shape of the wheel flange and dimensions at the throat radius conform to M.C.B. standards. The wheels are pressed on and securely keyed to heavy steel axles.

SINGLE SHIPMENT OF SIX AND ONE-HALF TON LOCOMOTIVES

alloy of bearing brass, and so designed that they will remain in position in case of derailment. The weight of the locomotive is supported from the journal boxes on heavy

Brake Mechanism

A strong and efficient brake rigging is a feature of these locomotives. While the arrangement of brake rods and levers varies with the size and type of the locomotive, the tension in all cases is obtained by the screw and nut principle. The method of employing this principle is clearly shown in the accompanying illustration of the brake stand. The pitch of the square threaded screw is such that a slight exertion on the part of the motorman produces ample shoe pressure, and the length of the threaded portion is sufficient to automatically compensate for practically all the brake shoe wear. An advantageous feature of this screw tension scheme is that the brakes are automatically locked in any position in which they are left by the operator without the use of pawls or ratchets.



SCREW AND NUT BRAKE STAND FOR LOCOMOTIVES

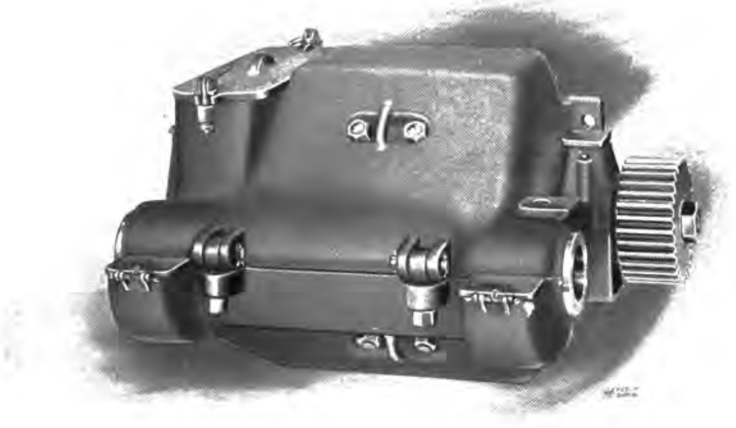
On locomotives weighing fifteen tons or more, air brakes are furnished. Either straight or automatic air brakes can be supplied as desired, but if, as is usually the case, the locomotive is to handle but a few cars over comparatively short distances, air line connections are not ordinarily made and straight air on the locomotive is, therefore,

INTERIOR OF CAB SHOWING ARRANGEMENT OF CONTROL APPARATUS INCLUDING COMBINED HAND AND AIR BRAKE CYLINDER

all that is required. The brake cylinder is of a special design and is provided with an auxiliary screw and handwheel mechanism which permits the brakes to be applied by hand in the event of an accident to the air system.

Cabs

The cabs are built of sheet steel securely riveted and provided with angle iron stiffening ribs. Suitable doors and windows are provided so that the motorman has an unobstructed view on all sides. The location of the control apparatus is so arranged as to be within convenient reach of motorman when leaning out of the cab window to receive signals from the trainman.



TYPE OF MOTOR USED ON HEAVY STANDARD GAUGE LOCOMOTIVES

ELECTRICAL EQUIPMENT

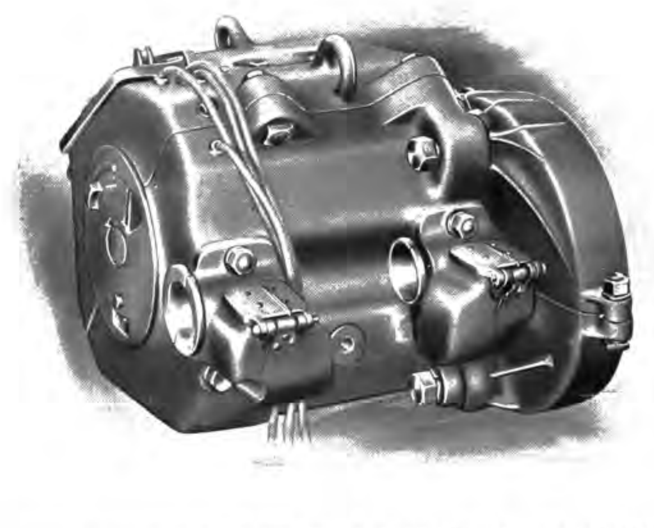
Motors

While varying with the weight of locomotive, and to some extent with the gauge, the motors furnished with any particular locomotive are of ample capacity. They are of the series wound, totally enclosed type with windings designed for the slow speed, high tractive effort requirements of locomotive service. They are of an exceptionally rugged design mechanically, are well protected against dust and moisture, are accurately machined to insure interchangeability of parts and in general are built to withstand rough usage.

They are mounted directly on the axles and drive through single reduction gearing. The gears are of the split type and are securely bolted together over the axle key. They are cast from a high grade steel and have machine cut teeth. The pinions are cut from a solid forged blank of superior steel and are keyed securely to the armature shaft. Gear and pinion are enclosed in a malleable iron dustproof case.

Controllers

The controllers are of the rheostatic magnetic blowout type especially designed for this class of service. A commutating switch is incorporated in the reverse cylinder, the handle of which has four "on" positions, two for each direction of motion, one with the motors in series and the other with the motors in multiple. The main and reverse cylinders are interlocked in the usual manner and the main cylinder provides for speed regulation with the motors connected either in series or multiple. This system of control, by permitting the motors to be started in multiple, allows them to exert their maximum tractive effort independently; so that when one motor slips its wheels, the other is not affected—a valuable feature when start-



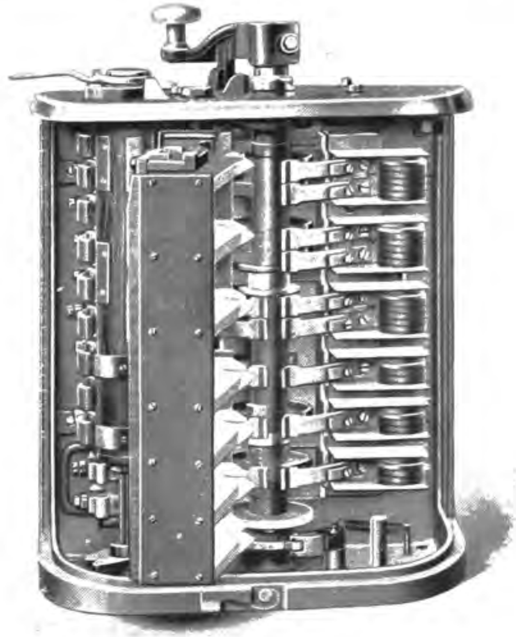
TYPE OF MOTOR USED ON SMALL NARROW GAUGE LOCOMOTIVES ing heavy loads. The series connection, in addition to giving a slow speed point, effects a considerable economy in current consumption; with motors in series the locomotive will develop a given drawbar pull with one-half the current input required when motors are in multiple, the speed being reduced in approximately the same ratio.

HAULAGE CAPACITY

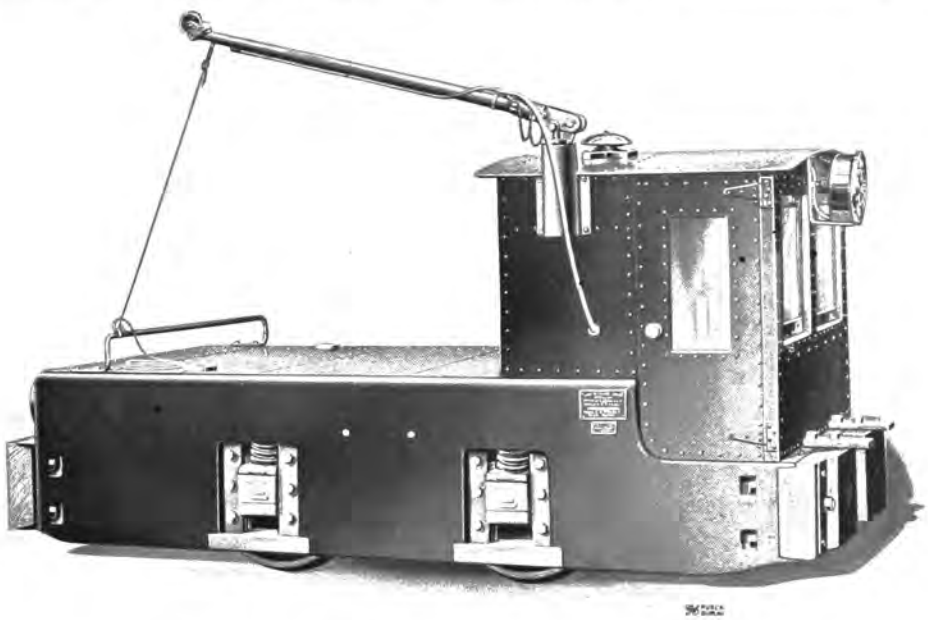
The amount of trailing load a locomotive will haul is determined by several factors, viz., the weight on the locomotive driving wheels, the coefficient of adhesion between the tread of the drivers and the track, the frictional resistance of the trailing load and the gradient of the track.

Adhesion

As motors are mounted on both axles of the single truck type of locomotives described in this bulletin, all four wheels develop traction and the weight on the drivers is, therefore, the total weight of the locomotive. The coefficient of adhesion between the tread of the drivers and the track is a variable quantity and depends upon the condition of the surfaces in contact. Experience has shown that under ordinary conditions with clear, dry rail this coefficient is about 25 per cent. A ten ton locomotive, for example,



CONTROLLER WITH COVER REMOVED



MINE TYPE LOCOMOTIVE EQUIPPED WITH CAB FOR SURFACE WORK

SEVEN TON MINE LOCOMOTIVE WITH CAB—AMERICAN SMELTING AND REFINING CO.
PUEBLO, COLO.

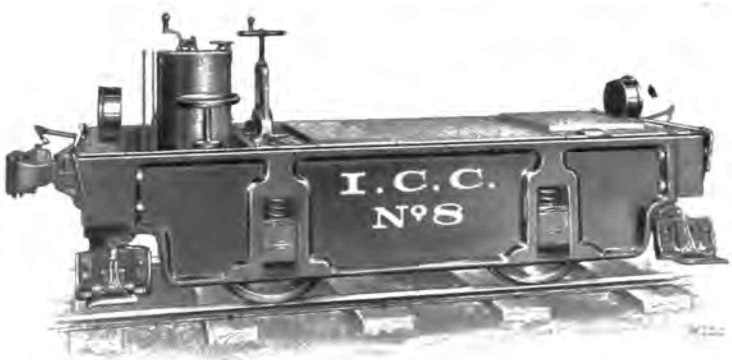
TWENTY-FIVE TON SWITCHING LOCOMOTIVE

would therefore, develop a maximum tractive effort of $10 \times 2000 \times 0.25 = 5000$ lbs. before slipping the wheels. With the rails slippery due to grease, snow, clay or other causes the adhesion is, of course, much less than this figure and falls to 15 per cent. or 12 per cent. and lower; but in general practice 25 per cent. maximum tractive effort is usually obtainable, and the application of sand will increase the adhesion in event of having to start the train on a slippery portion of the track. It is inadvisable, however, to work a locomotive at a load that demands the maximum tractive effort continually for there is then no reserve capacity and as a result the wheels slip frequently, thus causing them to wear rapidly. In addition to this, train movements are slow, more sand is used and the general wear and tear on track and equipment is considerably increased. No definite rule can be given for determining the weight of locomotive necessary to haul a given load, but as a general statement the weight should be such that the average load will require a tractive effort that is well within the maximum, say 10 per cent. or 15 per cent. less; so that there is ample margin left for starting, rounding sharp curves, ascending grades, etc.

SIX AND ONE-HALF TON LOCOMOTIVE ARRANGED FOR THIRD RAIL OPERATION

Although this holds in a general way, each particular haulage problem should be studied with reference to local conditions; the weight of rails, extent and location of grades, probable future increase of train weight and other similar considerations usually serving to govern the decision.

The proper selection of a locomotive is largely a matter of experience and familiarity with this class of work, and unless the type and size of the locomotive is definitely known, the interests of prospective purchasers will best be served if they submit their haulage requirements for recommendations. To this end several blank data sheet forms accompany this bulletin. These indicate the information that should be submitted in order that proper recommendations may be made.

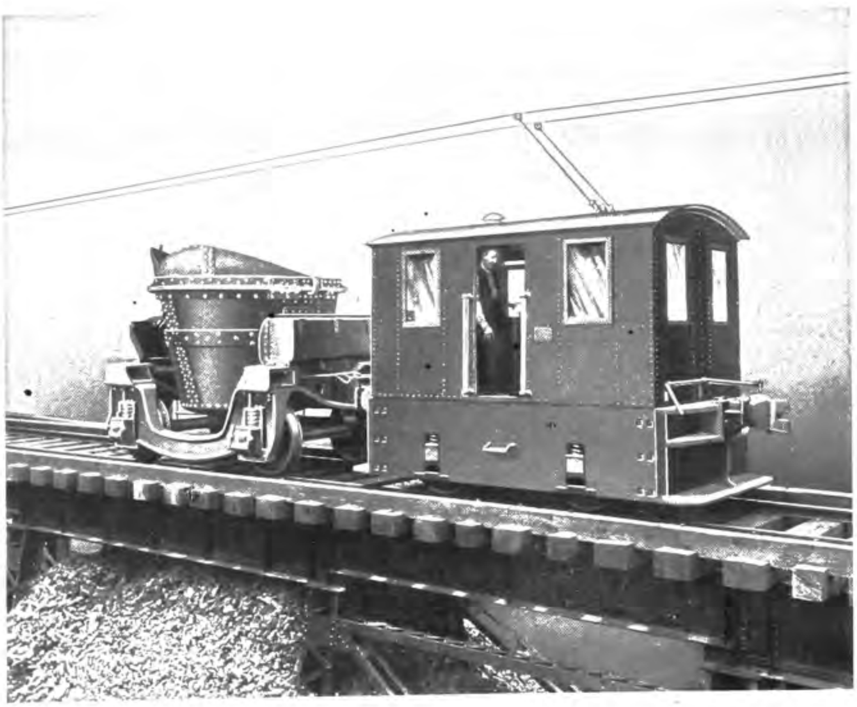


SAME LOCOMOTIVE AS THE ABOVE WITH CAB REMOVED

Load Resistance

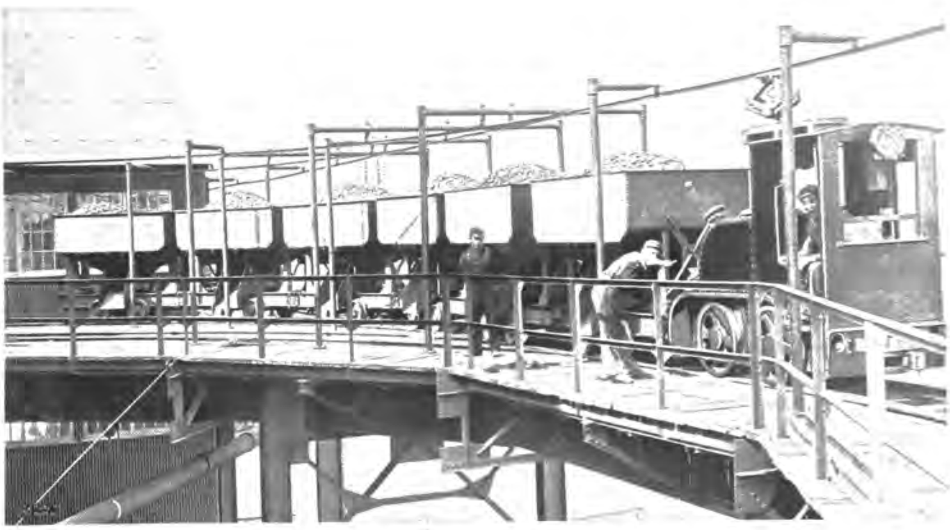
The frictional resistance of the trailing load is due to the friction of the wheel treads and flanges against the rail and the friction of the car journals. On good tracks with well laid, heavy rails and good jour-

SEVEN TON LOCOMOTIVE—SEMET-SOLVAY CO., ENSLEY, ALA.



FIFTEEN TON LOCOMOTIVE—NATIONAL STEEL CO., YOUNGSTOWN, O.

nals such as are usually found on standard freight cars, this combined car and track resistance may be as low as 8 or 10 lb. per ton; and light, badly laid rails in combination with poorly lubricated car journals may produce a resistance of 40 to 60 lb. per ton. Between 15 and 20 lb. per ton is a conservative figure to use for freight cars and the conditions usually found on spur tracks and sidings of factories and other industrial plants, while for narrow gauge roads with light rails and the ordinary industrial cars from 20 to 30 lb. is a fair able, therefore, to lay out curves to as large a radius as local conditions will permit. The resistance may be materially reduced by widening the gauge at curves. On sharp curves the gauge should be increased as much as the width of the wheel tread will permit. A great deal also depends on the wheel base of cars and locomotive. Ordinarily the radius of the sharpest curve should not be less than five or six times the wheel base. Diagram on page 12 gives a convenient method for determining the radius of short curves.



SIX TON LOCOMOTIVE—INDIANA STEEL CO., GARY, IND.

figure. As static friction is much greater than running friction, it obviously requires considerably more force to start a car from rest than to keep it moving after once started, but as a rule, unless the train is to be started on a grade and there are no brakes on the cars, the slack can be taken up at the several couplings and thus only one car at a time is actually started.

Curves

The additional track resistance due to curves is very considerable and extremely variable, and is, of course greater, the shorter the radius. On sharp curves the resistance is increased 100 per cent. or more. It is desir-

The simplest method of designating a curve is by its radius, i.e., the distance from the center line between the rails to the center of the circle of which they form an arc. Civil engineers sometimes designate a curve by degrees, specifying the number of degrees of central angle subtended by a chord 100 feet, but the sharper curves which are found in this class of work, are usually designated by their radii. For measuring the radius of sharp curves the following method is convenient. Measure a chord AC across the inner rail of a *uniform* portion of the curve, as shown in the diagram on page 12 and the perpendicular distance BD between the center of this line and the rail. The radius of the curve may then be determined by the formula $R = \frac{\overline{AB}^2 + \overline{BD}^2}{2\ BD} + \frac{1}{2}$ gauge.

For example:

$G = 36$ inches (gauge);

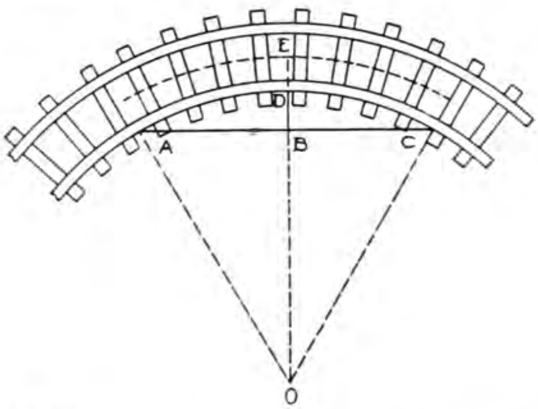
$AC = 20$ feet $= 240$ inches;

$AB = 120$ inches;

$BD = 21$ inches by measurement.

$$R = \frac{120^2 + 21^2}{42} + \frac{36}{2} = 372 \text{ inches} = 31 \text{ feet} = OE.$$

Care should be exercised to avoid having any portion of the straight track at either end of the curve included in the arc of the chord. It is also advisable to take measurements at several locations along the curve in order to compensate for irregularities.



Grades

The resistance due to grades is additional to the car and track resistance and is always 20 lb. per ton for each per cent. of grade. Thus, with a car and track resistance of 20 lb. per ton and a 4 per cent. grade the total train resistance is $20 + (4 \times 20) = 100$ lb. per ton. Not only does the grade greatly increase the total train resistance, but it also reduces the available draw bar pull of the locomotive, for of the total tractive effort developed at the drivers 20 lb. per ton on 1 per cent. of the weight of the locomotive for each per cent. grade is consumed solely in driving the locomotive itself up the grade.

It is at once apparent that the maximum adverse grade, in other words the limiting grade, of any system of tracks is the controlling factor in determining the size of locomotive necessary for a given trailing load.

THREE TON NARROW GAUGE LOCOMOTIVE

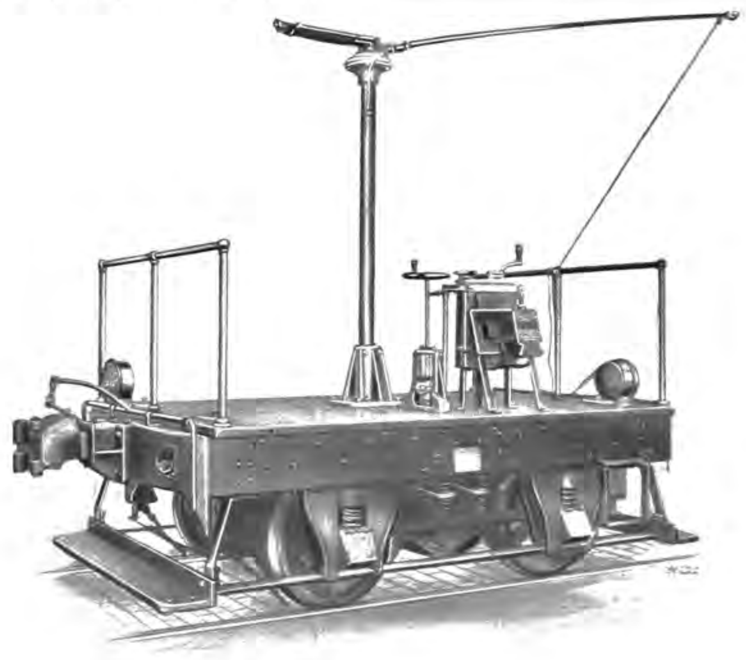
To illustrate: Assuming an 80 ton trailing load, a car and track resistance of 20 lb. per ton and a track that is practically level throughout except for a short stretch of 2 per cent. grade.

On the level portion the total train resistance is $80 \times 20 = 1600$ lb. and on the grade it is $80 \times [20 + (2 \times 20)] = 4800$ lb. A four to five ton locomotive would be sufficient to handle this train on the level, but to get it over the grade would require a locomotive weighing from thirteen to fourteen tons.

FIFTEEN TON STANDARD GAUGE LOCOMOTIVE

This example further indicates that, local conditions permitting, a reasonable amount of money spent in eliminating sharp grades is an exceedingly good investment. On short grades, say 100 to 200 ft., a locomotive may be worked close to the slipping point (or maximum tractive effort), particularly if the grade occurs at a point which is preceded by a stretch of straight level track In this case the locomotive may approach at full speed and the momentum thus gained will materially assist in getting over the grade.

Weight of Locomotive in Tons	Minimum Weight of Rail per Yard	Weight of Rail per Yard Recommended
3	16	20
4	16	25
5	16	25
6	16	30
7	20	40
8	20	40
10	25	45
15	40	50
20	50	60
25	60	80

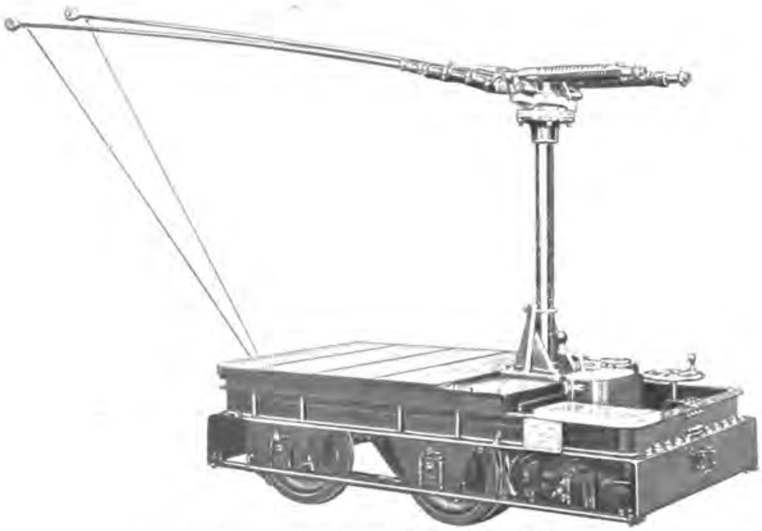


SEVEN TON STANDARD GAUGE LOCOMOTIVE FOR YARD SERVICE

Rails

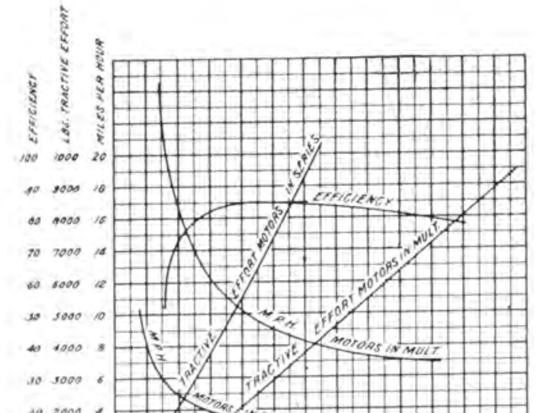
The weight of rail in pounds per yard is usually determined by allowing ten pounds per yard for each ton of locomotive weight per driving wheel. Thus a ten ton, four wheel locomotive would have $\frac{10}{4}=2.5$ ton per driver and the required weight of rail would be $2.5\times 10=25$ lb. per yard. This formula gives the minimum weight of rail, but much better results will be obtained by using the heavier rail recommended in the following table.

The accompanying curve sheet gives a graphical representation of the speed and tractive effort characteristics obtained with a typical two motor equipment of the direct current series wound type such as is furnished with a ten ton locomotive. As shown, speed and tractive effort are plotted against current input, the vertical divisions representing amperes and the horizontal divisions the corresponding speed and tractive efforts in miles per hour and pounds respectively. The series motor possesses the inherent quality of adjusting its speed and tractive effort to the load imposed upon it. For instance, the curves show that when develop-



TWO TON NARROW GAUGE LOCOMOTIVE

ing 3000 lb. tractive effort with the motors in multiple the current input is 250 amperes and the corresponding speed nine miles per hour. If now the locomotive should strike a grade or the load be otherwise increased so as to demand a tractive effort of 5500 lb., the motors would slow down and take 400 amperes input with the speed reduced to 7.4 miles per hour. If the controller cylinder were thrown to the "series" point, 5500 lb. tractive effort would be developed at one half the current input (200 amperes). As one-half the line voltage would now be impressed at the terminals of each motor, the speed would be reduced at a somewhat greater ratio and in this case would drop to 3.4 miles per hour.



TWELVE TON LOCOMOTIVE—UNION PORTLAND CEMENT CO., PORTLAND, UTAH

Drawbar pull (D.B.P.) is the pull in pounds at the locomotive coupling that is available for hauling. It is less than the tractive effort developed at the tread of the drivers by the amount of the losses incurred in propelling the locomotive itself. For these losses, which consist of journal and axle bearing friction and the friction at the wheel tread and flanges, 1 per cent. of the locomotive weight, or 20 lb. per ton, is allowed.

EIGHT TON LOCOMOTIVE—EMPIRE BRICK AND SUPPLY CO., WALSHVILLE, N. Y

Therefore D.B.P. = Te − 20 W

where Te = tractive effort in lb.

W = weight of locomotive in tons.

As a convenient measure of hauling capacity it is customary to assign to locomotives a rated (or running) drawbar pull. General Electric industrial locomotives are given a rated drawbar pull equal to 20 per cent. of the weight in pounds. This rating is based on a clean, dry rail and a straight, level track.

SPECIFICATIONS FOR ELECTRIC INDUSTRIAL HAULAGE

General Electric Company, Power & Mining Dept.

Company ....Date...
Location...Business ....

Road:

........................feet of single track;........................feet of double track;........................feet aggregate length of track; ....turnouts;........................sidings.

Track:

Gauge, measured from inside of one rail to inside of other..
Weight of rail per yard .. ..Length of rail...................... ...
Minimum radius of curves ....
Condition of track........ ....

Grades:

Maximum grade against load ....per cent. for........................ feet.
Maximum grade with load ....per cent. for...................... feet.
........................other grades of........................per cent.
Will locomotive have to start the train on the maximum adverse grade?................................
Will braking be done on cars?........................Or will locomotive have to control train on down grades?...

Trolley:

Location—center, right-hand, left-hand...
Maximum height..... ....Minimum height.. ....
Average height...

Locomotive:

If there are space limitations, what is width which can be allowed locomotive?................
What is maximum height which can be allowed locomotive?..
What is voltage of power supply?..
Is locomotive to be equipped with a cab?..

Cars:

Weight of empty car........................lb.
Weight of loaded car........................lb.
Wheel base of cars........................
Are car journals self oiling?........................
What is height of center of car coupling above rail?...
What is style of car coupling?..

Work to be done:

Number of cars handled in........................hours........................
Number of cars per trip........................

Remarks:

A map and profile of the track should be furnished whenever possible.

When cars are other than the standard freight, it is desirable to furnish a drawing or at least a rough sketch that will show the general shape and dimensions of the bumpers, arrangement of couplings and distance of bumpers above rail head.

A brief statement that will cover in a general way the character of the work to be done and the manner in which it is proposed to operate the haulage system will be helpful in working up recommendations.

SPECIFICATIONS FOR ELECTRIC INDUSTRIAL HAULAGE

General Electric Company, Power & Mining Dept.

Company..Date..
Location..Business..

Road:

..................feet of single track;..................feet of double track;..................feet aggregate length of track;..................turnouts;.................. sidings.

Track:

Gauge, measured from inside of one rail to inside of other..
Weight of rail per yard..................Length of rail..................
Minimum radius of curves..
Condition of track..

Grades:

Maximum grade against load..................per cent. for..................feet.
Maximum grade with load..................per cent. for..................feet.
..................other grades of..................per cent.
Will locomotive have to start the train on the maximum adverse grade?..................
Will braking be done on cars?..................Or will locomotive have to control train on down grades?..................

Trolley:

Location—center, right-hand, left-hand..................
Maximum height.................. Minimum height..................
Average height..................

Locomotive:

If there are space limitations, what is width which can be allowed locomotive?..................
What is maximum height which can be allowed locomotive?..................
What is voltage of power supply?..................
Is locomotive to be equipped with a cab?..................

Cars:

Weight of empty car..................lb.
Weight of loaded car..................lb.
Wheel base of cars..................
Are car journals self oiling?..................
What is height of center of car coupling above rail?..................
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SUPPLY DEPARTMENT

April, 1911 | *Bulletin No. 4831*

OIL BREAK SWITCHES FOR MANHOLE SERVICE TYPE F, FORM P-4

Type F, Form P-4 oil break switches are built for mounting on vertical flat surfaces, in manholes or in locations where there is danger of flooding. These switches are made single-, double- or triple-pole, single-throw, for use on circuits up to 7500 volts. The normal current rating is 200 amperes.

SINGLE-POLE MANHOLE SWITCH WITH TWO OUTLETS

CONSTRUCTION

The frame, cover and oil vessel are of cast iron and by means of gaskets all joints are made watertight. The frame is provided with a large vent hole, to which a pipe may be connected and extended above the water line to prevent any undue strain on the gaskets, due to gases generated when the switches are opened under load. The opening at the end of this vent pipe should be hooded.

The operating handle is outside the frame and is of such design that the switch can be operated with a hook. The shaft to which the handle is attached, passes through the frame in a watertight stuffing box.

The leads are carried to and from the switch through the bottom of the frame, watertight bushings being provided on the frame. The double- and triple-pole switches are so arranged that each lead may pass through a separate outlet, or one outlet may be used in each end of the frame for double or triple conductor cable.

The stationary contacts consist of flared fingers, of drop forged copper, supported from the contact blocks of the current carrying copper studs by heavy flat steel springs.

The studs are supported and insulated from the frame by porcelain insulators.

The movable contacts are wedge shaped copper blades, actuated by specially treated wooden rods, connected to the crosshead which in turn is operated by the handle and actuating mechanism.

The construction of the stationary and movable contacts is such that the arc is ruptured between the flared portion of the stationary and the upper extremity of the movable contacts, saving the actual contact surfaces from burning or pitting. This form of construction insures clean contact surfaces, uniform contact under pressure, and does not retard the opening of the switch.

OIL

The General Electric Company recommends the use of No. 6 transil oil, which has been especially developed for oil switch service. This oil is particularly adapted to this work because of its resistance to carbonizing and high flashing point.

For manhole switches used in extremely cold climates, a special oil can be furnished adapted for this service.

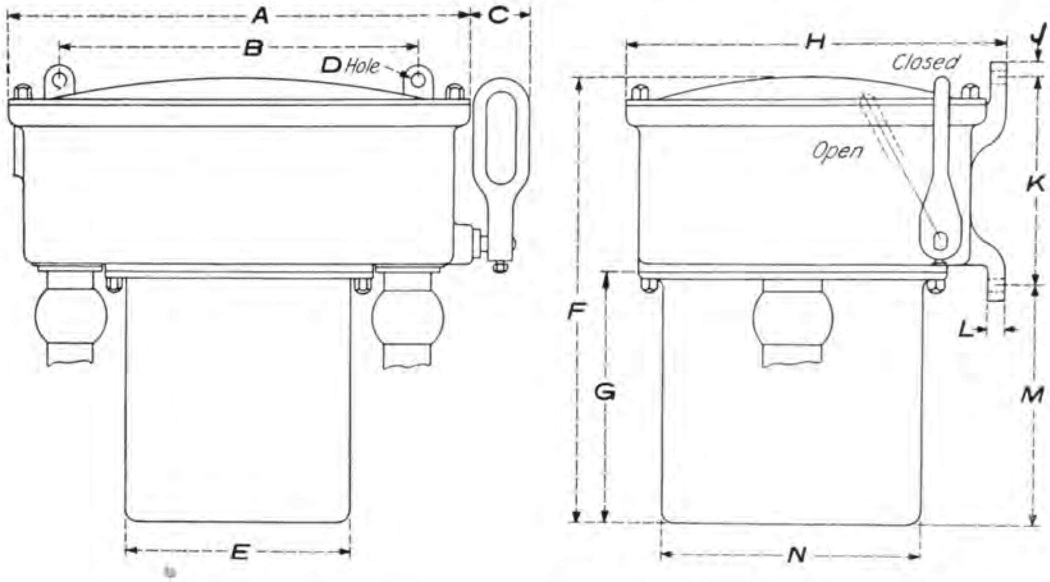
The oil vessel should be filled exactly to the mark indicating the amount of oil required, in order to insure complete submersion of contacts and at the same time to allow suitable air space for the successful operation of the switch.

Automatic (overload) manhole switches are not recommended, due to the effect of low temperatures on the automatic features, and the tendency of the oil to congeal or thicken at extremely low temperatures. While the thickening of the oil would not interfere with the opening and closing of a non-automatic hand-operated switch, automatic switches must depend in large measure upon gravity for actuating force in opening, and the thickened oil would have a tendency to delay or even prevent the opening of the switch. Further, the gases generated by an automatic switch in rupturing the system under short circuit conditions would, in spite of any vent which might be provided, have a deleterious effect upon the gaskets with consequent danger of water getting into the switch and causing serious damage.

CATALOGUE NUMBERS, WEIGHTS, ETC.

Poles and Throw	Ampere Capacity	Cable Inlets	Voltage	Rupturing Capacity	Shipping Wgt. in Lb.	Cat. No.
S.P.S.T.	200	2	7500	3000 kw.	150	120885
D.P.S.T.	200	2	7500		230	120886
D.P.S.T.	200	4	7500		215	120887
T.P.S.T.	200	2	7500		275	120888
T.P.S.T.	200	6	7500		265	120889

DIMENSIONS OF TYPE F, FORM P-4 OIL BREAK SWITCHES



DIMENSIONS IN INCHES OF TYPE F, FORM P-4 OIL BREAK SWITCHES

Poles and Throw	Cable Inlets	A	B	C	D	E	F	G	H	J	K	L	M	N
S.P.S.T.	2	10 7/8	7	2 3/8	9/16	4 3/16	19 3/8	11 1/4	13 5/8	5/8	8 3/4	1/2	10 5/8	9 11/16
D.P.S.T.	2	18	14	2 3/8	9/16	7 11/16	19 3/8	11 1/4	15 1/4	5/8	8 3/4	1/2	10 5/8	9 13/16
D.P.S.T.	4	15 1/4	11 1/4	2 3/8	9/16	7 11/16	19 3/8	11 1/4	15 1/4	5/8	8 3/4	1/2	10 5/8	9 13/16
T.P.S.T.	2	20 3/8	16	2 1/2	9/16	9 13/16	19 1/4	11 1/4	16 1/16	5/8	8 1/2	1/2	10 7/8	11 3/16
T.P.S.T.	6	17 5/8	13	2 1/2	9/16	9 13/16	19 1/4	11 1/4	16 1/16	5/8	8 1/2	5/8	10 7/8	11 3/16

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ELECTRICALLY OPERATED GOLD DREDGES

Dredging is the most recent of the mining methods employed for recovering values in auriferous ground located below the water level or in streams where the flow of water is too great to admit of success by other means. That this method has attained an important place in the industry is evidenced by the fact that, although the first successful dredge in California was started only about ten years ago, today more than one-quarter of the gold mined in that state is secured by the dredging process.

GOLD DREDGE NATOMA NO. 1, NATOMA (CAL.) CONSOLIDATED CO.

Electrical Equipment: Three 175 Kw., 60 Cycle 4000/575 Volt Type H Transformers, Switchboard and 550 Volt General Electric Induction Motors as Follows: Buckets 300 H.P., Winch 35 H.P., Shaker 75 H.P., Stacker 35 H.P., 14 In. High Pressure Pump 150 H.P., 10 In. Low Pressure Pump 35 H.P., 5 In. Priming Pump 15 H.P. and Tool Machine 2 H.P.

While the early types of steam driven dredges were partly successful, their operation was rendered expensive by the scarcity of available fuel and the cost of handling it.

With the rapid development of hydro-electric plants and large central generating stations, together with the increased distances to which electric current could be economically transmitted, it was found that the electric motor afforded a compact, easily controlled, and highly efficient substitute for steam drive; separate motors could be applied either directly or with short belts to the various units of the dredging machinery, and a larger percentage of the input power was thereby directly applied in useful work.

While many changes were necessary in the type of motor originally applied before satisfactory results were obtained, motor drive has indisputably proven its superiority to steam drive both in the cost of power and maintenance, and the modern dredger can now be supplied with motors especially designed for heavy duty, and capable of running continuously without danger and requiring a minimum of attention.

The standard form of dredge used today is the continuous chain, close connected bucket type, ranging in capacity from 3 cu. ft. to 13½ cu. ft. This type has been most successful and has been adopted by a majority of the large dredge owners. The accompanying illustrations show some of the dredges, the electrical equipment of which has been supplied by the General Electric Company, and indicate the possibilities of motor drive for this work.

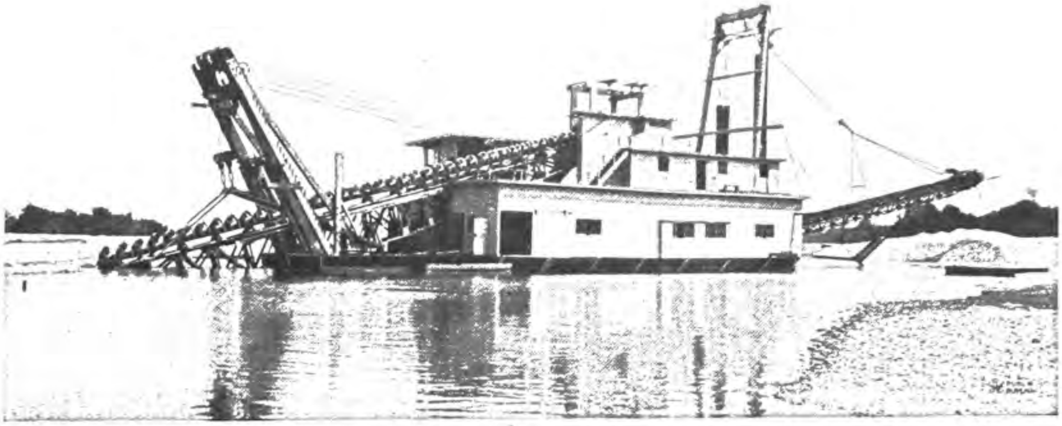
The following description will outline the electrical requirements of the various machinery units on the average modern dredger:

Main Drive

The speed of the bucket line varies from 50 ft. (with 18 to 25 buckets) per minute to 75 ft. (with 35 to 50 buckets) per minute, depending upon the condition of the ground.

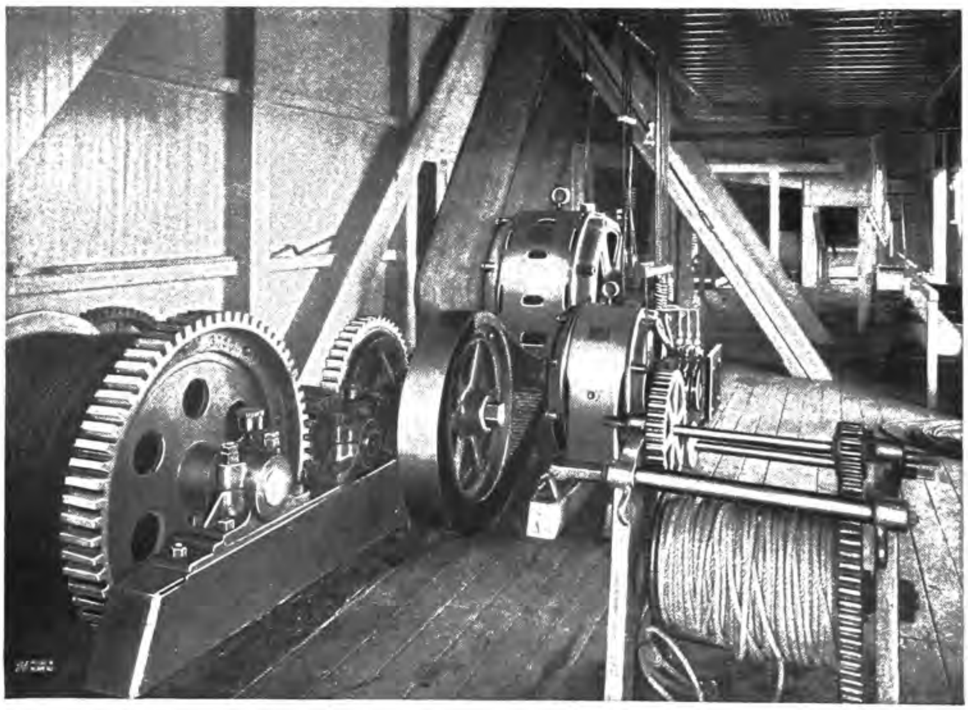
VIEW IN WINCH ROOM OF GOLD DREDGE NATOMA NO. 1 SHOWING CONTROLLERS FOR OPERATING BUCKET LINE, SCREEN AND WINCH MOTORS

For the operation and control of the bucket line, a variable speed motor is used. This is located on the lower deck and belted to the driving pulley, which is generally situated in the rear of the pilot house on the upper deck. The duty imposed upon this motor is severe as it must operate under conditions calling for power varying from approximately 75



GOLD DREDGE YUBA NO. 11, YUBA CONSTRUCTION CO., MARYSVILLE, CAL.

Capacity 7½ Cu. Ft.—Electrical Equipment: Three 125 Kw. 60 Cycle 4000/460 Volt Three-Phase Transformers, One 7½ Kw. 4000—115/230 Volt Transformers, Switchboard and the Following 440 Volt Induction Motors: Bucket 200 H.P., Winch 25 H.P., Screen 35 H.P., Stacker 25 H.P. 10 In. High Pressure Pump 75 H.P., 10 In. Low Pressure Pump 35 H.P. and 4 In. Priming Pump 10 H.P.



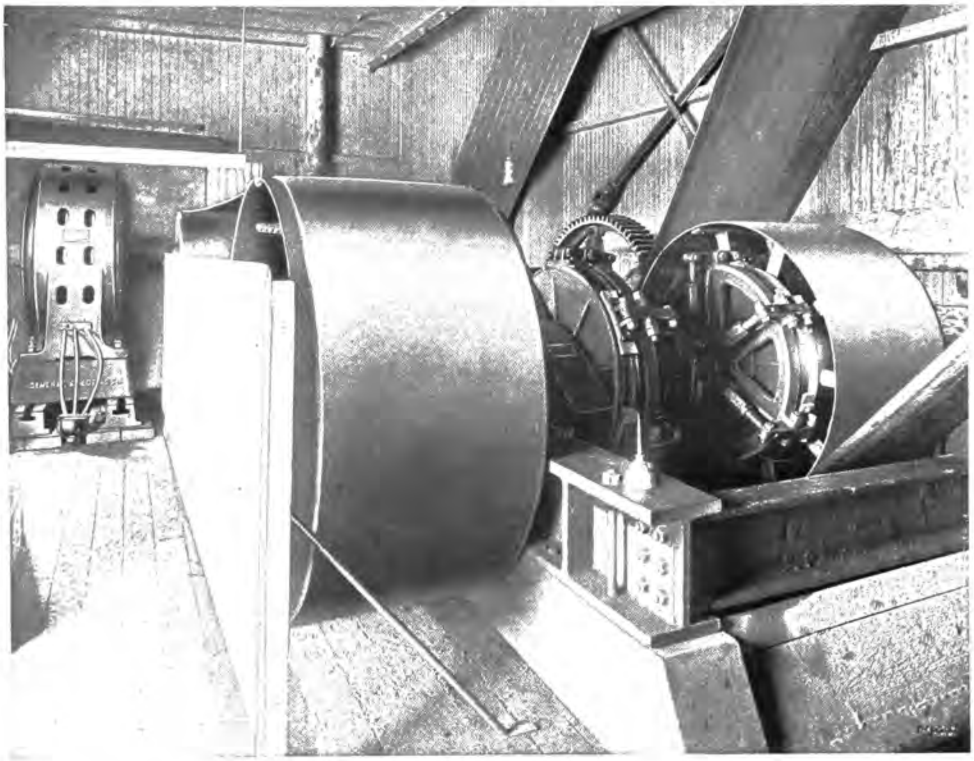
VIEW OF BUCKET LINE AND WINCH MOTORS, YUBA CONSTRUCTION CO. 7 CU. FT. GOLD DREDGE, OROVILLE, CAL.

per cent. overload down to 25 per cent. of its rated capacity. The motor recommended for this work is an alternating current induction type, known as Form M. This motor has been designed on liberal lines, and is equipped with a drum type controller, having 14 running points—forward and reverse—with the necessary resistance for continuous operation on any notch of the controller from one-half to full speed.

The maximum starting torque is required and obtained at about the fourth point of the controller, thereby leaving three points to bring the motor up to half speed, but requiring nearly its full rated output. As a result of these conditions, the ordinary motor designed for intermittent service cannot be successfully applied.

Winch

To keep the dredge in place, move it about, or hold it against the bank when digging; head lines are used, being controlled from the forward end, and generally operated by a 6-drum winch driven by a variable speed motor. The winch motor, while of smaller capacity, must be of the same rugged construction as the digger motor. It is equipped with a suitable controller and resistance to permit its continuous operation at from one-half to full load speed. It has been found advisable to equip the motors for this service with solenoid brakes, by means of which the motor can be brought to a standstill almost instantly. It is then ready for the reverse operation without the usual reversing of the motor through the controller. This latter



300 H.P. GENERAL ELECTRIC INDUCTION MOTOR DRIVING BUCKET LINE
GOLD DREDGE NATOMA NO. 1

method is bad practice, as the sudden reversing of the motor in this way causes a heavy strain on the windings, and may result in a burnout.

Pumps

The high and low pressure pumps for supplying water to the screens and sluices are generally operated by a separate motor direct connected to each pump. The high pressure pump is operated by a 720 or 900 r.p.m. motor, and the low pressure pump with a motor operating at 600 to 720 r.p.m.; each motor is operated on the pump base and direct connected to the pump by a flange coupling. The motor for this service is of the constant speed type, and a standard General Electric Form K is recommended. These motors are strong and compact in construction and have a large overload capacity.

INTERIOR OF YUBA NO. 12 SHOWING GOLD SAVING TABLES AND OVERHEAD WIRING FOR THE VARIOUS MOTOR CIRCUITS

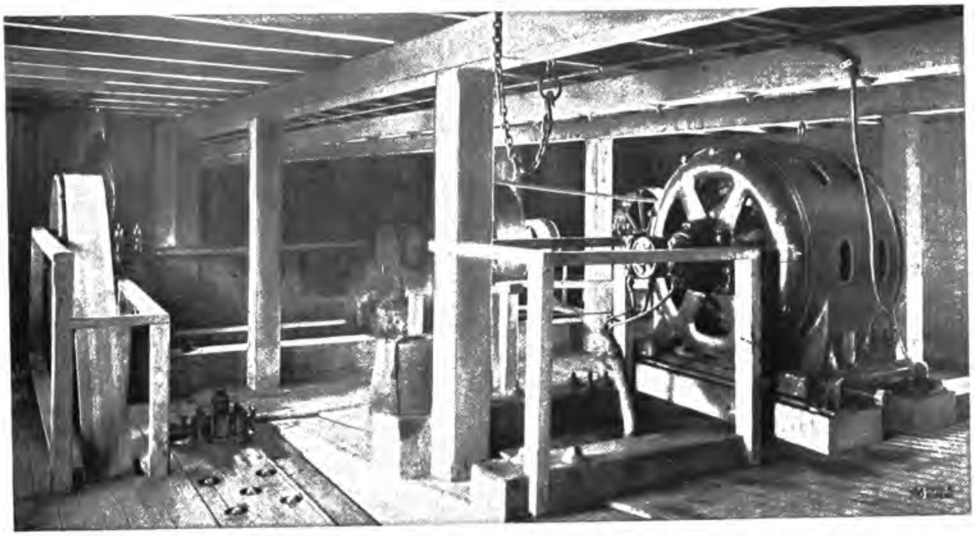
STACKER OF DREDGE EL ORO NO. 3 SHOWING HOUSE CONTAINING THE STACKER MOTOR

Priming Pump

For driving this pump when priming the large pumps, or for supplying water on the table during the "clean-up," a 10 h.p. high speed motor direct connected to a centrifugal pump will insure economy and efficiency in operation, as the motor when used intermittently will consume current only in direct proportion to the work done.

Screens

For the operation of either shaking or revolving screens, a Form M constant speed belted motor of from 25 to 50 h.p. capacity is usually required, and is generally installed on the upper deck. This motor is similar to the motor operating the winch and bucket line, but is equipped with a small reversible controller, with sufficient resistance in the armature circuit to bring it to full speed in about one minute.

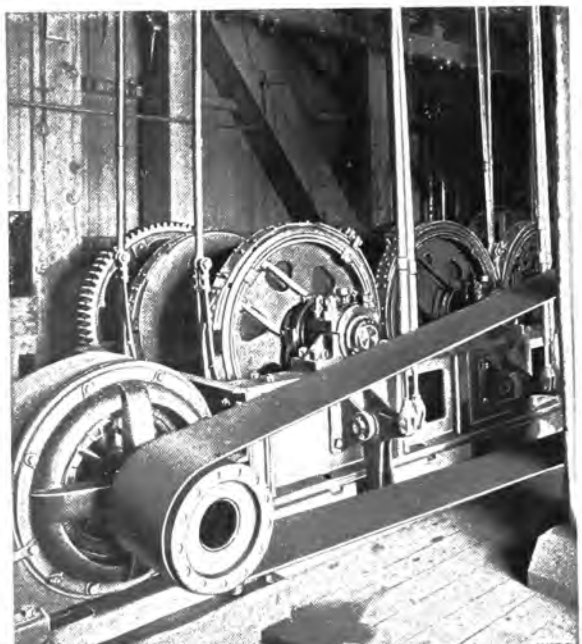


75 H.P. GENERAL ELECTRIC VARIABLE SPEED INDUCTION MOTOR OPERATING SHAKERS AND SCREENS—GOLD DREDGE NATOMA NO. 1

Stacker

For driving the conveyor belt of the stacker a 25 to 50 h.p. capacity Form M constant speed motor, similar to the one used on the screens, is required, located at the end of the ladder, and either belted or connected by silent chain drive. As it requires but little space it can be readily housed in the manner shown in illustration on page 5.

The special advantage in the Form M constant speed motor manufactured by the General Electric Company is, that it enables the operator to start the screen or stacker very slowly allowing them to attain nearly full speed by the time the motor has reached its full speed.



35 H.P. GENERAL ELECTRIC INDUCTION MOTOR DRIVING SHORE LINE WINCH—GOLD DREDGE NATOMA NO. 1

Transformers

Electric current for dredge operation is usually transmitted by the generating station to a substation located near the dredge, at three-phase, 60 cycles, and potential ranging from 2000 to 6000 volts. At the former voltage, the current is generally transmitted directly to the dredge by means of armored cable, carried on floats. The cable leads directly to the switchboard busbars, and the current is distributed from the switchboard to the various 2000 volt motors located on the dredge. If current is transmitted at 4000 to 6000 volts, it is transmitted through armored cable as before, to the dredge, the cable terminating at the main line oil switch, which is usually located near the rear of the dredge, being controlled, however, from the switchboard in the pilot house. From the main line oil switch the current passes to transformers with secondaries wound for the proper motor voltages, installed in fireproof compartments lined with galvanized iron and asbestos. These compartments are usually located in the side of the dredge.

The transformer capacity for dredge work is usually taken as two-thirds of the total horse-power load, allowing one kilowatt for each horse-power. It is advisable to divide the units into three single-phase transformers, each wound for delta connection on the primary side, so that in the event of a burnout two of the transformers can be used temporarily. The transformer which has been generally used on gold dredges is the General Electric Type H, 60 cycle single-phase oil cooled transformer.

GOLD DREDGE YUBA NO. 12, MARYSVILLE, CAL., ELECTRICAL EQUIPMENT IS THE SAME AS THAT OF YUBA NO. 11 SHOWN ON PAGE 3

Switchboard

In the early days of motor operated gold dredges the switchboard was a somewhat neglected feature, but it has now become an important part of a dredge installation, and is, in fact, absolutely necessary, due to the increased size of the dredges and the consequently larger capacity motors distributed throughout the equipment, which must be controlled from a central point in order to insure absolute safety and reliability in operation.

With the extended use of electricity on gold dredges, switchboards for this service have been thoroughly standardized, and their design reduced to the simplest form consistent with mechanical strength and electrical efficiency.

Many companies, either operating or contemplating the use of dredges, are sometimes in doubt as to the proper size of motor and the details of the auxiliary electrical equipment to be installed for a given sized dredge. The engineers of the General Electric Company have specialized on dredge equipment, and their services are always available to the prospective customer to assist in selecting the most efficient equipment for any given conditions of operation.

GENERAL ELECTRIC COMPANY

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May, 1911 **Bulletin No. 4834*

THE ELECTRICAL EQUIPMENT OF THE DETROIT RIVER TUNNEL

The tunnel which has been constructed under the Detroit River, to connect the tracks of the Michigan Central Railroad in the United States with those in Canada, has now been in continuous operation for some months for the use of both passenger and freight trains. The electrical equipment of this tunnel forms part of a very comprehensive scheme for improving the railroad facilities in and around Detroit, Mich. The most striking advantage secured is the elimination of the ferries that were formerly depended upon to transfer all passenger and freight trains between Windsor and Detroit.

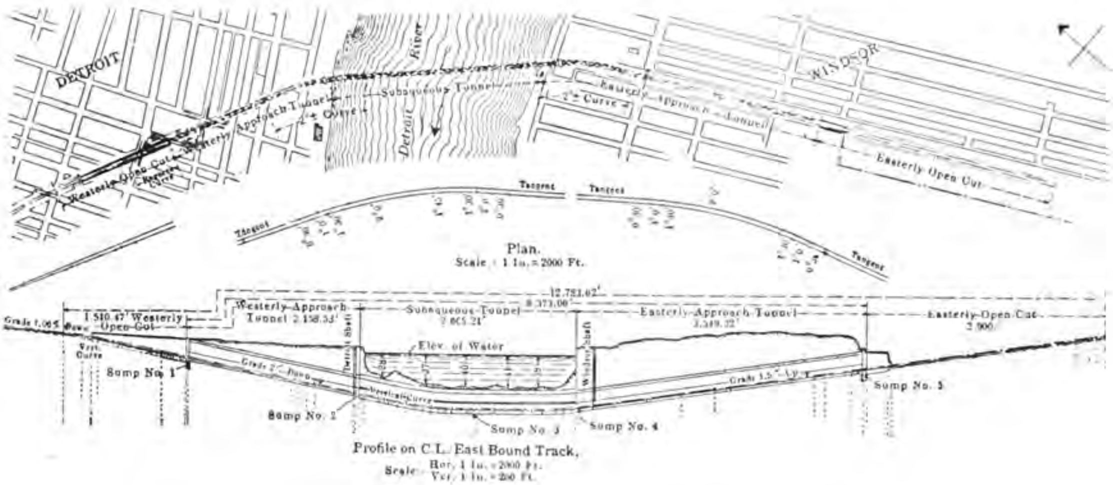


Fig. 1
PLAN OF TUNNEL AND APPROACHES, WITH PROFILE OF EASTBOUND TRACK

Under the old conditions each ferry boat took about 30 minutes to load, unload and make the crossing. The average capacity of each boat was 18 freight cars, so that three and often four ferry boats were required for many of the trains. This involved many delays. Again, in winter a very considerable amount of time was lost owing to the presence of heavy ice in the river. Under the new conditions a train of any practical length and weight can be hauled through the tunnel in less than 6 minutes.

The scheme of improvements at Detroit comprises the construction of two new depots for the Michigan Central Railway, one at Windsor and the other at Detroit, both conveniently located. The extensive yards on both sides of the river have been reconstructed and electrified, the third-rail layout being of a most complete nature. These improve-

* Reprinted from the *Electric Railway Journal*, January 14 and January 21, 1911.

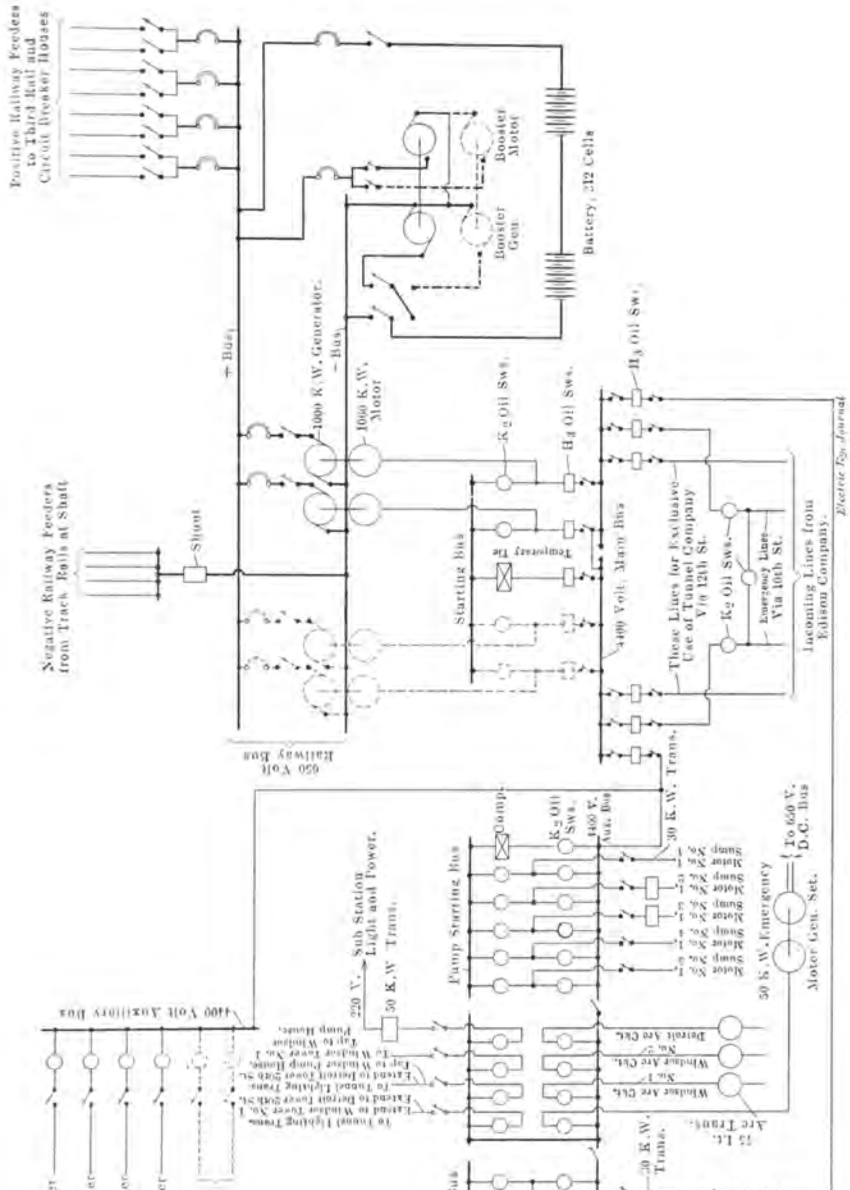


Fig. 2

SUBSTATION WIRING DIAGRAM, SHOWING PRINCIPAL CONNECTIONS ments provide for the direct passage of passenger trains between Canada and the United States, with none of the switching which was formerly necessary.

The entire scheme involved the building of a double-track tunnel, the two new depots referred to, a substation, two inspection sheds for the electric locomotives, five signal towers (also used as circuit breaker houses for the third-rail feeders), the reconstruction of the yards on both sides of the river and the electrification of the whole.

car movement per day is about 1100 cars and there are 16 passenger trains. If the foreign roads should desire to use the tunnel and have all their business that is now floated across the river taken through the tunnel it will approximately double the present schedule in number of trains and tonnage. The total estimated capacity of both tunnels taken together amounts to the enormous figure of 247,200 tons per 24 hours. Some important details of the tunnel are shown in Fig. 1, which gives the principal lengths

Fig. 3
VIEW OF THE CONVERTER STATION

It is probable that this electrification will not affect the Michigan Central Railway alone, as it seems likely that the other roads entering the United States from Canada, and vice versa, at this point, including the Canadian Pacific, Grand Trunk, Wabash and Père Marquette, will ultimately make use of the tunnel to expedite the handling of the traffic at this point and to eliminate the serious delays incident to ferrying. Taking the above into consideration, it is of great interest to note the estimated capacity of the tunnel.

The present schedule is for Michigan Central trains only. The average freight

and grades as well as the localities of the approaches, portals, sumps, etc. The general layout can best be appreciated by a study of Fig. 2, in which only the more important electric circuits are given.

The broader features of the electrical scheme considered above are of a very simple nature, there being only the one substation. This substation is supplied with three-phase, 60-cycle energy at 4400 volts from the Detroit Edison Company. Two feeders are installed between the Delray power house and the substation for the exclusive use of the tunnel company. In addition a third feeder from the Delray power house supplies the

Washington Street substation of the Edison Company through oil switches in the tunnel substation, so that in case of trouble on the two lines for the exclusive use of the tunnel company either or both of the other lines can be switched so as to give the tunnel company a direct feeder from Delray and a back feed from the Washington Street substation. These feeders are run in separate ducts.

The General Electric Company designed, manufactured and installed all of the electrical apparatus in the substation, yards and tunnels, with the exception of the storage battery and the apparatus for regulating the battery.

Substation

The substation is a very substantial building of concrete and steel, faced with red brick. Fig. 3 gives a good idea of its external appearance. It is located close to the Detroit shaft and is only 125 ft. from the center line of the tunnel. It is built on made ground and for this reason is supported on wooden piles. The interior view (Fig. 12), the plan of the first floor (Fig. 5) and the longitudinal section (Fig. 6) together with the three sectional elevations (Figs. 7, 8 and 9), show very clearly the general arrangement of the building.

The more important items of apparatus installed for traction purposes only are—two horizontal 1000 kw., 514 r.p.m. synchronous motor motor-generator sets; one 50 kw. motor-generator set, and a Gould storage battery of 312 cells with Type U 1543 and Type U 1559 L L tanks, with a capacity of 630 amp. for eight hours.

Fig. 4
STANDARD LOCOMOTIVE

The railway switchboard consists of the following:

One swinging bracket for voltmeters and ammeters.
One control battery panel.
One substation light and power panel.
Two blank panels for future railway feeders.
Four direct current railway feeder panels with a capacity of 1000 amp. at 650 volts each.
Three battery panels for switching main battery and booster leads together with the necessary switching apparatus for the battery regulating devices.
Two direct current railway generator panels each with a capacity of 1000 kw. at 650 volts.
Two combination exciter and three-phase synchronous motor panels with a capacity of 1000 kw. at 440 volts, and 15 kw. at 125 volts.
One starting compensator and two circuit feeder panels for auxiliary buses with a capacity of 400 kw. at 4400 volts for each tie switch circuit.
Two blank panels for future synchronous motors.
One swinging bracket for synchronizing instruments.

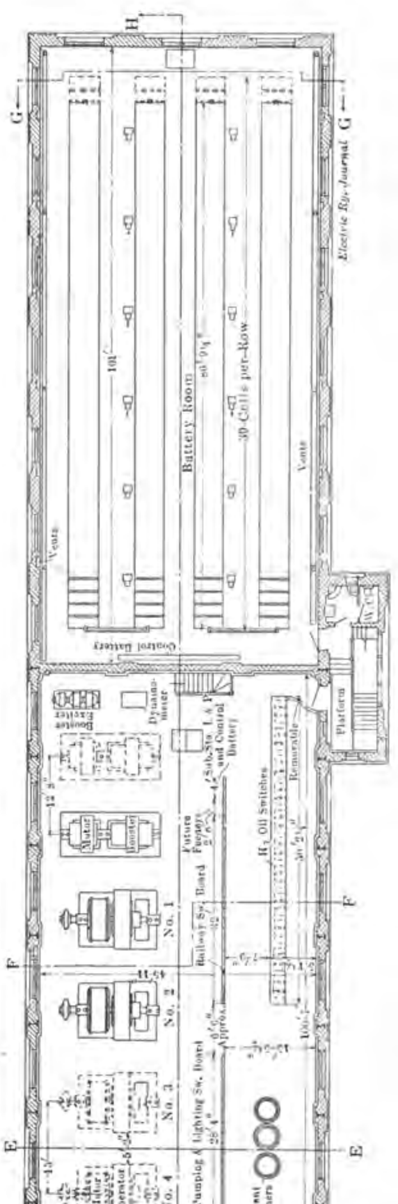


Fig. 5
PLAN OF FIRST FLOOR OF SUBSTATION

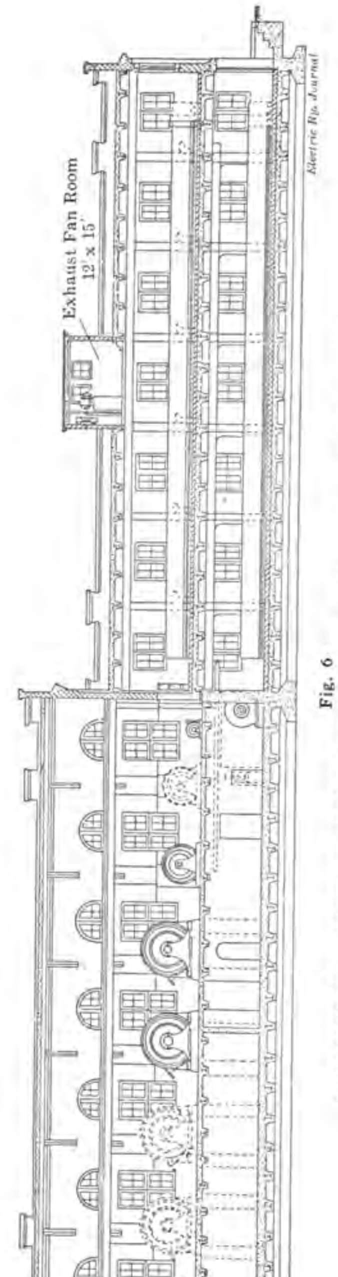


Fig. 6
LONGITUDINAL SECTION ALONG THE LINE H-H ON THE PLAN OF SUBSTATION

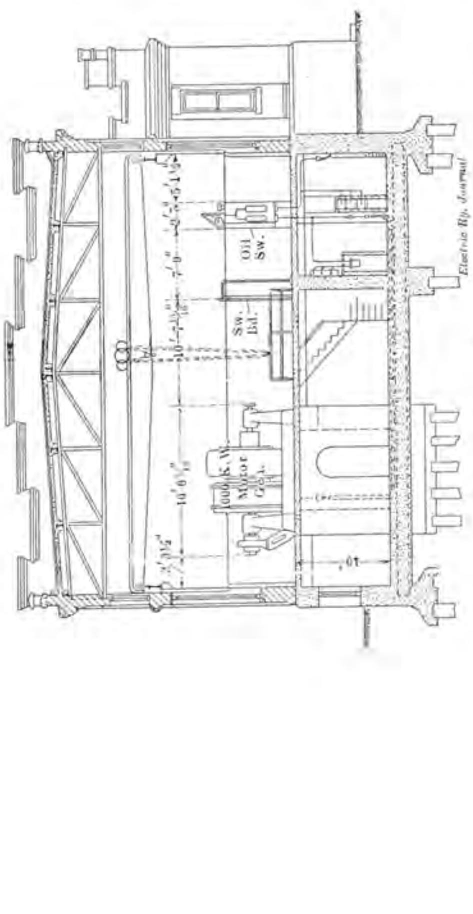


Fig. 8
CROSS-SECTION OF SUBSTATION ALONG LINE F-F SHOWN ON PLAN

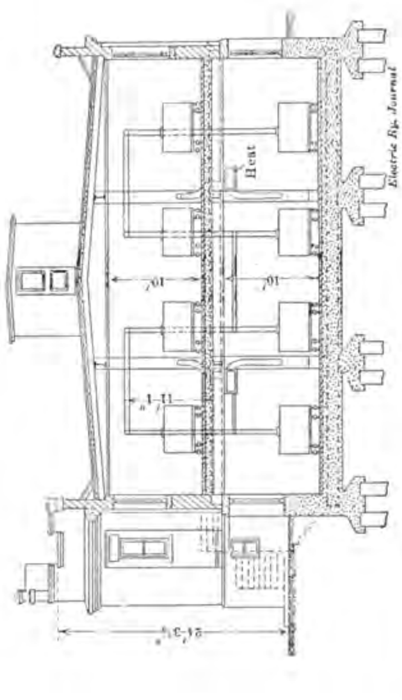


Fig. 9
CROSS-SECTION OF SUBSTATION ALONG LINE G-G SHOWN ON PLAN

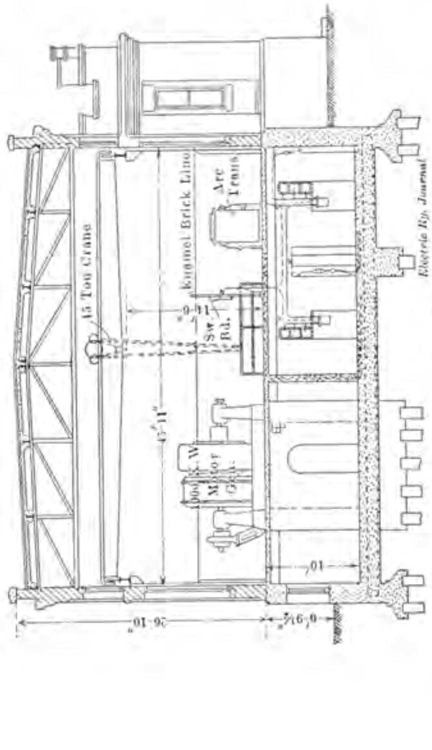


Fig. 7
CROSS-SECTION OF SUBSTATION ALONG LINE E-E SHOWN ON PLAN

Fig. 16 is an illustration of the railway switchboard, and the lighting and auxiliary board can be seen to the right of the same illustration, while Figs. 14 and 15 show the back of the board. The constant current transformers used for the arc lighting of the yards are shown in the latter view.

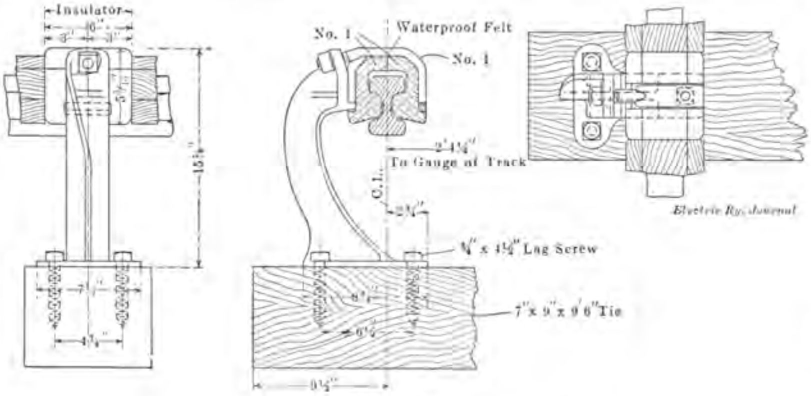


Fig. 10
UNDER-RUNNING THIRD RAIL

The motor-generator sets consist of a General Electric alternating current, three-phase, 14 pole, 1060 kw., 4400-volt synchronous motor, direct-connected to a 1000 kw., 8-pole, 650 volt direct current generator. The pair of machines forming a two-bearing set, are mounted on a common base and run at a speed of 514 r.p.m. The shaft is extended at the motor end to accommodate a direct-connected exciter. Tests show that the synchronous motors of these sets will come up to synchronism in about 45 seconds on the 35 per cent. tap of the compensator. The guarantees provide that these machines shall operate continuously with a temperature rise not exceeding 35 deg. C. at unity power-factor and that they shall carry an overload of 50 per cent. for two hours with a temperature rise not exceeding 55 deg. C. The efficiencies of the synchronous motors are as follows:

	Half Load	Three-Quarter Load	Full Load
Guaranteed	91	93	94
Test	92	94.1	95.3

The direct current machines are shunt wound units designed to operate in parallel with the storage battery. They have commutating poles and also auxiliary shunt fields which are separately excited from the storage battery booster and play an important part in the scheme for regulating the load. The auxiliary winding is of such strength that when the generator is operating under normal load at 650 volts the voltage can be raised to 700 or reduced to 575, so that it can be used for either charging or discharging the battery. The regulating devices will be considered in fuller

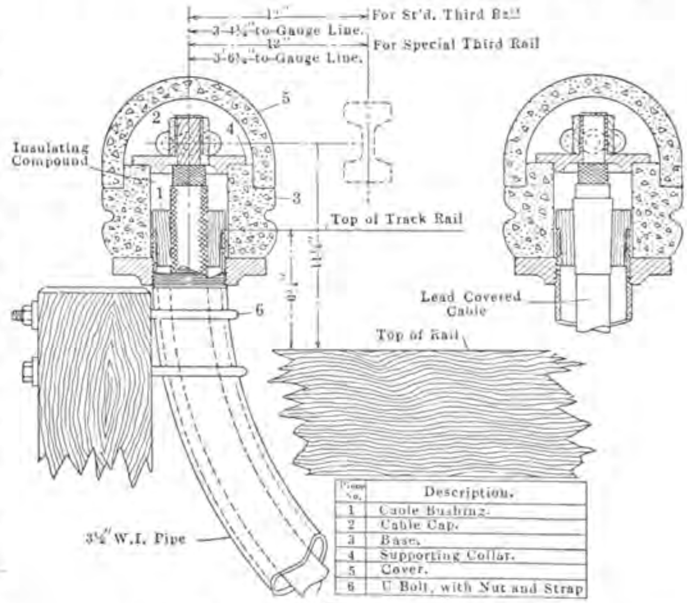


Fig. 11
TERMINAL INSULATION OF THIRD-RAIL CABLES

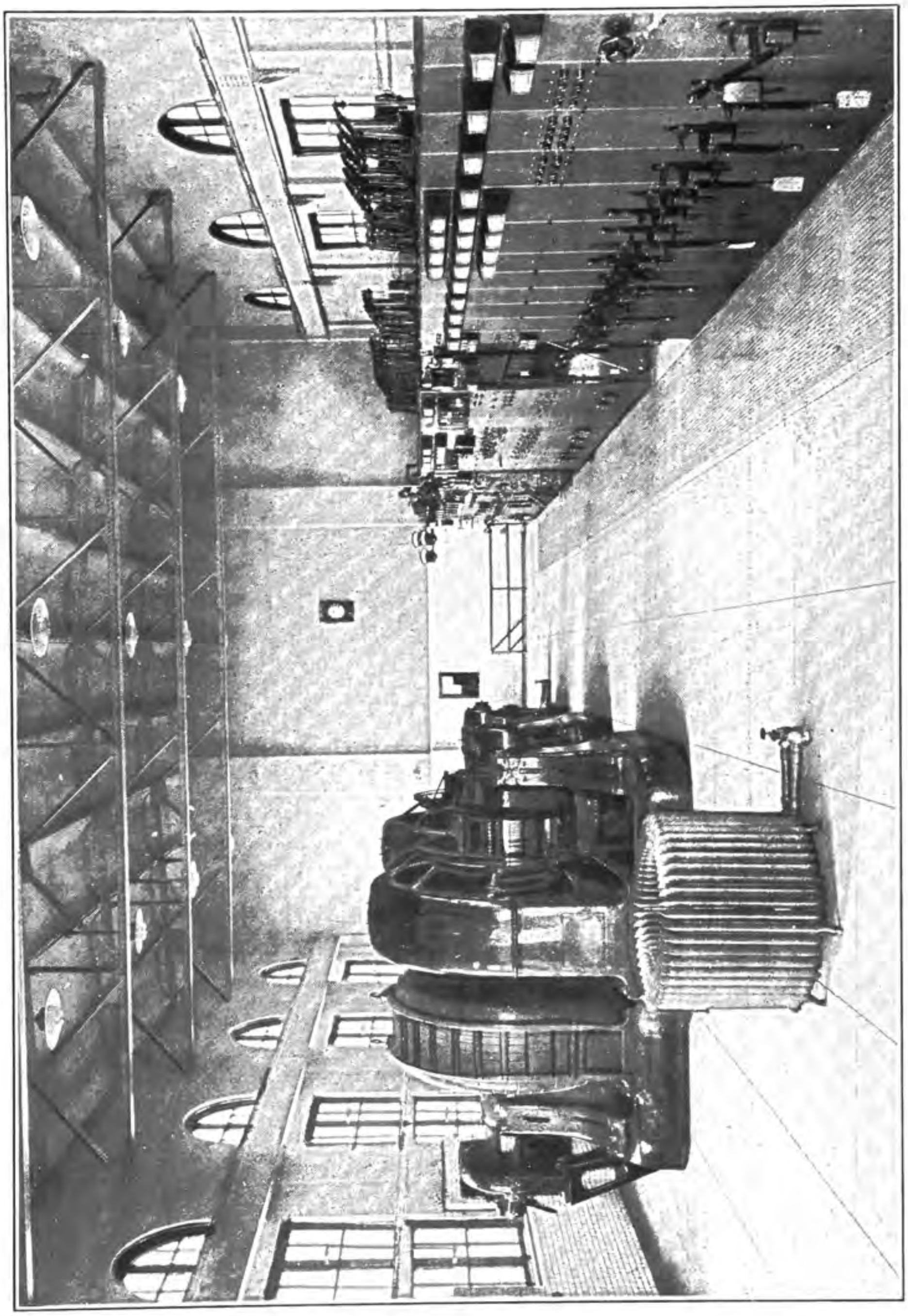


Fig. 12
INTERIOR OF CONVERTER STATION, SHOWING THE MOTOR-GENERATOR SETS

detail in the latter part of the present article. These motor-generator sets are seen in the general view of the interior of the station (Fig. 12).

The 50 kw. motor-generator set consists of a 75 h.p., 650 volt shunt wound direct current motor direct connected to a 50 kw., 4400 volt, three-phase generator. The two machines are on a common base and form a three-bearing set. This unit is installed to provide a small amount of 4400 volt alternating current by driving the set from the main storage battery in case of total shutdown of the Edison lines. In this manner one-half of the tunnel lighting, a small amount of pumping, signal lights and signal track transformers can be operated, while the railway load would be carried on the main battery.

The main items of interest in the auxiliary apparatus are—three 75 light constant current transformers for yard lighting, one substation lighting transformer and the switchboard for controlling the auxiliaries in the substation yards and tunnel.

Each of the four three-phase incoming lines is of 200,000 cir. mil. capacity, and delivers the energy to the substation at 4400 volts, 60 cycles, each lead passing through an H-3 oil switch to the 4400 volt main substation bus, which is sectionalized so that either half can be made dead when necessary for inspection or repairs.

It should be noted that the starting bus is fed from the main bus through an H-3 oil switch and a compensator, thus giving a lower voltage for starting. The leads from the main bus to the starting bus pass through both H-3 and K-2 oil switches, while the leads to the machines are taken from a point between these two switches. Hence, in starting when the K-2 switch is closed a lower voltage is impressed on the machines, and when speed is attained the K-2 switch is opened and the H-3 switch closed, giving full voltage at the machine. These switches are inter-connected to eliminate improper operation.

From the direct current end of the machines the energy is fed directly through circuit breakers to the 650 volt direct current bus, passing through recording wattmeters en route. The negative feeders from the track rails to the negative bus and the different

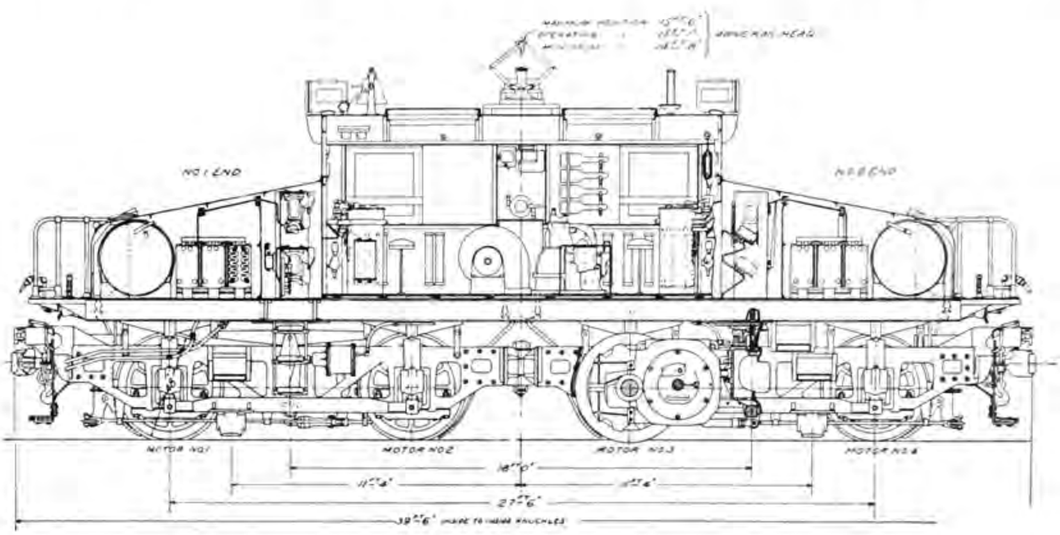


Fig. 13
LOCATION OF APPARATUS ON LOCOMOTIVE

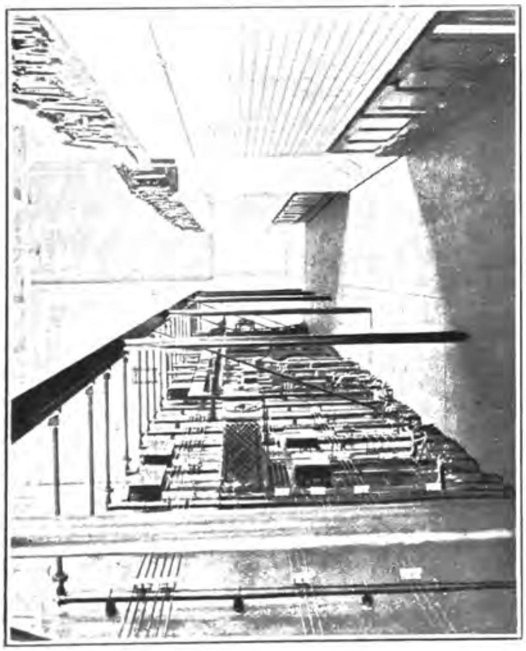


Fig. 14. REAR OF THE MAIN SWITCHBOARD IN SUBSTATION

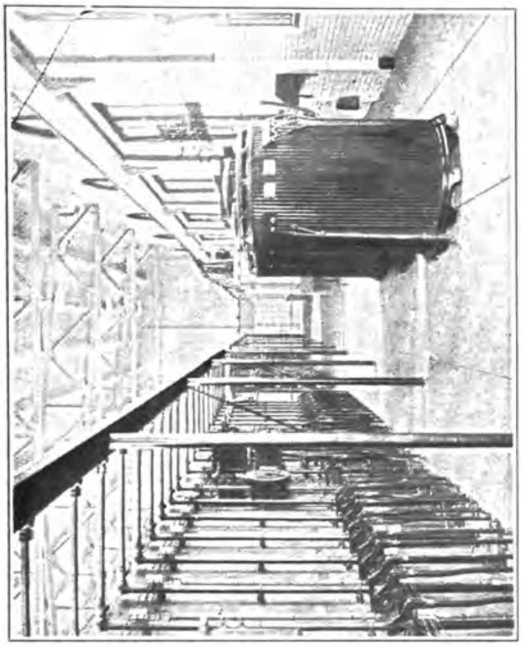


Fig. 15. CONSTANT CURRENT TRANSFORMERS

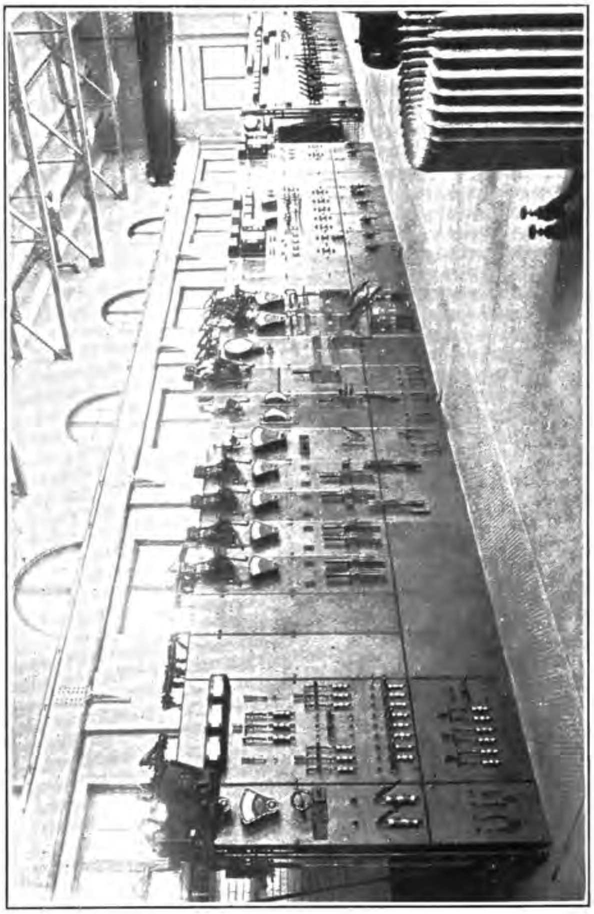


Fig. 16. MAIN SWITCHBOARD

third-rail feeders pass through circuit breakers and switches to the respective feeding points. The most essential details of the booster and battery connections will be dealt with in greater detail later.

There are four auxiliary buses, two for the sump pump equipment, one for lighting and the fourth auxiliary bus for miscellaneous purposes. The two sump pump buses are duplicates, the second being installed to insure continuous operation under all circumstances. These two pumping buses and the lighting bus are at a potential of 4400 volts and are provided with connecting switches. They are fed from the main substation bus through H-3 oil switches. The starting bus for the pump motors is fed through a K-2 oil switch and compensator and the arrangements are so similar to those already described for the main machine buses that further description is unnecessary, the only exception being that in this case both of the oil switches in each lead between the bus and the starting bus are of the K-2 type. It should be noted that in the case of Sump No. 2 and Sump No. 3 the transformers are located in the substation and in all other cases high-tension feeders are taken from the substation to the sump chambers.

The lighting bus is of a simple nature, each lighting feeder simply passing through a K-2 oil switch to its respective field of duty. In the case of the yard lighting the 75 light constant current transformers are located in the substation, while the feeders for the incandescent lighting of the tunnel, etc., are taken to transformers located at convenient points. A 50 kw. transformer located in the substation reduces the potential to 220 volts for the substation lighting and power. The 50 kw. emergency motor-generator set already described feeds into this lighting bus.

The auxiliary bus for miscellaneous purposes provides for the lighting of the Michigan Central Depot, grain elevators in the railway yards, the necessary light and power for both the Detroit and Windsor yards, as well as providing for future requirements.

The substation is equipped with an overhead travelling crane built by the Northern Engineering Works.

Third Rail

The entire third-rail layout has a very neat appearance and is complete in every detail. The length of the third rail installed in the tunnel approaches and yards when reduced to a single track basis exceeds 19 miles. The third rail employed is of the bullhead form and weighs 70 lb. a yard. It was supplied by the Lackawanna Steel Company and its chemical composition is as follows:

Carbon	0.10
Manganese	0.40
Silicon	0.05 or less
Phosphorus	Not to exceed 0.10 and as much less as possible.
Sulphur	Not to exceed 0.08 and as much less as possible.

It is rolled in lengths of 30 ft. and 33 ft. It is of the under-running type, and in this and in other details it is similar to the third rail of the New York Central Terminal electrification. The wood protection is of Georgia and Carolina long-leaf yellow pine, made in lengths of 10 ft. and 12 ft. The

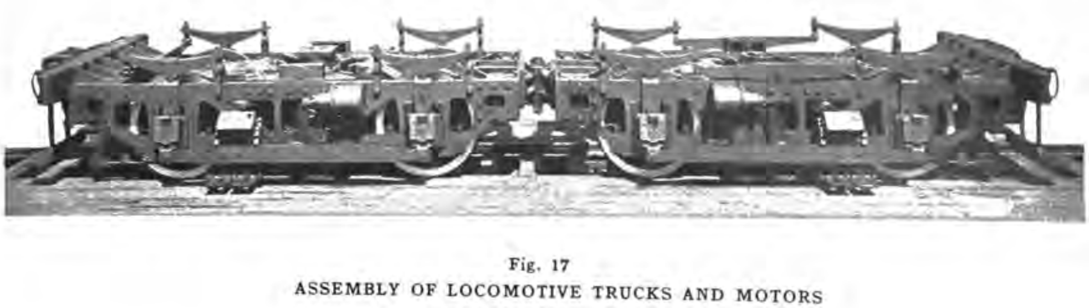


Fig. 17
ASSEMBLY OF LOCOMOTIVE TRUCKS AND MOTORS

Fig. 18. LAYOUT OF THIRD-RAIL FEED AND JUMPER CONNECTIONS

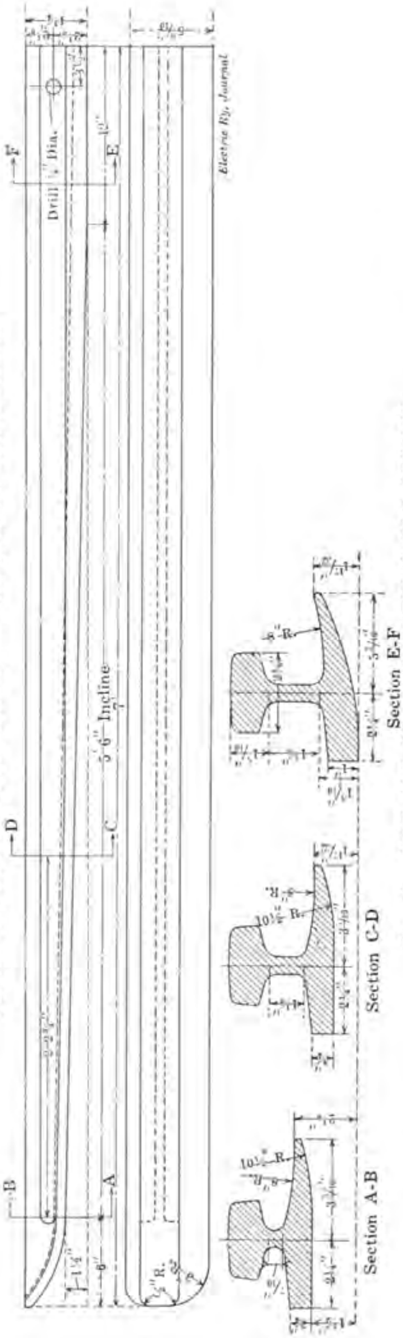


Fig. 19. PLAN AND SECTION OF THIRD-RAIL INCLINE

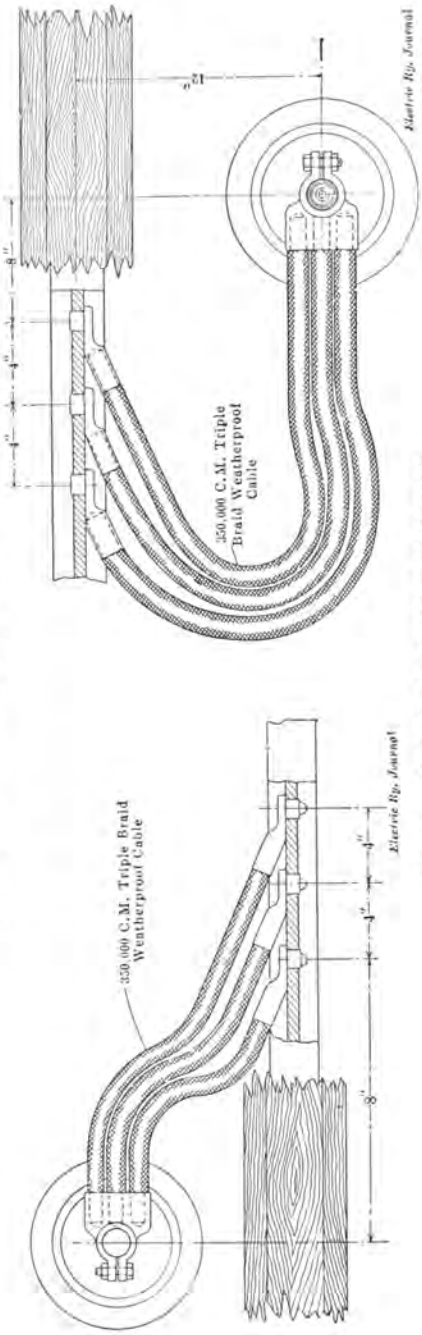


Fig. 20. DETAILS OF THIRD-RAIL CABLES

form and dimensions for both straight work and special work, such as inclines, etc., will be seen in Figs. 10 and 19. The brackets for supporting the third rail are of malleable iron.

The third-rail insulators are of vitrified and glazed porcelain. The specifications call for an insulation resistance of 10 megohms from hook-bolt slot to rail slot after immersion in water for 72 hours, and an insulation resistance of not less than 0.20 megohms when subjected to a precipitation of 3/8 in. of water per minute. A compression test of 85,000 lb. and a tensile strength of 1400 lb. are also called for, in addition to an impact test. The latter consists of dropping a 3/4 lb. steel ball from a height of 30 in. The insulator standing 100 such blows is rated as 100, and others according to the number of blows withstood. Test insulators are taken from each delivery, and none are accepted that show fracture after less than 40 blows. The insulators are of Ohio Brass manufacture.

The third-rail jumpers are inclosed in lengths of iron pipes buried in the ground with the ends brought above the surface by a curvature which will permit of drawing the cables with ease. This pipe is held in position against wooden anchor posts by means of U-bolts. A cast iron flange screwed to the end of the pipe furnishes a steady and level support for the lower half of the semi-porcelain cover. The end of the cable is insulated and held in position and moisture is excluded by a split bushing made of hard maple and by filling the annular space between the cable and porcelain with an insulating compound. Finally this compound is retained and the cable held in a central position by a metal flange screwed to the copper terminals soldered to the end of the cable. The whole is protected from mechanical damage and weather by the upper half of the semi-porcelain cap. All these details will be seen by reference to Figs. 11 and 20, part of which also show the cable terminal details between the jumpers and third rail.

The clearances of the third rail are as follows: On tangents and curves of over 800 ft. radius the distance between the center line of the third rail to the inner edge of the nearest track rail is 2 ft. 4¼ in., while on curves of 800 ft. radius and less it is 2 ft. 6¼ in., while the distance between the under surface of the third rail and the upper surface of the track rails is 2¾ in.

Locomotives

At present there are six electric locomotives in service. They were designed and manufactured by the General Electric Company, and the Schenectady Works of the American Locomotive Company built the mechanical equipment. These locomotives have attracted general attention owing to the fact that they are the most powerful direct current machines ever constructed, so far as tractive effort is concerned. They were designed for hauling both freight and passenger trains through the tunnel, and also for switching service in the yards. They are of an articulated design of the 0-4-4-0 type, weigh 200,000 lb., and are equipped with four GE-209 motors. The specifications call for units capable of handling an 1800 ton trailing load from one yard to the other and negotiating a 2 per cent. grade when two locomotives are operated in multiple unit, and of performing this service continuously with a 15 minute layover at each end. It is of interest to note that the locomotives are performing this service in a most satisfactory manner. The actual grades on which they are operating are 2 per cent. on the Detroit side, extending for a distance of 4000 ft.; 1½ per cent. on the Windsor side for a distance of 7500 ft., and an approximately level extension into the yards. Fig. 4 shows the appearance of these locomotives, and Fig. 19 shows the principal dimensions.

The GE-209 motors are standard box frame commutating pole units rated at approximately 300 h.p. each. Single reduction gearing is used, the gear ratio being 4.37 and the driving wheels 48 in. in diameter. This type of motor is illustrated in Fig. 21. When working at a maximum capacity the motors are capable of slipping the driving wheels and at the slipping point of the wheels the locomotive develops an instantaneous tractive effort of from 50,000 to 60,000 lb. When developing a tractive effort of 50,000 lb. the locomotive develops 1450 h.p., and its speed is 11 miles per hour. The maximum speed of the locomotive when running light on level track is about 35 miles per hour.

armature, and then escapes through suitable discharge openings over the commutator. The blower employed has a capacity of 2000 cu. ft. of air per minute, at a pressure of 2½ in. of water. It is driven by a direct current, series wound motor.

The control is of the well-known Sprague-General Electric multiple unit type with two master controllers in the main cab and the motor contactors in the auxiliary cab. The

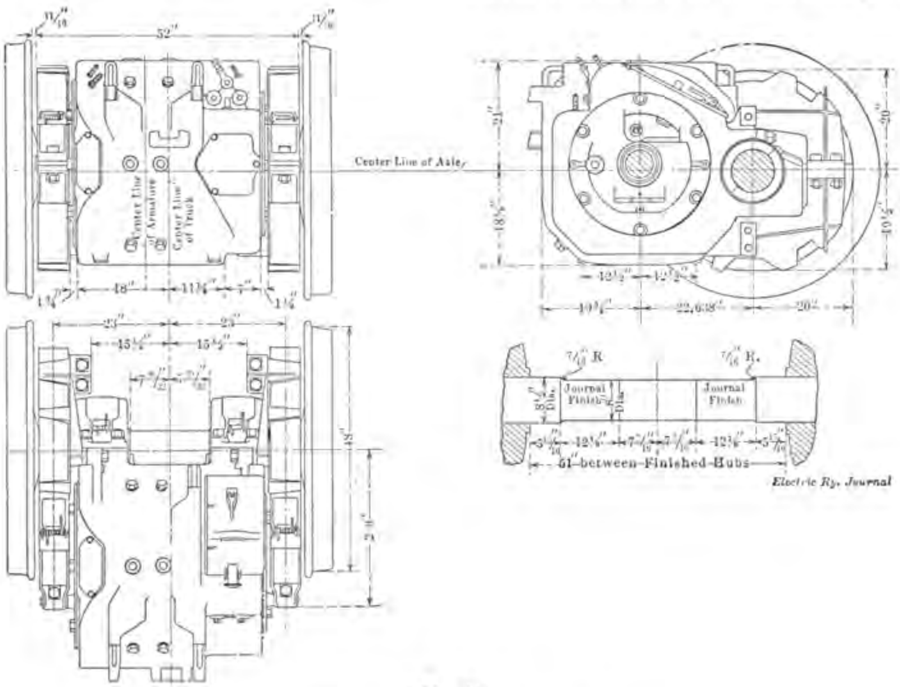


Fig. 21
GE-209-A RAILWAY MOTOR

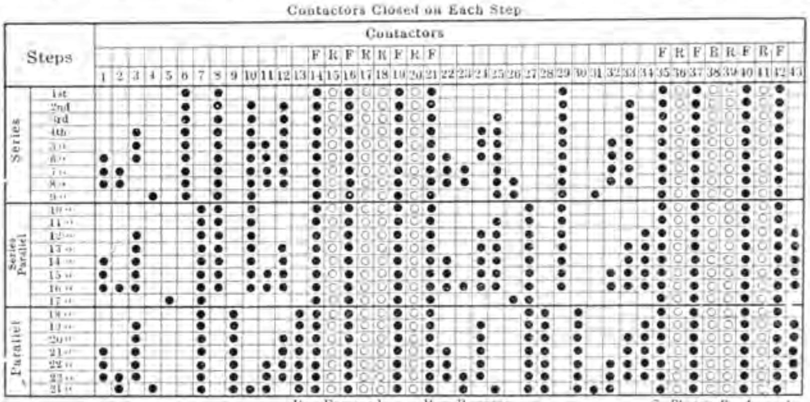
A point of interest in these locomotives is that they are provided with two gears and pinions per motor, one at each end of the shaft. This construction was adopted owing to the unusually heavy overloads that the motors will be called upon to carry. This form of construction maintains the armature shafts and axles absolutely parallel with one another and to a very great extent eliminates the wear and breakage of pinions.

The motors are operated under forced ventilation, air being delivered to the motor frame at the end remote from the commutator. The air passes between the field coils and

master controllers are of the General Electric Company's new design, especially developed for handling four GE-209 commutating pole motors. Each controller has 24 points, 9 for use when the motors are all in series, 8 when the motors are two in series (the pairs in parallel) and 7 when all four motors are in parallel. The ninth, seventeenth and twenty-fourth points are running points. A diagram of the motor connections is given in Figs. 22 and 23.

This large number of steps and the fine subdivisions of the rheostat enable the torque on the first running point to be reduced to a low value, which is a very desirable factor in handling long, heavy freight trains, where it is necessary first to take up the slack in the drawbars. It also gives a smooth acceleration over the bridging points on the control;

Contactors Closed on Each Step



F = Forward K = Reverse *Electric Ry. Journal*

Fig. 22
DIAGRAM OF CONTROLLER CONNECTIONS

further, it reduces the increase of torque between each successive step to such a low value as to enable the locomotive to work up to a high tractive effort while accelerating a train under adverse conditions without exceeding the slipping point of the wheels in the transition from point to point.

A centrifugal governor brake makes it impossible to throw the controller from the "off position" to the full "on position" in less than a predetermined time.

The braking equipment is mechanically independent on each truck, as there is one pair of 12-in. brake cylinders on each truck and the provision of separate valves and cutout cocks permits either truck being cut out without affecting the other. The air compressor, which is of the CP-26 type, is located in the center of the main cab. It is a two stage, four cylinder compressor geared direct to a 600 volt direct current series motor, and has two low and two high pressure cylinders arranged in such a manner as to divide the work of compression into four equally distributed impulses per revolution. The capacity is 100 cu. ft. piston displacement per minute when pumping against a back pressure of 135 lb. per sq. in.

The general design of the superstructure of the locomotive will be seen by reference to the illustrations. The main cab houses the master controller, auxiliary controlling apparatus, blower and air compressor, etc., while the auxiliary cab contains the motor control contactors, rheostats, air tanks, etc. The design is such that an excellent view of the track is obtained from the engineer's seat. The main cab covers a floor area of 15 ft. 6 in. by 10 ft., while each of the auxiliary cabs occupies a space of 9 ft. by 6 ft. The

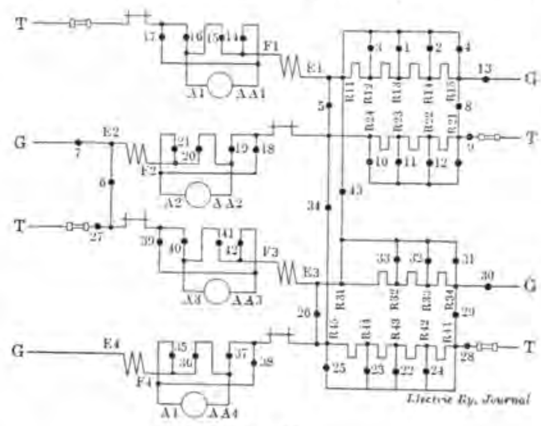


Fig. 23
WIRING DIAGRAM

running gear is illustrated in Fig. 17. It will be seen that it consists of what may be termed two trucks of the locomotive type coupled together by a massive hinge. This coupling is so designed as to enable the rear truck to resist any tilting tendency of the forward truck. In this manner the articulated running gear has lateral flexibility and at the same time possesses vertical rigidity.

In addition to the third-rail shoes these locomotives are equipped with an overhead current collector which is raised or lowered at will by a foot-operated valve in front of the motorman.

Pumping Equipment

The arrangements provided for keeping the tunnel free from water are of interest. The capacity of the machinery installed for this purpose was based on the heaviest rainfall for 35 years and the addition of an ample margin of safety. Five pumping stations or sumps have been constructed. One is situated at each portal, there is one at each

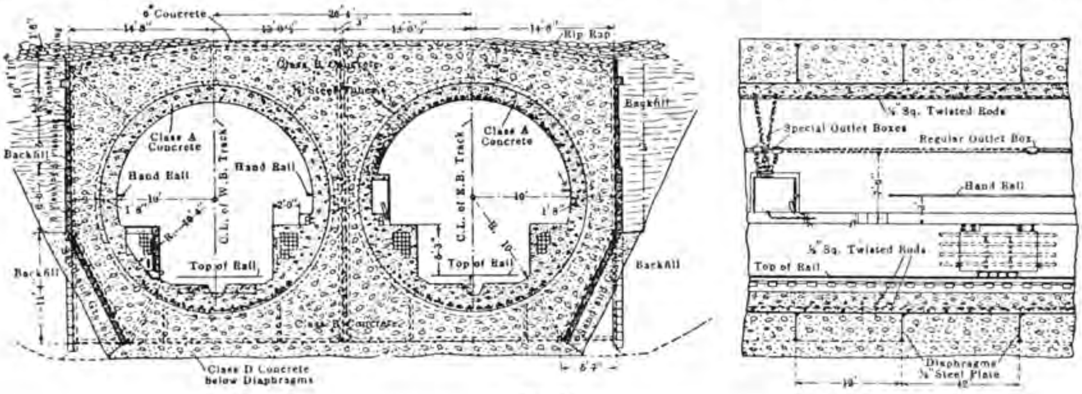


Fig. 24

CROSS-SECTION OF TUNNEL AND LONGITUDINAL SECTION OF EAST-BOUND TRACK

The following table gives the principal details concerning these locomotives:

Number of motors	4
Gear ratio	4.37
Number of driving wheels	8
Diameter of driving wheels	48 in.
Total wheel base	27 ft. 6 in.
Rigid wheel base	9 ft. 6 in.
Length, inside knuckles	39 ft. 6 in.
Length of main cab	15 ft. 6 in.
Height of cab	12 ft. 6 in.
Maximum height, trolley up	15 ft. 6 in.
Maximum height, trolley retracted	14 ft. 8 in.
Maximum width	10 ft. 2⅝ in.
Width of cab	10 ft. 1 5/6 in.
Total weight	199,000 lb.

At the present time only four locomotives are in service at a time, the other two being in reserve. The locomotives start the train from rest in the yards and on the down grade in the tunnel the train attains full speed and is running free when the level subaqueous section is reached. The controller is here put to the full-on position and the load is automatically taken on the up grade at the other end of the tunnel.

shaft and the fifth is in the center of the subaqueous section.

The pump motors range from 15 h.p. to 30 h.p. in size, and are operated from the substation. An annunciator system, installed for each sump, rings a bell and lights a red pilot lamp in the substation when the water in either sump reaches the high water setting for the float equipment. The bell alarm is cut off when the operator starts either pump set located in the sump from which the alarm was received, and when the water in the sump is pumped to the low-water level for which the float equipment is set a green pilot lamp is lighted on the sump control panel and the pump is shut down.

Lighting System

The tunnel is lighted by approximately 860 incandescent lamps, which are spaced 40 ft. apart on both side walls of either tunnel. The lamps have carbon filaments, are of 16 c-p. each, and are provided with aluminum shades so as to reflect the light in the direction of travel and thus avoid glare in the eyes of trainmen.

Transformers are placed in niches at suitable points to both tunnels and the primaries are fed by 440 volt feeders from the substation, while the 104 volt secondary side of the transformers is fed directly to the lamps. There is a lighting cabinet in each transformer niche to control the lighting in its immediate vicinity, and each cabinet controls eight local lighting circuits and in some cases signal track transformers have a primary feed from the lighting cabinets. These transformers are single-phase, of 7½ kw. capacity, and are connected alternately to the different legs of the three-phase feeders in such a manner as to balance the load.

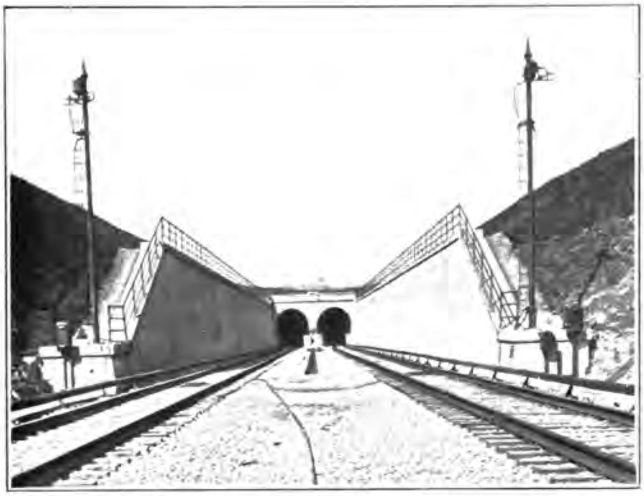


Fig. 25
WINDSOR APPROACH

The lighting of the yards is accomplished by one hundred 7⅜ amp. 490 watt, series alternating current arc lamps. Each lamp is supported on a cast iron pole of neat design. This lighting system is fed from the constant current transformers already mentioned. The motor-generator room of the substation is lighted by 21 clusters of tungsten 40 watt lamps. Two of the clusters in the center of the station are fed from the main storage battery for emergency lighting. The other clusters are fed from the substation light and power transformer equipment.

Tunnel Details

In this article it would be interesting to deal at some length with the tunnels themselves, as undoubtedly their construction is one of the most interesting pieces of engineering work accomplished in recent years, but as this part of the subject has already been covered in other articles only a few of the most important facts bearing on the scheme of electrification will be mentioned.

Fig. 24 shows a section through the tunnel and Fig. 28 is the reproduction of a view in the tunnel showing the third rail.

Fig. 26
LOCOMOTIVE AT DETROIT APPROACH

The subaqueous portion of the tunnels was built up in 11 different sections on land and afterward sunk in position on a concrete bench placed on the bottom of a trench dredged in the river bed. These sections when in place were bolted together, gaskets being used to insure the waterproofing of the joints. With this form of construction it was questionable whether stray current would not lead to electrolysis at these joints. Therefore copper bonds were employed to make the metallic portion of the tunnel a continuous conductor with the Detroit end tied in with the negative return feeders.

4 ft. long. They are of Louisiana long-leaf yellow pine. The long ties for supporting the third rail brackets are of the same section 6 ft. long and are spaced with 10 ft. centers. The distance from center line to center line of the tracks in the tunnel is 20 ft. 6 in. on tangent and 26 ft. 4 in. on maximum curves.

Fig. 25 shows the Windsor approach, while Fig. 26 is a view of the Detroit approach. The latter picture was taken with the locomotive in the portal to show the ample clearances provided in the tunnel. It also shows the point where the ordinary yard track construction gives way to the special construction for the tunnel.

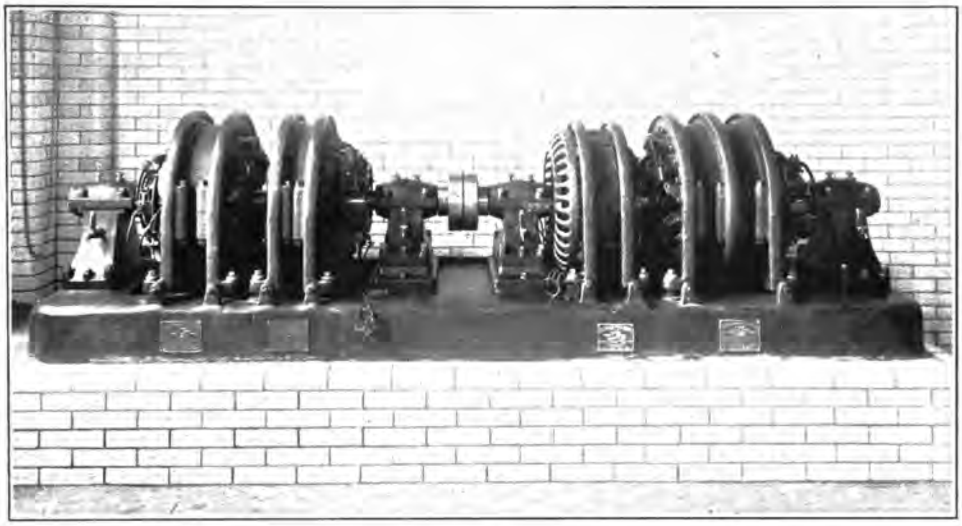


Fig. 27
EXCITER SET FOR BOOSTER

The running rails are of special composition; they weigh 100 lb. per yard, and are of the A.S.C.E. standard section. Each joint is bonded with two General Electric bonds, each of 500,000 cir. mil. capacity. The drainage scheme of the tunnels calls for a continuous open gutter for the entire length of each tunnel, which made necessary a special form of ties for the track rails. Fig. 28 shows the construction adopted. The ties are embedded in concrete, protruding only about 3 in. above the surface. Dowels were placed in the concrete between each tie to prevent any possibility of slipping, and to make the roadbed a thoroughly homogeneous mass. These ties have a section of 8 in. by 11 in. and are

Referring back to Fig. 24, the conduits provided in the tunnel for the different electric cables will be noticed. Those on the extreme right are reserved for future power requirements. The telephone, telegraph and signal cables are carried in the large nest of ducts in the base of the dividing wall between the two tunnels, while the cables for tunnel lighting are taken in the three ducts shown under the left bench wall on the right-hand tunnel. The power cables for the operation of the tunnel and Windsor yards are carried in the ducts shown in the extreme right of the drawing presented on page 16.

To avoid the use of poles throughout the yards all cables are carried in ducts underground. Vitrified clay ducts are employed in the tunnel and throughout the yards, and iron conduits are used for the secondary wiring for the lighting of the tunnel. This lighting conduit is built in the concrete lining of the tunnel and runs directly into the junction boxes holding the incandescent lamps.

The splicing chambers are spaced approximately 400 ft. apart on straight work and are all properly drained and ventilated. In the tunnel their width and height is necessarily small on account of the limited space, but is sufficient for all the requirements. They are each 8 ft. in length.

The lead covered cables are supported in the manholes from malleable iron cable racks hung from vertical tee irons secured to the walls of the splicing chambers. These tee irons are provided with holes for practically their entire length to facilitate the adjustment of the cable supports and for the better accommodation of the cables. In many places double cable supports have been used to reduce the amount of fanning necessary from the cable ducts to the splicing sleeves. Ground connections are provided in the manholes for grounding the lead covers of all cables.

As the substation is located near the Detroit shaft this shaft is employed as the cable run instead of the Detroit portal. There are three vertical wells in this shaft for the exclusive use of the cables, the concrete surfaces of each well consisting of a series of shallow grooves each large enough for a single cable of the largest size; thus there is a barrier on each side of every cable. The weight of the lead cable is taken by wooden clamps held by U-bolts set in the concrete. These are spaced approximately 4 ft. apart.

The total amount of cable installed was 229,000 ft., of which by far the greater portion is multiple conductor. Most of this cable has varnished cambric insulation of a thickness depending upon the voltage of the circuit on which it is used, and a lead covering is used on all cables except the 110-volt lighting cable, which is located in the iron conduit, where there is no possibility of water accumulating.

Fig. 28
TRACK CONSTRUCTION IN THE TUNNEL

In the splicing chambers the lead covering is protected by a covering of asbestos felt 1/8 in. thick, applied with a one-half lap and coated with silicate of soda. This precaution was taken to prevent communication of fire from one cable to another, where, on account of the somewhat limited space, it was impossible to separate the cables properly with barriers or split ducts.

Regulation of Load

The nature of the load and the mode of regulation are such as to warrant a somewhat detailed account.

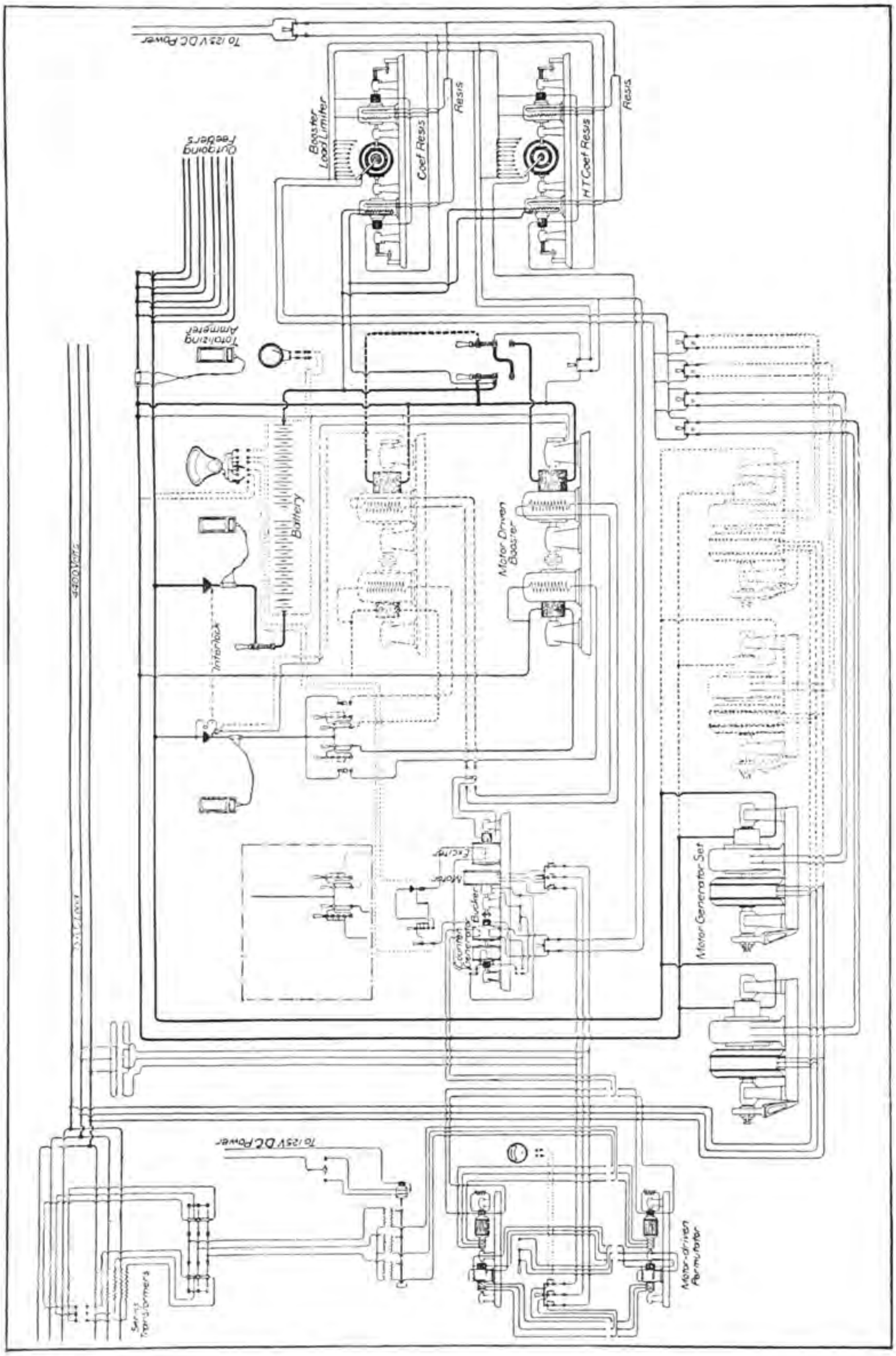


Fig. 29

WIRING DIAGRAM, SHOWING THE PRESENT AND FUTURE CONNECTIONS OF THE APPARATUS IN THE CONVERTER STATION

The power is purchased on a maximum demand basis, which makes it necessary for economical operation to eliminate as far as possible excessive peaks from the incoming lines. A Gould storage battery has been installed to take care of the fluctuations of load and the regulation devices are such that the first 800 amp. are taken from the motor-generator sets; then the battery takes care of the load from 800 amp. up to 8360 amp.; that is, the battery takes 7560 amp. Anything above this figure is again taken from the motor generators. The maximum load is 9100 amp. When this load is being carried the motor-generator sets would be delivering 1540 amp. (their full load rating), and the battery would be supplying 7560 amp.

The battery consists of 312 cells, Type U-43 plate elements in 59 plate tanks. These plates are 18½ in. square, and each element has a capacity of 630 amp. for 8 hours, 1260 amp. for 3 hours, 2520 amp. for 1 hour, or 5040 amp. for 20 minutes, and is capable of withstanding discharges up to 8000 amp. capacity.

When a total of 59 plates is installed in the tanks each element will have a capacity of 870 amp. for 8 hours, 1740 amp. for 3 hours, 3480 amp. for 1 hour or 6960 amp. for 20 minutes, and will be capable of withstanding discharges up to 11,000 amp.

The battery installation is for the purpose of taking care of the fluctuations in the load and insuring a practically constant input from the Detroit Edison Company. It consists of the battery, a motor-driven booster, an exciter set for the booster and a small rectifier set for obtaining current for regulating purposes, which varies according to the ampere times the power-factor on the incoming supply. One floor of the battery house is shown in Fig. 30, while the exciter set, the motor-driven booster and the small regulating rectifier set are illustrated respectively in Figs. 27, 31 and 33. The load requirements are such that, taken in connection with the relatively low average demand, a practically instantaneous response to load changes must be obtained from the battery and booster, and to accomplish this result

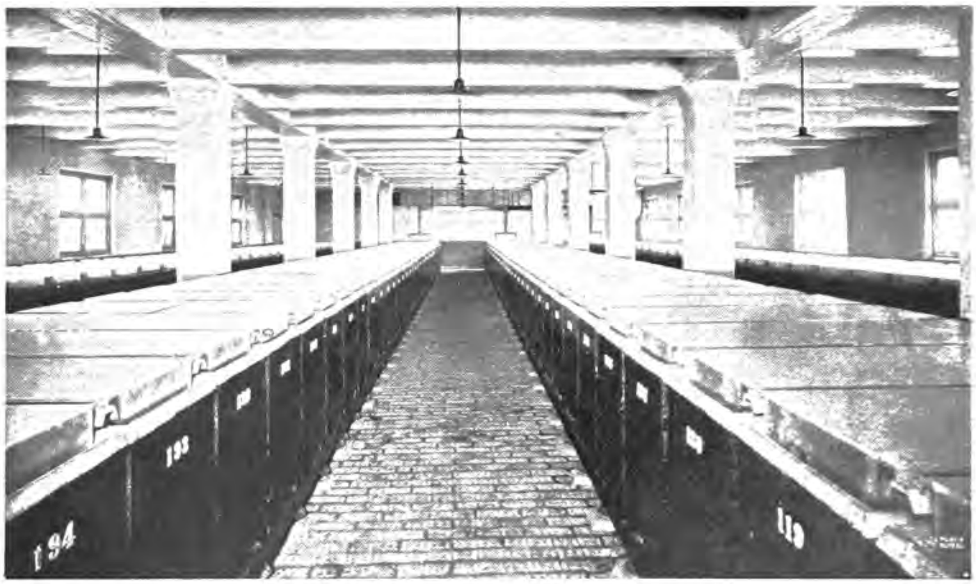


Fig. 30
LOWER BATTERY ROOM

a special Gould high-voltage exciter has been provided, which upon the change of load occurring impresses an abnormal voltage on the booster field. This voltage is maintained

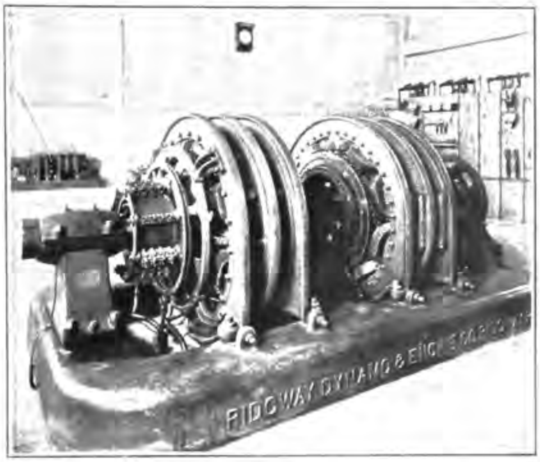


Fig. 31
BOOSTER SET

until the proper current flows through the booster field circuit to cause the booster to respond and so compel the battery to charge or discharge in accordance with the load changes.

To reduce the size of the battery required to accomplish the work and also the size of the booster necessary, it is desirable to have the station voltage changed inversely according to the demand on the station; that is, to have a high station voltage when the load is light and a low station voltage when the load is heavy. It is, however, not desirable that the variations in station voltage should occur at times other than times of maximum and minimum. To accomplish this a load-limit device (see Fig. 32) has been installed, which changes the excitation of the direct current end of the motor-generator sets either when the booster voltage capacity is reached or when the booster current capacity is reached, but at all other times permits normal excitation of the motor-generator set. This causes the motor-generator set voltage to be increased when the booster voltage reaches the limit in a charge direction or when the booster current reaches the limit in a charge direction, and decreases the voltage of the motor-generator set when either the booster voltage or current capacity in a discharge direction is exceeded.

Inasmuch as the energy is purchased on a kilowatt-hour basis, it is desirable that when the voltage is decreased on the motor-generator sets, the current be increased, and to accomplish this a booster load limit device has been installed. This apparatus, in the event of a load carrying beyond the capacity of the battery and booster, automatically shifts the excess load from it to the motor-generator set, thus preventing the opening of the battery circuit breaker and the consequent transference of the total load to the motor-generator set, which would result in the opening of the motor-generator circuit breakers. This load limit device is actuated

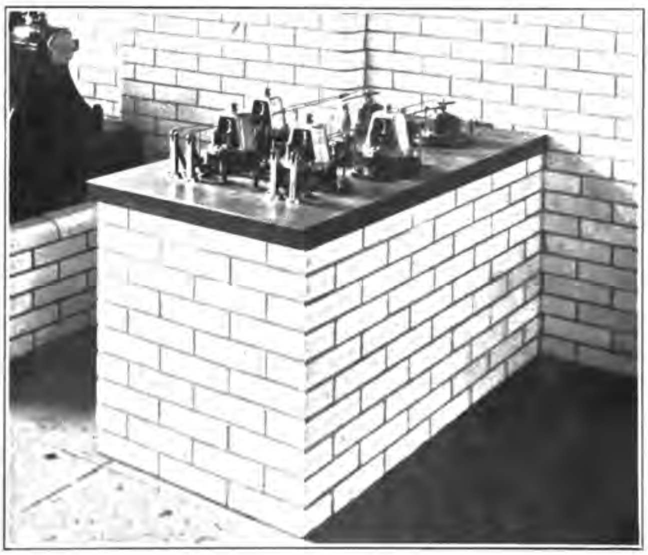


Fig. 32
QUADRUPLE LOAD LIMIT DEVICE

by battery discharge current and battery charge current, and by booster voltage in a charge direction and in a discharge direction.

When the battery is discharging and this load-limit device is actuated, additional load is thrown on the motor-generator sets, and when the battery is charging and the load-limit device is actuated the load is removed from the motor-generator sets, but this device, like the load-limit control of the motor-generator sets, does not come into operation until certain limits have been reached. At all other times the regulating apparatus and the battery preserve practically constant load on the lines from the Detroit Edison Company.

It is thought that the following details of the apparatus may be of interest: In the incoming lines from the Detroit Edison Company series transformers are inserted and from these series transformers current is led to a small rectifier set which consists of a synchronous motor and a small permutator. The synchronous motor drives the permutator in synchronism with the voltage, but in a reverse direction to the direction of the field set up by the current from the series transformers. This results in a field which is fixed in space so long as the power-factor is unchanged. The permutator is provided with two sets of brushes, one practically at 90 electrical degrees to the other, one set being connected to the field of the counter machine and the other set connected to a by-pass circuit. The brushes are so set that with the normal current flowing from one set of brushes through the field of the counter machine no current flows through the by-pass circuit when the power on the incoming lines from the Edison Company is at 100 per cent. power-factor. When set in this way a change in power-factor on the incoming lines without a shift of current will cause the current supply from the permutator to the field of the counter machine to be reduced and the current to flow in the by-pass circuit, and by proper adjustment of the resistance of the two paths the current flowing through the counter machine field is at all times proportional to the current multiplied by the power-factor on the incoming lines from the Edison Company.

From the counter machine armature a circuit extends to and includes one field of the exciter and the armature of the bucker, this bucker being a machine designed to generate constant voltage irrespective of the direction and amount of current through its armature and provided to furnish a constant opposing force for the regulation to work against. The voltage of this bucker is equal to the voltage of the counter machine when the normal load is on the incoming lines, and any change in load on the incoming lines will cause current to flow from the counter machine or to the counter machine through the exciter field, depending on whether the load is increased or decreased. From the exciter armature a circuit extends to the booster field and includes a reverse series winding on the exciter. This winding cuts down the exciter voltage when current flows to the booster field, thus permitting an abnormal voltage to be obtained from the exciter and applied to the booster field as long as required, or until current begins to flow through the booster field circuit, when this voltage is cut down in proportion to the current flow to the booster field. The wiring details of this apparatus are shown in Fig. 29.

In this plant the time which is required to reverse the booster from approximately 80 volts in one direction to approximately 80 volts in the other direction, with normal voltage applied to its terminals, is approximately 4½ seconds. By using the differential exciter voltage as high as 300 volts can be impressed on the booster field, which is wound for approximately 20 volts. The result is that the response of the booster is enormously quickened, and this excess voltage is cut down exactly as desired, so that at no time does an excessive or abnormal current flow through the booster field. Means are provided whereby the average load supplied by the Detroit Edison Company can be changed at will to accommodate this system to different schedule conditions. Means are also provided whereby the regulation can be changed from 7½ per cent. to 33 1/3 per cent.; that is to say, the incoming power from the Detroit Edison can be kept constant within the limits of plus or minus 7½ per cent., or can be permitted to vary plus or minus 33 1/3 per cent. from any desired average.

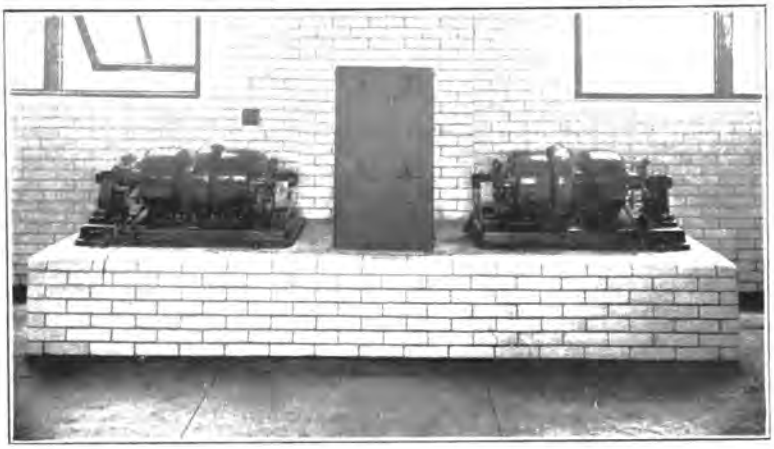


Fig. 33
RECTIFIER OR PERMUTATOR SETS

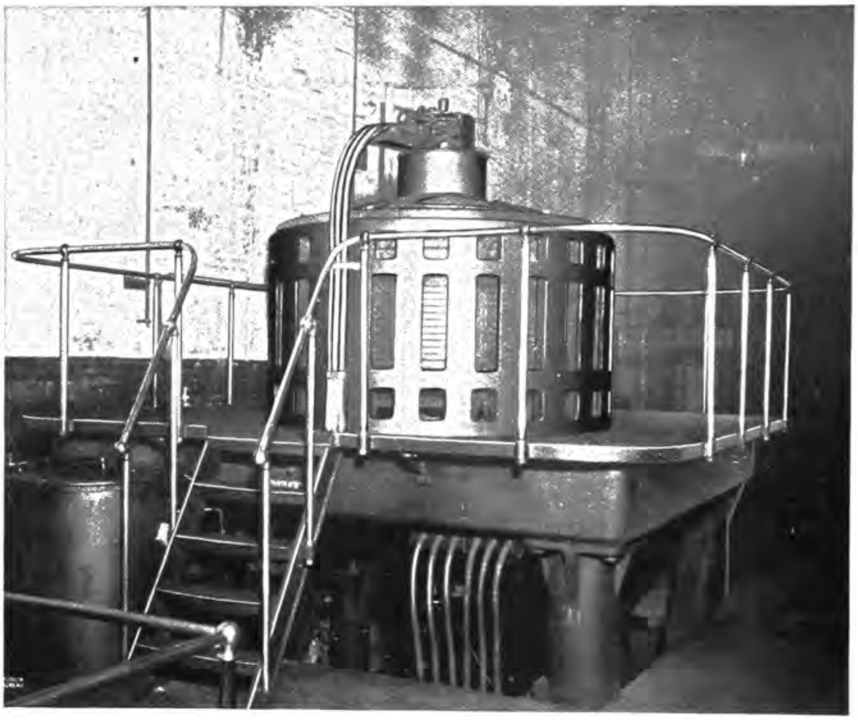
General Electric Company
Schenectady, N.Y.

May, 1911 — Bulletin No. 4835

ELECTRICALLY-DRIVEN PUMPS

Pumping machinery of various forms constitutes a part of practically all operations involved in modern industrial development, and in many cases, such as irrigation, and drainage projects, sewage disposal, fire-fighting equipment, and various forms of water supply, pumps are of vital importance, as upon their efficiency, continued service and cost of operation, the results obtained are directly dependent.

The inherent superiority of motor drive for the operation of both centrifugal and reciprocating pumps has long been recognized, and the recent notable improvements tending toward higher efficiency and greater economy in the operation of electric motors has made their adoption for the driving of all forms of pumping machinery an economical necessity wherever electric current is available.



1500 H.P. INDUCTION MOTOR DRIVING CENTRIFUGAL PUMP
MUNICIPAL PUMPING PLANT, BUFFALO, N. Y.

Inasmuch as there are a great many installations in localities supplied with electric current in which the pumps are still operated by steam, it might be well to state definitely the points which constitute the

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superiority of electric drive when compared with steam drive for pumps.

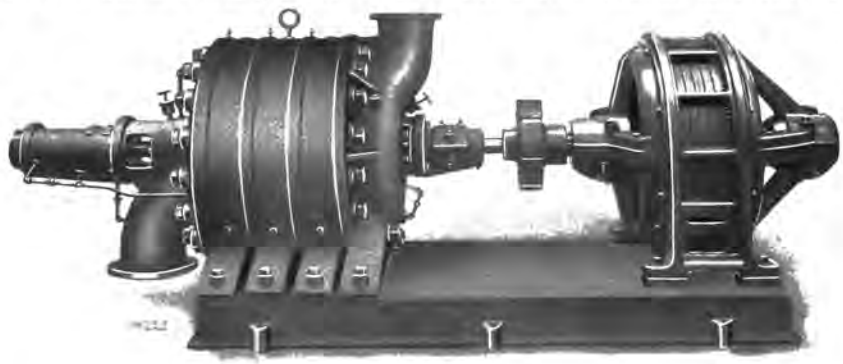
The cost of installing a motor-driven pump is usually less than with other systems and there is far less waste of power than that involved in friction and leakage on steam lines, as well as a reduction in the amount of space required.

As the electric motor is not dependent upon the location of boilers and the running of steam pipes, a motor-driven pump may be installed with entire freedom as to location, and in many instances can be used where the application of steam-driven pumps would be impossible.

The energy required to operate the motor-driven pump is carried along wires which can be more easily run and are less liable to injury than steam piping. The use of motors obviates the condensation losses inherent in steam piping systems, and eliminates the problem as to the disposal of exhaust steam. In addition to this, there is an entire absence of the heat which is unavoidable in steam pumping outfits.

Due to the absence of piping with its possibilities of loss by leakage and consequent necessity for repairs, the cost of maintenance is greatly reduced.

All the reasons given above apply to installations where steam is available. In the case of new installations, the value of the motor-driven equipment is enhanced by the fact that its location can be decided independently of the source of power, and that it requires no expert supervision. If the current is purchased from a central station, the cost of operation is directly proportional to the load, and if the service is intermittent, the expense for power ceases the instant the motor is stopped. In other words, the expense of operation is only incurred while the pumping set is actually running, and the first cost, interest charges, and maintenance of steam boilers and their attendants is avoided. The motor can be readily adapted to drive all forms of pumping machinery, the best results being obtainable with centrifugal pumps, which are usually most efficient at high speed; the motor can in that case be direct-connected, thereby eliminating the friction loss involved by transmitting power through gears. For high duty piston pumps the motor permits the direct application of a larger percentage of the initial power developed than is possible in steam drive with its inevitable losses through leakage, exhaust or loss of pressure in piping.



10 IN. FOUR-STAGE TURBINE PUMP, CAPACITY 2000 GAL. PER MIN. AT 150 LB. PRESSURE DRIVEN BY A 260 H.P. INDUCTION MOTOR

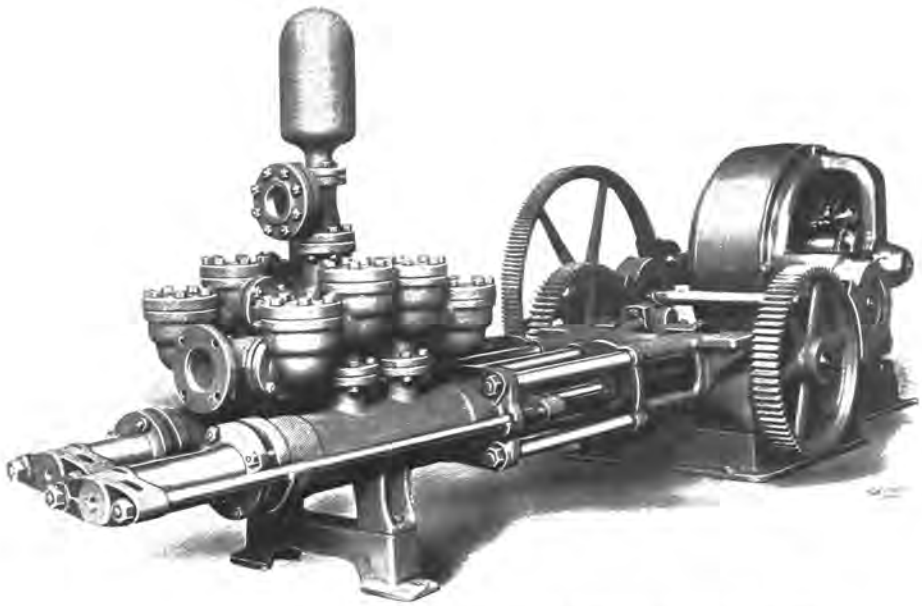
The following pages illustrate and describe, briefly, some typical installations of modern motor-driven pumps, but owing to the practically unlimited field occupied by pumping apparatus, no attempt has been made to describe types suited for every individual case. The installations shown will, however, indicate the general adaptability of motors for the operation of all forms of pumping machinery.

MINE PUMPS

Due to the severe service conditions ordinarily encountered in the operation of pumps in mines, the superiority of motor drive has been more thoroughly demonstrated in this particular industry than in any other. In the electric operation of mine pumps the source of power may be located at the surface near the mine, or at a distance from it, and the initial power developed applied at the pumps with a minimum loss in transmission.

When motor-driven pumps are installed in the mines the conducting wires can be readily run so as to leave the pump shaft practically free from all machinery. Provision need be made only for the pump itself and for the discharge pipes, and, as these occupy very little space, they can usually be placed in one of the hoisting compartments. There is also an entire absence of the danger which the presence of leaky steam pipes in a mine may involve.

The motors occupy a small amount of space, operate with high efficiency, are easily controlled and their location in the mine may be limited solely by the work to be done. Where conditions of extreme dampness prevail, the motors can be so constructed as to be absolutely waterproof. For temporary or intermittent service portable or motor-driven pumping sets may be used either mounted on trucks or skids, and provided with cables for connection to the feeder circuit. The use of the electric motor is the only method by which a portable pumping set can be easily and economically operated in mines.

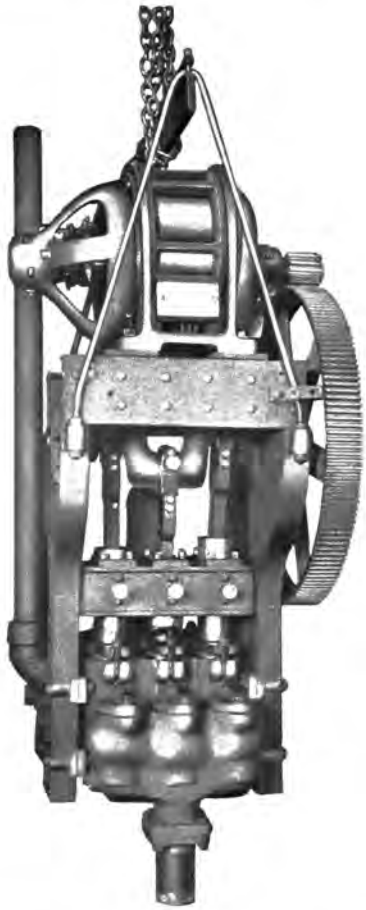


DUPLEX MINE PUMP DRIVEN BY DIRECT CURRENT MOTOR

SINKING PUMPS

The illustration on page 4 shows a typical mine-sinking pump driven by a General Electric induction motor. This type is arranged for mounting on a float so that it will always operate at the surface of the water, and can be raised or lowered with the variations in the water level, the current being supplied to the motor by means of flexible cables.

The electric motor is equally adapted for the operation of high and low head pumps, and can readily be arranged to maintain high pumping efficiency under widely fluctuating heads. Special motors can be provided to meet unusual requirements, but the standard line of General Electric motors designed for pumping service will successfully meet all of the conditions ordinarily encountered in mining operations.



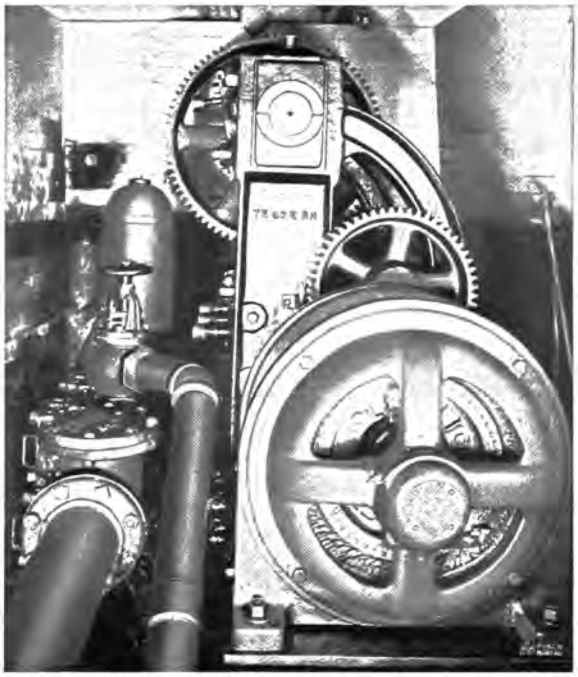
4½ BY 6 IN. VERTICAL TRIPLEX SINKING PUMP DRIVEN BY 7½ H.P. INDUCTION MOTOR

As an indication of the ability of the standard type of motor to operate successfully under unusually severe conditions, the following extract from a technical journal is given.

REMARKABLE PERFORMANCE OF A MOTOR-DRIVEN MINE PUMP

The performance of apparatus under exceptional circumstances reveals the weak or strong points in its design, and its suitability for the service for which it has been installed.

A twenty horse power, three-phase, 220 volt standard induction motor made by the General Electric Company recently demonstrated the ability of the standard motors manufactured by this company to operate successfully under the trying conditions met with in mines without being totally enclosed. This motor is geared to a mine pump, located at the bottom of a shaft at the mines of the Richmond Iron Works, Richmond Furnace, Mass., and is installed in a chamber where the air is always very damp and moisture is continually dripping from the roof timbers. It is protected from this water by a piece of tarred paper tacked above it, so as to deflect the water.



20 H.P. INDUCTION MOTOR DRIVING A MINE PUMP RICHMOND IRON WORKS, RICHMOND FURNACE, MASS.

During a heavy thaw the surface water broke in on one of the upper levels and flooded the mine. The water rose so rapidly that the electric pump was soon under water, the top of the motor being two feet below the surface. Under such circumstances it was imperative that the pump should continue in operation as long as possible, and so it was not shut down. It continued to operate perfectly and at the end of two hours, during the whole of which time the motor was submerged, it had pumped itself clear of water. It was then stopped only long enough to clean the dirt and chips from around the rotor, and put oil in the bearings, and was then started up again. This pump has been running about twenty hours a day ever since and the motor has apparently suffered no injury from its unusual experience.

MUNICIPAL PUMPING

The efficiency and economy of motor-driven pumps have caused their extensive adoption, where electric power is available, for the operation of water supply and sewage disposal pumps in municipal pumping plants. The use of motors for this service insures such economies in operation that in some instances existing steam pumping sets have been either abandoned or else held simply as reserves for emergency use.

As compared with steam-driven pumps for municipal work, the motor-driven outfit occupies less room and results in a greatly reduced expenditure for maintenance and supervision.

Where water is supplied to reservoirs or storage tanks the operation of the motor-driven pumps may be rendered entirely automatic by the use of float or pressure switches, which can be adjusted to start and stop the motor promptly when variations in the water level occur, and thereby tend to maintain the water storage at any required volume.

If current is purchased from an outside central station it is usually feasible to arrange the pumping periods so that the maximum demand for current will occur during off peak hours; especially low rates for current may thereby be obtained.

CENTRIFUGAL LIFT PUMPS IN SEWAGE DISPOSAL PLANT—DRIVEN BY SYNCHRONOUS MOTORS DIRECT-CONNECTED—ST. BENARD STATION, NO. 3, NEW ORLEANS, LA.

In sewage disposal plants centrifugal pumps are generally used, as their construction enables them to successfully handle liquids containing a large percentage of solid matter in suspension. The operating conditions of sewage disposal pumps usually comprise low head and relatively great volume, and a typical installation of this character using direct-connected horizontal shaft synchronous motors is shown herewith.

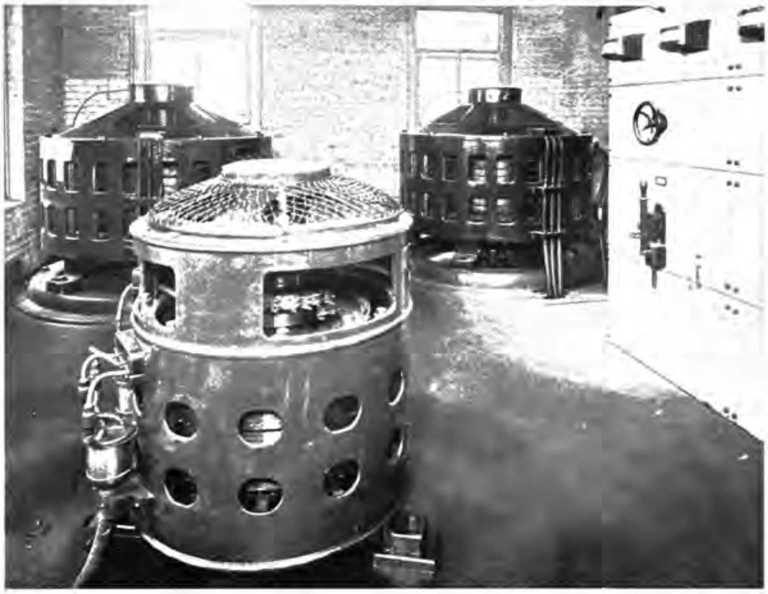
DRY DOCK PUMPING

The characteristics of motor-driven pumps render them especially valuable for use in both floating and graving dry docks. For the former type the motors can be readily supplied with current from a shore station, either by catenary suspension of the conductors or by laying them on a series of floats. The service demanded of the pumps is intermittent, and if current is obtained from an outside source the power cost of emptying the dock may be definitely determined in every instance.

The load on the pumps increases inversely as the head against which the pumps are delivering water, and as a rule the motors are designed so that at the start the efficiency increases with the increase in the head of water; this tends to keep the motor load constant.

The accompanying illustration shows three vertical shaft induction motors driving centrifugal pumps, which serve a graving dock at the Erie Basin, Brooklyn, N. Y. The larger units are used intermittently for emptying the dry dock, while the smaller motor is operated continuously so as to handle any leakage which may accumulate.

An automatic switching device is provided for each of these motors, which, in the event of a continued overload, causes the motor to be cut out of circuit and at the same time rings an alarm bell.



TWO 350 H.P. INDUCTION MOTORS IN BACKGROUND, 50 H.P. INDUCTION MOTOR IN FOREGROUND—DRY DOCK, ERIE BASIN, N. Y.

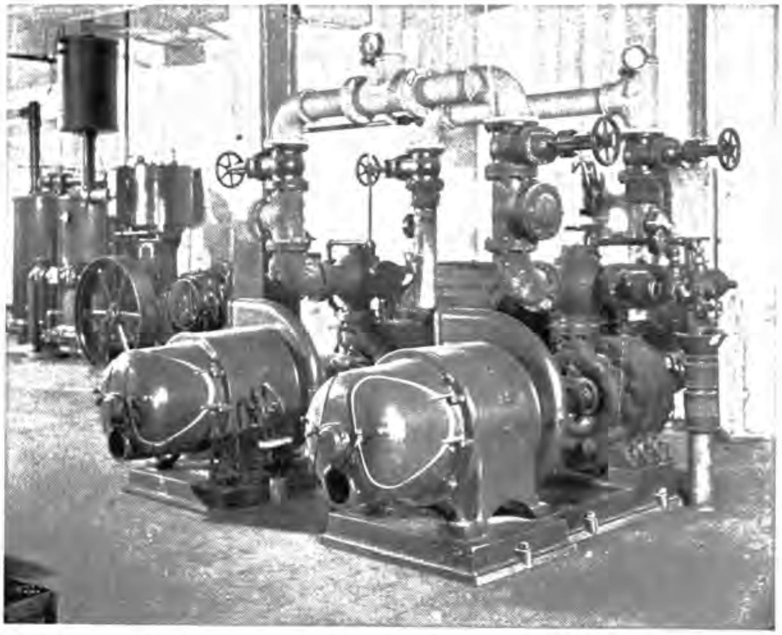
Inasmuch as the pumping operations give a heavy peak load of short duration it was decided that it would be more economical to use central station power than to incur the expense of providing an isolated generating outfit capable of supplying the maximum intermittent demand for current. The cost of the equipment was thereby confined to that involved in the purchase and installation of the motors, controllers, transformers and switchboard.

FIRE PUMPS

The electric motor constitutes an ideal medium for the application of power to fire pumps, inasmuch as it entails practically no expense for up-keep while it is idle, and upon the breaking out of a fire, by simply throwing a switch, the full water pressure is available.

A factor which may be of considerable importance is the ease with which a motor-driven fire pump may be made to operate automatically or manually controlled from a distance. As in other types of pumps, those intended for fire service, either reciprocating or centrifugal type, can be designed to develop the highest possible efficiency when operated by motors especially constructed for this service. The illustrations herewith show both reciprocating and centrifugal pumps driven by General Electric direct current motors.

It will be noted that the triplex pump on page 9 is driven by an open type motor, while the two centrifugal pumps shown herewith are direct-connected to totally enclosed motors provided with a special ventilating equipment which will insure cool running of the motors under the most adverse conditions. In comparing motor-driven fire pumps with the steam-driven type, the very great economy of the former is demonstrated by the fact that the cost of operation is entailed only during those periods when the pump is actually in service. It is unnecessary to maintain steam continuously for these units as is the case with steam-driven pumps, and if the plant is equipped with a generating outfit an additional factor of safety may be obtained by connecting the motor-driven pump with a central station circuit. In the event of a shut-down of the plant or injury to the generators the efficiency of the fire fighting equipment will by this means remain unaffected.



TWO 75 H.P., 1500 R.P.M. DIRECT CURRENT MOTORS DRIVING THREE-STAGE CENTRIFUGAL UNDERWRITERS' FIRE PUMPS—JORDAN, MARSH COMPANY, BOSTON, MASS.

The following description of an electric fire pump equipment extracted from "Insurance Engineering" indicates the character of the outfit which experience has demonstrated is most suitable for this service, and gives the efficiencies obtained under working conditions approximating those which would be encountered during a fire.

MOTOR-DRIVEN FIRE PUMP EQUIPMENT
Siegel, Cooper Company, Chicago, Ill.

The pump was built under the National Standard specifications. * * * It has four stages and is designed for a net delivery pressure of 150 pounds and a rated capacity of 1500 gallons per minute. The pump shaft is mounted on high-grade ball bearings and is direct-connected to a 200 h.p. shunt-wound, 220 volt motor running at 1100 r.p.m. The motor, built by the General Electric Company, is of the fully enclosed type and is ventilated by forced draft through the casing, from a self-contained fan on the armature shaft. The suction of the fan is piped to cool air outside the pump room, while the discharge outlet is at the top of the motor case and is arranged so as to guard against the admission of water. Substantial cast iron doors, or hinged covers, fitted with thumbscrew fastenings and rubber gaskets, provide easy access to the commutator.

* * *

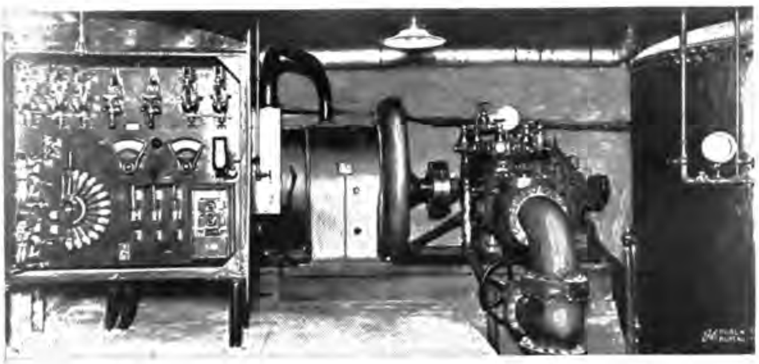
The motor is provided with both manual and automatic control, designed and built with special reference to the requirements of this class of service, by the General Electric Company. The entire starting apparatus is mounted on a single slate panel enclosed in a splash-proof ventilated steel cabinet, raised two feet above the floor and having hinged doors at the front and back.

* * *

Six leads of fire department hose, each 100 feet long, were attached to the outlets at the pump, laid out to the alley pavement, and arranged so that three lines discharged to street north and three to street south of the building, where catch basin covers were removed to facilitate the disposal of water. The playpipes were all 1⅛ inch, smooth bore.

The pump output was measured in pressure, and gallons per minute at the nozzles with a Sanborn piezometer. A Weston combination voltmeter and ammeter was placed in the power circuit at the starting panel for the electrical readings. Crosby 300 pound test gauges, recently calibrated, were attached at the center line of the pump, on suction and discharge ends. All readings, including speed, voltage, amperes, suction pressure, discharge pressure and nozzle pressures were taken simultaneously at the end of five minute periods.

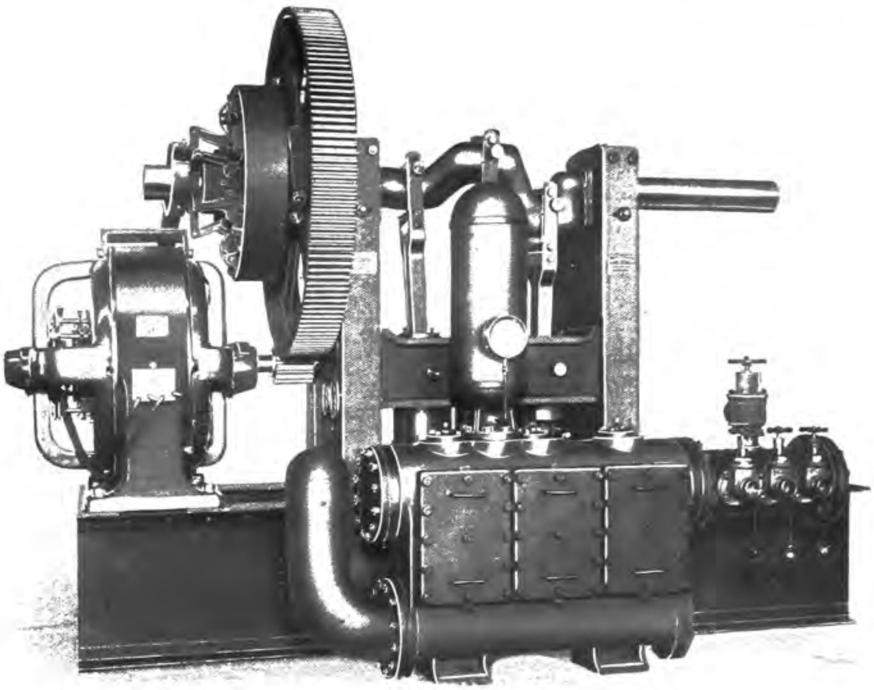
A series of readings were taken under different conditions during a continuous run of two hours with the results indicated in the accompanying table.



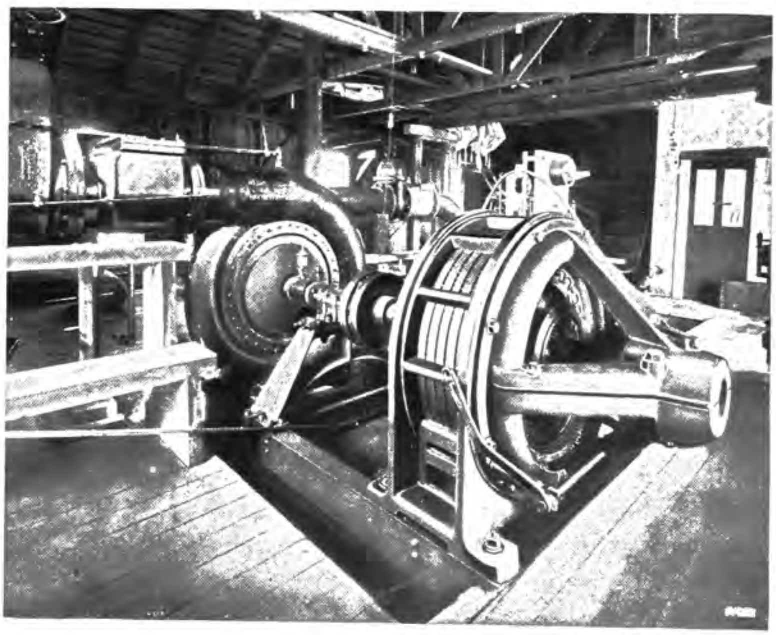
200 H.P., 1100 R.P.M. DIRECT CURRENT MOTOR DRIVING FIRE PUMP
SIEGEL, COOPER COMPANY, CHICAGO, ILL.

No. Streams	Gallons per Minute	Net Pump Pressure	Net Motor Output	Pump Efficiency Per Cent.
Shut off	0	187	78.8	....
1 wide open	508	184	133.6	44.0
1 throttled	251	184	110.3	24.4
2 throttled	506	186	128.8	44.1
3 throttled	759	191	149.2	56.5
4 throttled	1008	186	170.3	64.6
5 throttled	1255	167	186.6	66.5
6 throttled	1518 (rated capacity)	151	196.4	68.0
6 wide open	2022	80	202.1	46.0
6 wide open	2298 (high speed)	118	282.2	56.0
6 wide open	2022	80	202.1	46.0

The pump ran smoothly and when shut down at the end of the tests the bearings were in excellent condition. The temperature rise in windings of the motor was 30 degrees C.



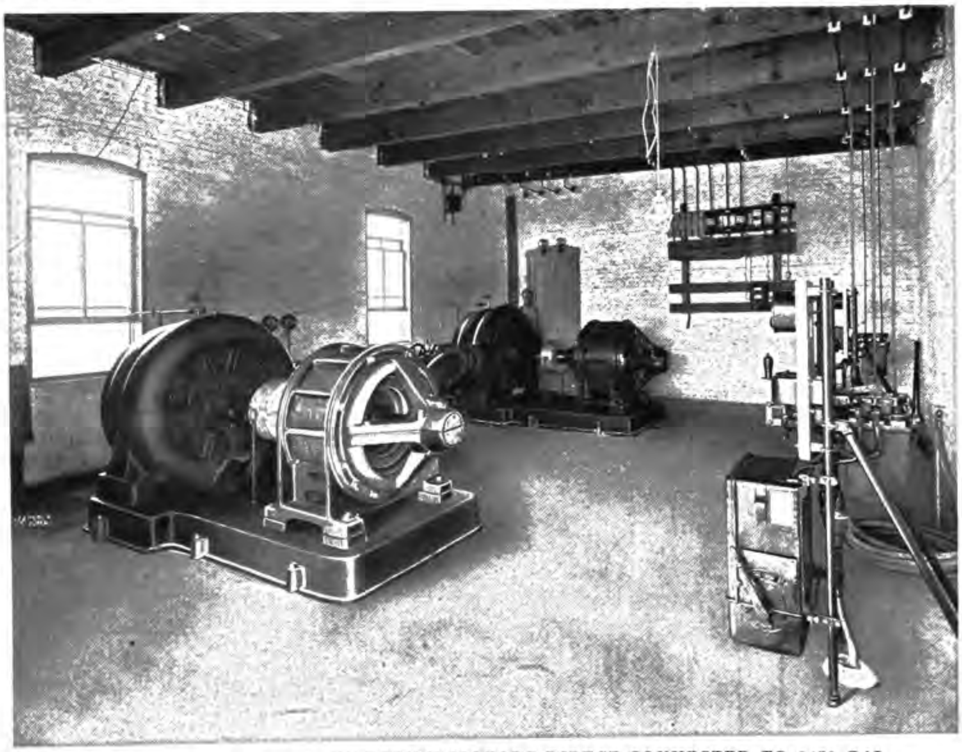
DIRECT CURRENT MOTOR GEARED TO 11 BY 12 IN. VERTICAL TRIPLEX UNDERWRITERS' PUMP



175 H.P., 600 R.P.M. INDUCTION MOTOR DRIVING 14 IN. SINGLE-STAGE TURBINE CENTRIFUGAL PUMP, CAPACITY 6000 G.P.M., 70 FT. HEAD FOR IRRIGATION—HAZELWOOD COMPANY, SPOKANE, WASH.

IRRIGATION PUMPING

The extensive development of hydro-electric projects, together with the ease with which electric current can be economically distributed at high potentials over long distances, has rendered it feasible for a large number of irrigation pumping outfits to be operated electrically and at a much lower cost than would be possible if other forms of power were used.



TWO 50 H.P., 900 R.P.M. INDUCTION MOTORS DIRECT-CONNECTED TO 3450 GAL. CENTRIFUGAL PUMPS—NORTHERN PACIFIC IRRIGATION COMPANY

The working conditions of the average irrigation plant require the pumping of a large volume of water against a comparatively low head, and for this class of service a motor-driven centrifugal pump is generally adopted.

By utilizing motor drive for irrigation pumping, the power station, even for the very largest projects, can usually be efficiently handled by a single attendant. Due to the fact that the motor-driven pump when once started, will operate continuously without further attention, it is customary in some instances to delegate the work of starting and stopping the motors to the ditch-man. It is also entirely practicable to start and stop the motors at a considerable distance from the power house by means of remote control switches, and where electric pumps are used for the irrigation of comparatively small areas, the amount of water supplied can be automatically regulated, thereby reducing the amount of attention required by the motors to that entailed in a periodical cleaning and renewal of the lubrication.

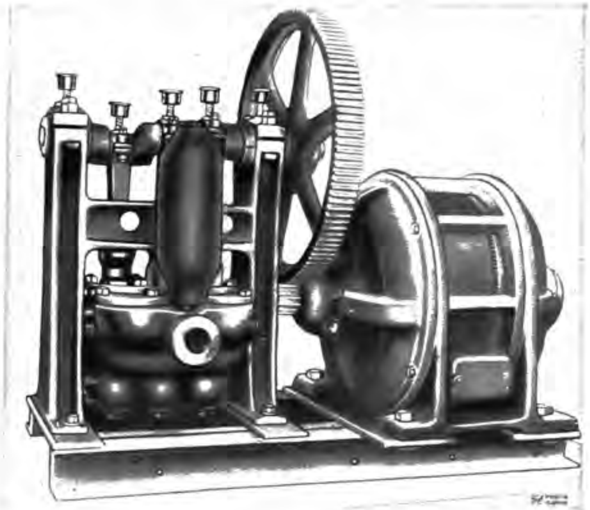
The motor-driven pump for irrigation work has been so successful that practically all recent developments along this line have adopted electric drive, since, in addition to the high efficiency of the motor-driven pumps while in operation, the energy consumption is in direct proportion to the work done, and the cost of attendance is minimized by the fact that all the work of this nature required, can usually be performed by a man ordinarily engaged in other work.

PUMPS FOR COFFER DAMS AND EXCAVATION WORK

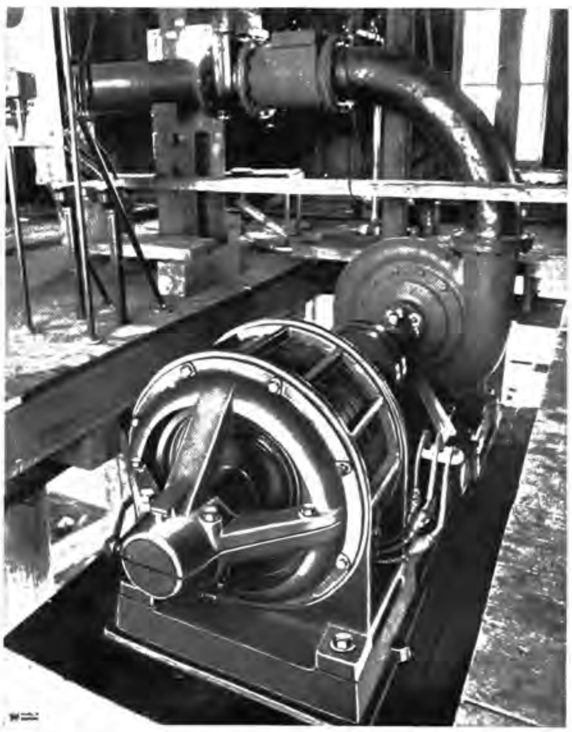
The use of pumps for intermittent service during the construction of coffer dams or for the drainage of excavations, is a very important factor in the amount of time required for the completion of work of this nature, and the fact that motor-driven pumping sets are comparatively light in weight and can be installed and operated by simply running temporary wires, frequently enables them to be used economically in positions where the use of engine-driven pumps could only be accomplished with extreme difficulty and by the use of expensive labor.

INDUSTRIAL PUMPS

For the operation of pumps which are used to move heavy liquids or semi-fluid material, the use of motor drive, with the uniform torque thereby developed, insures the operation of the pumps under these conditions with the maximum possible efficiency. In cases where pumps are required for the movement of inflammable liquids the use of the polyphase induction motor, which has no moving electrical contacts, will eliminate all danger from sparks and will insure the operation of the pumps under conditions of maximum safety. When electric drive is used in the operation of pumps handling acids or corrosive liquids, motors with special windings can be readily provided to minimize the deterioration, due to the destructive action of fumes or of contact with the liquid itself, or standard motors may be entirely enclosed and provided with an independent ventilating system. This latter system can also be applied in cases where motors have to operate under conditions involving abnormally high temperatures.



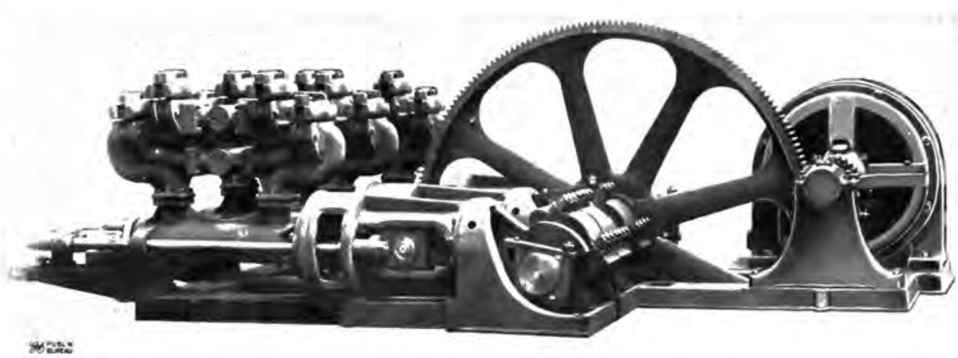
INDUCTION MOTOR GEARED TO TRIPLEX PUMP



150 H.P., 720 R.P.M. INDUCTION MOTOR DRIVING 12 IN. SINGLE-STAGE TURBINE CENTRIFUGAL PUMP, CAPACITY 5000 G.P.M., 70 FT. HEAD

BOILER FEED PUMPS

The question of the amount of space which is available for the installation of boiler feed pumps is frequently of considerable importance in modern power houses, and the fact that direct connected or back geared motor-driven pumps occupy less space for a given capacity than steam-driven pumps has resulted in their extensive use where electric current is available.



INDUCTION MOTOR OPERATING HIGH PRESSURE RECIPROCATING PUMP

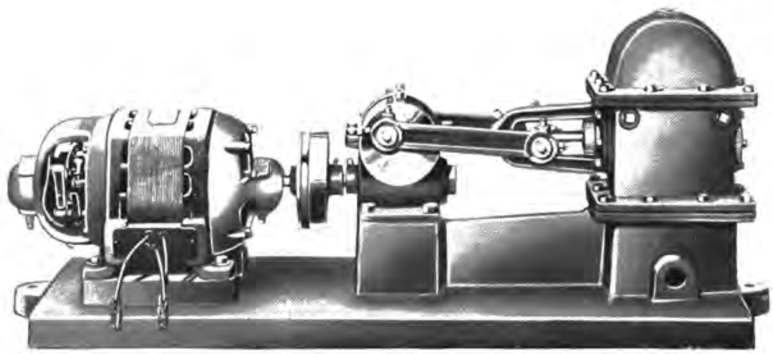
The multi-stage centrifugal pump direct connected to a high speed motor has an added advantage in that the high speed at which this type of pump may be operated permits the use of smaller sizes than would be practicable with other types.

In connection with condensers the uniform speed of the motor-driven centrifugal pump insures the maintenance of a steady flow of the condensing water which is constantly maintained regardless of fluctuations in the load on the main unit. Practically any pressure required for boiler feed may be obtained by the multiplication of the stages of motor-driven pumps operating at high speeds. Both pump and motor are simple in design and have few wearing parts, so that the cost for repairs, oiling and attendance is low in pumping sets of this type when compared with steam-driven pumps.

HYDRAULIC PRESSURE PUMPS

In equipping hydraulic pressure systems with motor for the pumps, the regulation of the pressure may be maintained within narrow limits by means of pressure switches which automatically start and stop the motor, and thereby tend to constantly compensate for loss of pressure or maintain it at any desired point.

The high speed and positive torque of the electric motor insure the instant response of the pumping set to variations of pressure, and the compensation for losses is therefore practically instantaneous.



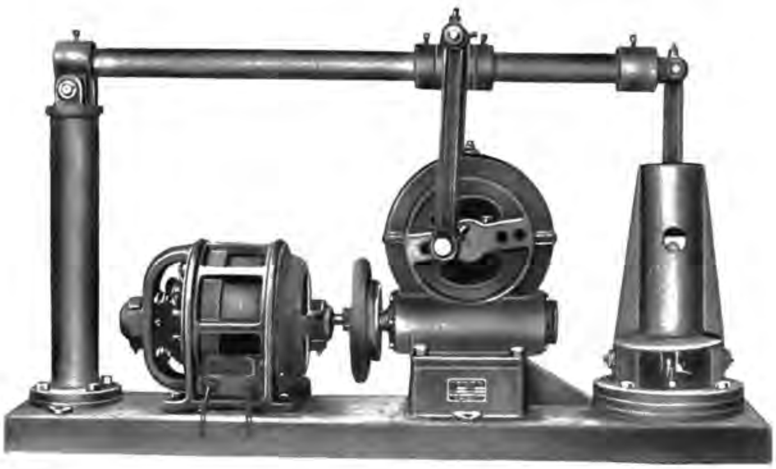
ALTERNATING CURRENT MOTOR CONNECTED TO HOUSE PUMP, SUITABLE FOR OPEN TANK OR PRESSURE TANK SYSTEM

HOUSE PUMPS

Perhaps the most numerous application of motor-operated pumps is found in the water supply systems of private and public buildings. The simplicity of motor-driven pumping sets and the ease with which they may be controlled by persons not experienced in the handling of machinery, render them particularly valuable for operation in buildings where the comparatively small volume of the water required would render the cost of engine-driven pumps prohibitive.

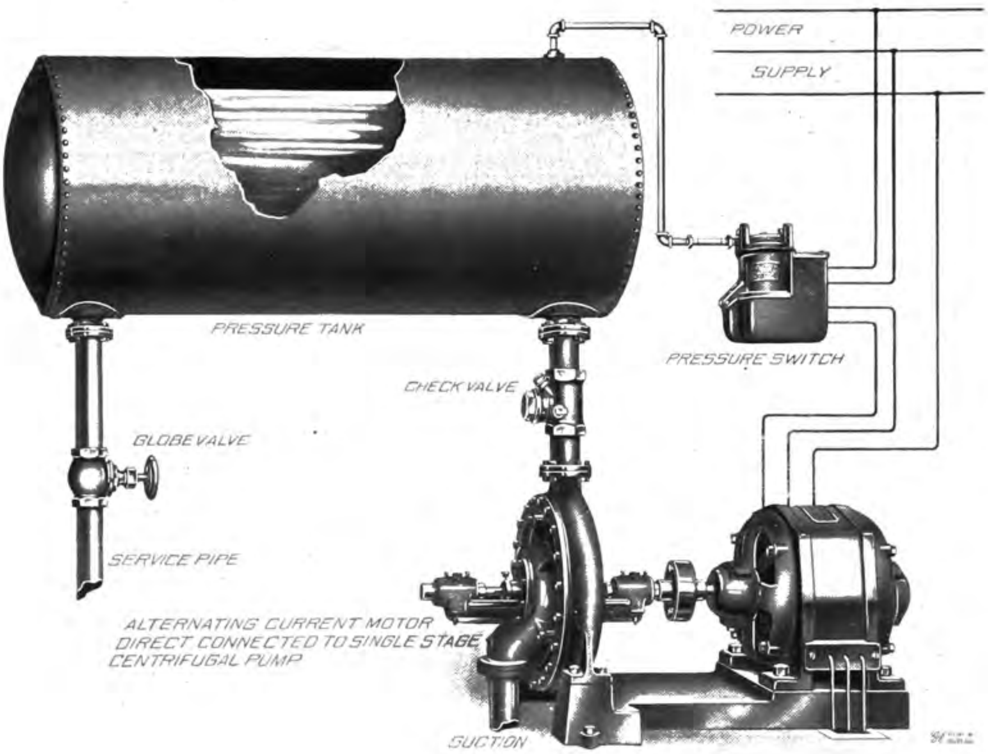
In office buildings and dwellings there is an added feature of value in that the use of motor drive does not develop obnoxious fumes or disseminate dust and soot which are unavoidable in the operation of engine-driven pumps. Finally, the ease with which the operation of the pumps may be made automatic renders the electric pump pre-eminent in this field.

There are three general systems of installation usually adopted for motor-driven house pumps: The first, known as the open tank system, where the water is pumped from a cistern or well into an open elevated tank, from which it flows by gravity to the different points at which it is to be used. For this system the motor-driven pump is simply used to fill the tank. The second system is similar to the above, except that the tank is automatically kept filled and, therefore, requires no attention. A copper ball floating upon the water in the tank controls the motor switch by means of a chain which actuates a switch; starting the pump as soon as the water in the tank has dropped to a predetermined point, and stopping the pump when a given high water level has been reached.

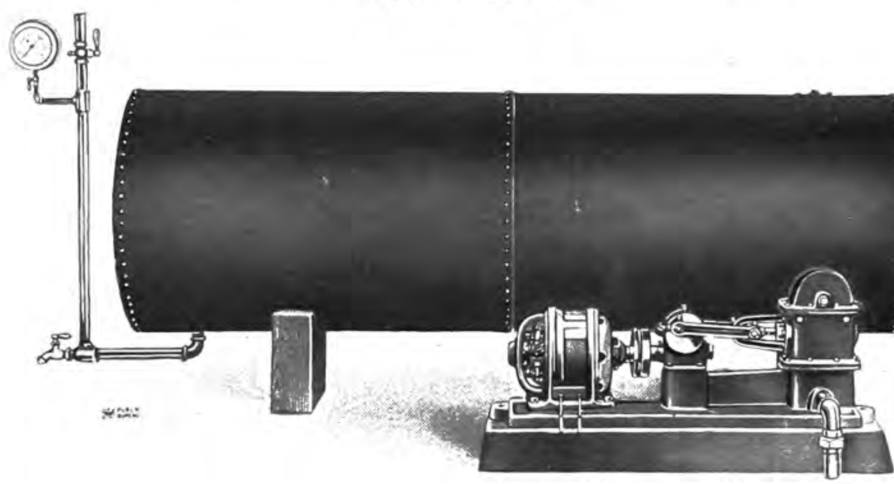


ALTERNATING CURRENT MOTOR DRIVING DEEP WELL PUMP HEAD

The third method includes the use of a closed pneumatic tank and the motor-driven pump is, in this case, automatically started and stopped by a pressure governor and switch combined, thereby maintaining the volume of water at a pre-determined point as in the second system. The pressure switch and the float switch are both designed to give positive action in closing and breaking the electric circuit, and can be adjusted so as to maintain the variation and volume of the water supplied within very close limits.



SINGLE-STAGE CENTRIFUGAL PUMP DRIVEN BY INDUCTION MOTOR WITH AUTOMATIC PRESSURE SWITCH



ALTERNATING CURRENT MOTOR DRIVING HOUSE PUMP IN CONNECTION WITH PRESSURE TANK SYSTEM

USEFUL DATA

The Unit of Specific Gravity, as given by Rankine is the weight of a cubic foot of distilled water at 39.1 deg. F. or 62.425 pounds. A more generally accepted standard today is its weight at 62 deg. F. or 62.355 pounds. For ordinary calculations, however, a cubic foot of fresh water is assumed to weigh 62½ pounds.

Ordinary Sea Water has a specific gravity of 1.026, and hence weighs 63.979, or approximately 64 pounds.

One United States Gallon contains 231 cubic inches, and weighs 8.330 pounds for fresh water, or 8.547 pounds for sea water. A United States gallon = 3.7854 liters; 1 liter = .2641 gallons.

One Imperial Gallon contains 277.274 cubic inches, and weighs 10.005 pounds for fresh water, or 10.266 pounds for sea water.

One Cubic Foot of Water (1728 cubic inches) contains 7.481 United States gallons, or 6.232 Imperial gallons.

A Miner's Inch is a more or less indefinite unit, depending on the locality, varying from 1.36 to 1.73 cubic feet per minute. The most common measurement, however, is through an aperture 2 inches high, and of any required length, through a plank 1¼ inches thick. The lower edge of the aperture should be 2 inches above the bottom of the measuring box, and the plank 5 inches high above the aperature, thus making a 6 inch head above the center of the aperture. Each square inch of this opening represents a miner's inch, which, under these conditions, will equal a flow of 1½ cubic feet per minute.

Pressure in Pounds per square inch of a column of water equals head in feet multiplied by 0.433.

Head in Feet of a column of water equals pressure in pounds per square inch multiplied by 2.30947.

One Atmosphere equals a pressure of 14.696 pounds per square inch, or a head of 33.94 feet of water, or 30 inches of mercury.

The Boiling Point of Water at mean atmospheric pressure (14.696 pounds per square inch) at sea level is 212 deg. F. At an absolute pressure of 6 pounds per square inch (17.70 inches of vacuum) this drops to 170.1 deg. F.; while at 3 pounds absolute (23.83 inches of vacuum), the boiling point is only 141.6 deg. F.

In Pumping Hot Water the suction head of the pump must be small as possible on account of lowering of the boiling point under high vacuum, and consequent loss of suction from the presence of vapor. Whenever possible, water should flow to pump suction.

Most Efficient Velocity of Flow in centrifugal pumps is from 10 to 12 feet per second.

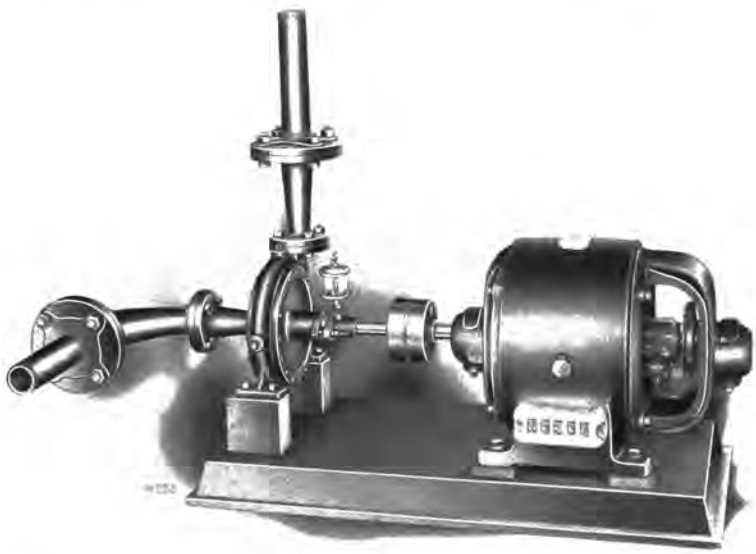
For Suction and Discharge Pipes maximum velocity of flow depends on friction produced. (See tables.

For Wooden Flumes Maximum Safe Velocity of Flow equals 7 or 8 feet per second.

For Earth Ditches Maximum Safe Velocity of Flow equals about 2 feet per second.

Water Horse Power, or useful work done in pumping, equals capacity in gallons per minute multiplied by total head in feet, and divided by 3,960. For sea water, add 2.6 per cent. to result.

A Column of Water One Foot High exerts a pressure of 0.433 pounds per square inch.



CENTRIFUGAL HOUSE PUMP DRIVEN BY DIRECT CURRENT MOTOR

THEORETICAL HORSE POWER REQUIRED TO RAISE WATER TO DIFFERENT HEIGHTS

Gallons per Min.	FEET ELEVATION										
	5	10	15	20	25	30	35	40	45	50	60
5	.006	.012	.019	.025	.031	.037	.044	.05	.06	.06	.07
10	.012	.025	.037	.050	.062	.075	.087	.10	.11	.12	.15
15	.019	.037	.056	.075	.094	.112	.131	.15	.17	.19	.22
20	.025	.050	.075	.100	.125	.150	.175	.20	.22	.25	.30
25	.031	.062	.093	.125	.156	.187	.219	.25	.28	.31	.37
30	.037	.075	.112	.150	.187	.225	.262	.30	.34	.37	.45
35	.043	.087	.131	.175	.219	.262	.306	.35	.39	.44	.52
40	.050	.100	.150	.200	.250	.300	.350	.40	.45	.50	.60
45	.056	.112	.168	.225	.281	.337	.394	.45	.51	.56	.67
50	.062	.125	.187	.250	.312	.375	.437	.50	.56	.62	.75
60	.075	.150	.225	.300	.375	.450	.525	.60	.67	.75	.90
75	.093	.187	.281	.375	.469	.562	.656	.75	.84	.94	1.12
90	.112	.225	.337	.450	.562	.675	.787	.90	1.01	1.12	1.35
100	125	.250	.375	.500	.625	.750	.875	1.00	1.12	1.25	1.50
125	.156	.312	.469	.625	.781	.937	1.094	1.25	1.41	1.56	1.87
150	.187	.375	.562	.750	.937	1.125	1.312	1.50	1.69	1.87	2.25
175	.219	.437	.656	.875	1.093	1.312	1.531	1.75	1.97	2.19	2.62
200	.250	.500	.750	1.000	1.250	1.500	1.750	2.00	2.25	2.50	3.00
250	.312	.625	.937	1.250	1.562	1.875	2.187	2.50	2.81	3.12	3.75
300	.375	.750	1.125	1.500	1.875	2.250	2.625	3.00	3.37	3.75	4.50
350	.437	.875	1.312	1.750	2.187	2.625	3.062	3.50	3.94	4.37	5.25
400	.500	1.000	1.500	2.000	2.500	3.000	3.500	4.00	4.50	5.00	6.00
500	.625	1.250	1.875	2.500	3.125	3.750	4.375	5.00	5.62	6.25	7.50

Gallons per Min.	FEET ELEVATION										
	75	90	100	125	150	175	200	250	300	350	400
5	.09	.11	.12	.16	.19	.22	.25	.31	.37	.44	.50
10	.19	.22	.25	.31	.37	.44	.50	.62	.75	.87	1.00
15	.28	.34	.37	.47	.56	.66	.75	.94	1.12	1.31	1.50
20	.37	.45	.50	.62	.75	.87	1.00	1.25	1.50	1.75	2.00
25	.47	.56	.62	.78	.94	1.09	1.25	1.56	1.87	2.19	2.50
30	.56	.67	.75	.94	1.12	1.31	1.50	1.87	2.25	2.62	3.00
35	.66	.79	.87	1.08	1.31	1.53	1.75	2.19	2.62	3.06	3.50
40	.75	.90	1.00	1.25	1.50	1.75	2.00	2.50	3.00	3.50	4.00
45	.84	1.01	1.12	1.41	1.69	1.97	2.25	2.81	3.37	3.94	4.50
50	.94	1.12	1.25	1.56	1.87	2.19	2.50	3.12	3.75	4.37	5.00
60	1.12	1.35	1.50	1.87	2.25	2.62	3.00	3.75	4.50	5.25	6.00
75	1.40	1.69	1.87	2.34	2.81	3.28	3.75	4.69	5.62	6.56	7.50
90	1.68	2.02	2.25	2.81	3.37	3.94	4.50	5.62	6.75	7.87	9.00
100	1.87	2.25	2.50	3.12	3.75	4.37	5.00	6.25	7.50	8.75	10.00
125	2.34	2.81	3.12	3.91	4.69	5.47	6.25	7.81	9.37	10.94	12.50
150	2.81	3.37	3.75	4.69	5.62	6.56	7.50	9.37	11.25	13.12	15.00
175	3.28	3.94	4.37	5.47	6.56	7.66	8.75	10.94	13.12	15.31	17.50
200	3.75	4.50	5.00	6.25	7.50	8.75	10.00	12.50	15.00	17.50	20.00
250	4.69	5.62	6.25	7.81	9.37	10.94	12.50	15.72	18.75	21.87	25.00
300	5.62	6.75	7.50	9.37	11.25	13.12	15.00	18.75	22.50	26.25	30.00
350	6.56	7.87	8.75	10.94	13.12	15.31	17.50	21.87	26.25	30.62	35.00
400	7.50	9.00	10.00	12.50	15.00	17.50	20.00	25.00	30.00	35.00	40.00
500	9.37	11.25	12.50	15.62	18.75	21.87	25.00	31.25	37.50	43.75	50.00

The theoretical horse power required to elevate water is found by multiplying the gallons pumped per minute by the total lift (including friction) in feet, and dividing by 4000. A close approximation of the actual horse power required for 100-foot lift is 1.7 times the theoretical; for 200-foot lift, 1.45 times; and for 300-foot lift, 1.3 times, for triplex pumps; for deep well pumps, double the theoretical power for safe estimates.

FRICTION OF WATER IN PIPES

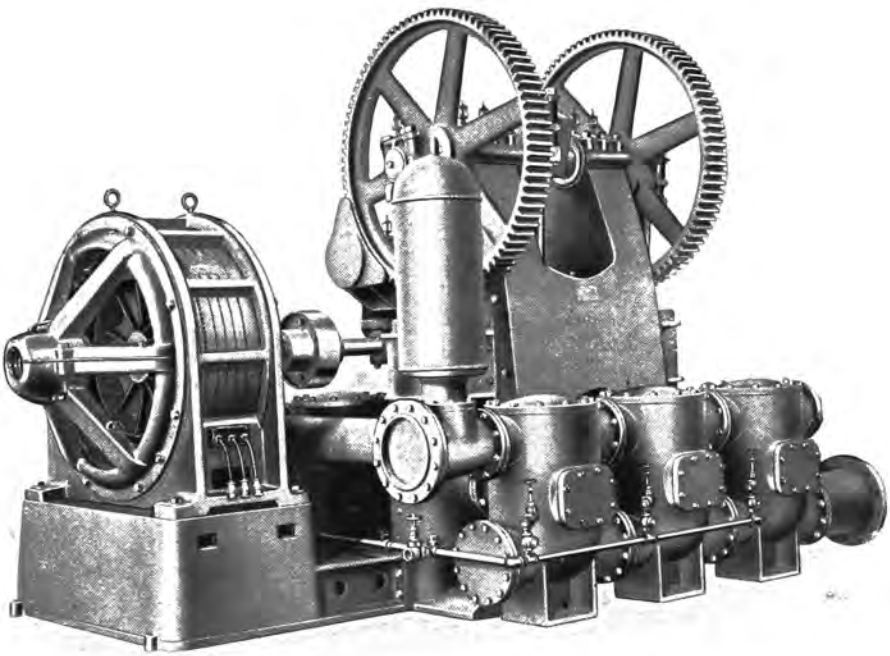
FRICTION LOSS IN POUNDS PRESSURE PER SQUARE INCH FOR EACH 100 FEET OF LENGTH IN DIFFERENT SIZE CLEAN IRON PIPE, DISCHARGING GIVEN QUANTITIES PER MINUTE

Gallons per Min.	SIZES OF PIPES—INSIDE DIAMETER																	
	¾ in.	1 in.	1¼ in.	1½ in.	2 in.	2½ in.	3 in.	4 in.	5 in.	6 in.	7 in.	8 in.	10 in.	12 in.	14 in.	16 in.	18 in.	20 in.
5	3.3	.84	.31	.12	.03	..	..	..	..	..	..	..	..	..	..	..	..	..
10	13.0	3.16	1.05	.47	.12	.03	..	..	..	..	..	..	..	..	..	..	..	..
15	28.7	6.98	2.38	.97	.27	.06	..	..	..	..	..	..	..	..	..	..	..	..
20	50.4	12.3	4.07	1.66	.42	.13	.03	..	..	..	..	..	..	..	..	..	..	..
25	78.0	19.0	6.40	2.62	.67	.21	.10	..	..	..	..	..	..	..	..	..	..	..
30	..	27.5	9.15	3.75	.91	.30	.12	.03	..	..	..	..	..	..	..	..	..	..
35	..	37.0	12.4	5.05	1.26	.42	.14	.05	..	..	..	..	..	..	..	..	..	..
40	..	48.0	16.1	6.52	1.60	.51	.17	.06	..	..	..	..	..	..	..	..	..	..
45	..	..	20.2	8.15	2.01	.62	.27	.07	..	..	..	..	..	..	..	..	..	..
50	..	..	24.9	10.0	2.44	.81	.35	.09	.03	..	..	..	..	..	..	..	..	..
75	..	..	56.1	22.4	5.32	1.80	.74	.21	.06	.03	..	..	..	..	..	..	..	..
100	..	..	..	39.0	9.46	3.20	1.31	.33	.12	.05	..	..	..	..	..	..	..	..
125	..	..	..	..	14.9	4.89	1.99	.51	.17	.07	..	..	..	..	..	..	..	..
150	..	..	..	..	21.2	7.0	2.85	.69	.25	.10	..	.02	..	..	..	..	..	..
175	..	..	..	..	28.1	9.46	3.85	.95	.34	.14	..	.03	..	..	..	..	..	..
200	..	..	..	..	37.5	12.47	5.02	1.22	.42	.17	.08	.05	.01	..	..	..	..	..
250	..	..	..	..	..	19.66	7.76	1.89	.65	.26	.13	.07	.03	.01	..	..	..	..
300	..	..	..	..	..	28.06	11.2	2.66	.93	.37	.18	.09	.04	..	..	..	..	..
350	..	..	..	..	..	..	15.2	3.65	1.28	.50	.25	.12	.05	.02	..	..	..	..
400	..	..	..	..	..	..	19.5	4.73	1.68	.65	.32	.16	.06	..	..	..	..	..
450	..	..	..	..	..	..	25.	6.01	2.10	.81	.42	.20	.07	.03	..	..	..	..
500	..	..	..	..	..	..	30.8	7.43	2.70	.96	.49	.25	.09	.04	.017	.009	.005	..
600	..	..	..	..	..	..	..	10.6	3.45	1.72	.86	.348	.13	.05	.024	..	..	..
750	..	..	..	..	..	..	..	..	5.40	2.21	1.11	.53	.18	.08	.038	..	..	..
1000	..	..	..	..	..	..	..	..	9.60	3.88	1.91	.94	.32	.13	.062	.036	.02	.012
1250	..	..	..	..	..	..	..	..	..	..	..	1.46	.49	.20	..	..	..	..
1500	..	..	..	..	..	..	..	..	..	..	..	2.09	.70	.29	.135	.071	.040	..
1750	..	..	..	..	..	..	..	..	..	..	..	..	.95	.38	..	..	..	..
2000	..	..	..	..	..	..	..	..	..	..	..	..	1.23	.49	.234	.123	.071	.042
2500	..	..	..	..	..	..	..	..	..	..	..	..	..	.77	.362	.188	.107	..

FRICTION OF WATER IN ELBOWS

DISCHARGING GIVEN QUANTITIES OF WATER PER MINUTE THROUGH DIFFERENT SIZE CLEAN ELBOWS. CALCULATED FROM WEISBACH'S FORMULA FOR SHORT BENDS WITH RADIUS EQUAL TO THE RADIUS OF THE PIPE

Gallons per Min.	SIZES OF ELBOWS																
	¾ in.	1 in.	1¼ in.	1½ in.	2 in.	2½ in.	3 in.	3½ in.	4 in.	5 in.	6 in.	7 in.	8 in.	10 in.	12 in.	14 in.	18 in.
5	.07	.027	.008	..	..	..	..	..	..	..	..	..	..	..	..	..	..
10	.28	.094	.031	..	..	..	..	..	..	..	..	..	..	..	..	..	..
15	.63	.212	.069	.04	..	..	..	..	..	..	..	..	..	..	..	..	..
20	1.12	.376	.123	.069	..	..	..	..	..	..	..	..	..	..	..	..	..
25	1.74	.585	.194	.108	.038	..	..	..	..	..	..	..	..	..	..	..	..
30	..	.845	.278	.157	.055	..	..	..	..	..	..	..	..	..	..	..	..
35	..	1.15	.380	.215	.076	.037	..	..	..	..	..	..	..	..	..	..	..
40	..	1.5	.495	.278	.098	.049	..	..	..	..	..	..	..	..	..	..	..
45	..	..	.626	.352	.125	.062	.026	..	..	..	..	..	..	..	..	..	..
50	..	..	.77	.43	.153	.08	.032	..	..	..	..	..	..	..	..	..	..
60	..	..	1.11	.62	.22	.112	.044	.026	.015	.006	..	..	..	..	..	..	..
70	..	..	1.52	.86	.304	.148	.06	.035	.021	.009	..	..	..	..	..	..	..
75	..	..	1.74	.98	.35	.172	.072	.04	.024	.01	..	..	..	..	..	..	..
80	..	..	1.98	1.11	.392	.196	.08	.044	.027	.012	..	..	..	..	..	..	..
90	..	..	..	1.45	.5	.248	.104	.06	.035	.014	..	..	..	..	..	..	..
100	..	..	..	..	.612	.32	.128	.068	.043	.017	.008	..	..	..	..	..	..
125	..	..	..	..	.97	.48	.2	.112	.067	.027	.013	..	..	..	..	..	..
150	..	..	..	..	1.39	.685	.286	.16	.096	.039	.019	.01	..	..	..	..	..
175	..	..	..	..	..	.935	.390	.218	.132	.053	.026	.014	..	..	..	..	..
200	..	..	..	..	..	1.28	.512	.272	.172	.068	.032	.02	..	..	..	..	..
250	..	..	..	..	..	..	.8	.446	.268	.109	.052	.029	.017	..	..	..	..
300	..	..	..	..	..	..	1.14	.64	.384	.156	.076	.042	.025	..	..	..	..
350	..	..	..	..	..	..	..	.88	.530	.215	.103	.057	.034	..	..	..	..
400	..	..	..	..	..	..	..	1.09	.688	.272	.128	.08	.044	..	..	..	..
450	..	..	..	..	..	..	..	..	.870	.352	.170	.094	.057	.023	..	..	..
500	..	..	..	..	..	..	..	..	1.07	.436	.208	.116	.068	.028	.016	..	..
750	..	..	..	..	..	..	..	..	..	.970	.470	.260	.156	.063	.031	..	..
1000	..	..	..	..	..	..	..	..	..	1.74	.832	.464	.272	.112	.064	.033	..
1100	..	..	..	..	..	..	..	..	..	..	1.045	.575	.329	.127	.063	.040	..
1250	..	..	..	..	..	..	..	..	..	..	1.31	.728	.435	.175	.086	.052	..
1500	..	..	..	..	..	..	..	..	..	..	..	.84	.624	.232	.124	.074	..
2000	..	..	..	..	..	..	..	..	..	..	..	..	1.055	.436	.205	.131	.50
2200	..	..	..	..	..	..	..	..	..	..	..	..	1.308	.513	.252	.159	.066
2500	..	..	..	..	..	..	..	..	..	.	..	.	1.68	.68	.327	.206	.078



125 H.P. INDUCTION MOTOR DRIVING 10 BY 12 IN. TRIPLEX PUMP

INFORMATION REQUIRED FOR ESTIMATES

It is essential in order to secure the most serviceable apparatus, that the following information be furnished. Conditions vary so much that preliminary proposals cannot be made until some idea of the work to be performed is available, but if the customer will give the information indicated, definite figures can be given promptly.

1. Source of water or other fluid:
2. Character of fluid, whether salt, fresh, clean, dirty, acid, etc.:
3. If solid matter is contained, state size and character of largest pieces:
4. Number of pumps required, and pumping capacity desired, in gallons per minute, per hour, or per day of 24 hours:
5. State whether the service will be continuous or intermittent:
6. Total head in feet to be pumped against
7. Suction lift, if any; also pressure on suction line, if any:
8. Length and diameter of discharge pipe, and number of turns:
9. Length and diameter of suction pipe and number of turns:
10. Character of electric supply, if direct current state voltage: if alternating current state voltage, phase and frequency:
11. Form of motor control desired, whether hand-operated, automatic, or if pump is to be controlled from a distance:
12. Type of pump desired, horizontal or vertical:
13. Will pump operate submerged? If not, state method available for priming:
14. GENERAL: Give information in regard to any working conditions which might influence the efficiency of the pumping set:

Name:

Address:

GENERAL ELECTRIC COMPANY

PRINCIPAL OFFICES, SCHENECTADY, N. Y.

SALES OFFICES

(Address nearest office)

BOSTON, MASS.	84 State Street
NEW YORK, N. Y.	30 Church Street
Rochester, N. Y.	Granite Building
Syracuse, N. Y.	Post-Standard Building
Buffalo, N. Y.	Ellicott Square Building
New Haven, Conn.	Malley Building
PHILADELPHIA, PA.	Witherspoon Building
Baltimore, Md.	Electrical Building
Charlotte, N. C.	Trust Building
Charleston, W. Va.	Charleston National Bank Building
Erie, Pa.	Marine National Bank Building
Pittsburg, Pa.	Oliver Building
Richmond, Va.	Mutual Building
ATLANTA, GA.	Empire Building
Birmingham, Ala.	Brown-Marx Building
Macon, Ga.	Grand Building
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Nashville, Tenn.	Stahlman Building
Indianapolis, Ind.	Traction Terminal Building
CHICAGO, ILL.	Monadnock Building
Detroit, Mich.	Majestic Building (Office of Soliciting Agent)
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Kansas City, Mo.	Dwight Building
Butte, Montana	Electric Building
Minneapolis, Minn.	410 Third Ave., North
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Spokane, Wash.	Paulsen Building

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Dallas, Tex.	Lamar & Caruth Sts.
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Oklahoma City, Okla.	Insurance Building

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Schenectady, N. Y., Foreign Dept.
New York, N. Y., 30 Church St.
London, E. C., England, 83 Cannon St.

For all CANADIAN Business refer to
Canadian General Electric Co., Ltd., Toronto, Ont.

General Electric Company
Schenectady, N.Y.
SUPPLY DEPARTMENT

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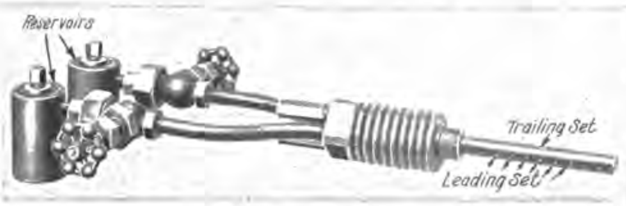
THE G.E. STEAM FLOW METER

The economical handling of steam like that of electricity, gas and other commodities depends on accurate information which will show the exact amount being generated, consumed or distributed.

Since the leading set of openings extends approximately across a diameter of the pipe, the velocity pressure transmitted to the meter is the mean velocity pressure due to the flow of the steam.



NOZZLE PLUG FOR STEAM FLOW METER

The G.E. recording and indicating steam flow meters provide a means for obtaining this information.

Principle of Operation and Description of the Nozzle Plug

If the temperature and pressure of the steam be constant, the rate of flow in a pipe will be proportional to the velocity. To measure this velocity, a nozzle plug is screwed into the pipe at the point where the steam flow is to be metered. One set of openings, known as the leading set, extends horizontally across the steam main and faces against the direction of flow. The other three openings near the center of the plug constitute the trailing set. The steam, impinging against the leading set of openings sets up a pressure in them which is equal to the static pressure plus a pressure due to the velocity head. The pressure in the trailing set is equal to the static pressure minus a pressure due to the velocity head.

The introduction of the nozzle plug in the steam main causes an inappreciable drop in pressure even at very high rates of flow. The nozzle plugs can be used interchangeably on either vertical or horizontal pipes.

Operation on Steady Flow

The meters are carefully calibrated, before leaving the factory, to operate under steady flow conditions, such as occur when supplying steam to steady flow turbines, heating systems, manufacturing processes, departments of a factory, etc.

For determining the steam output of boilers, the initial factory calibration of the meter will be correct if the nozzle plug is properly installed in the riser between a boiler and a header, no matter for what purpose the steam is used.

Operation on Periodically Intermittent Flow

The meters will accurately measure steam supplied to reciprocating engines, pumps, etc., provided the nozzle plug can be inserted in the steam main at a point where the flow is continuous; or, provided the meters can be recalibrated after being installed.

In recalibrating the meters for periodically intermittent flow, it is necessary to condense and weigh the steam and at the same time record the flow as indicated by the meter. In this way a correction curve can be obtained and applied to all future readings of the meter under the same conditions.

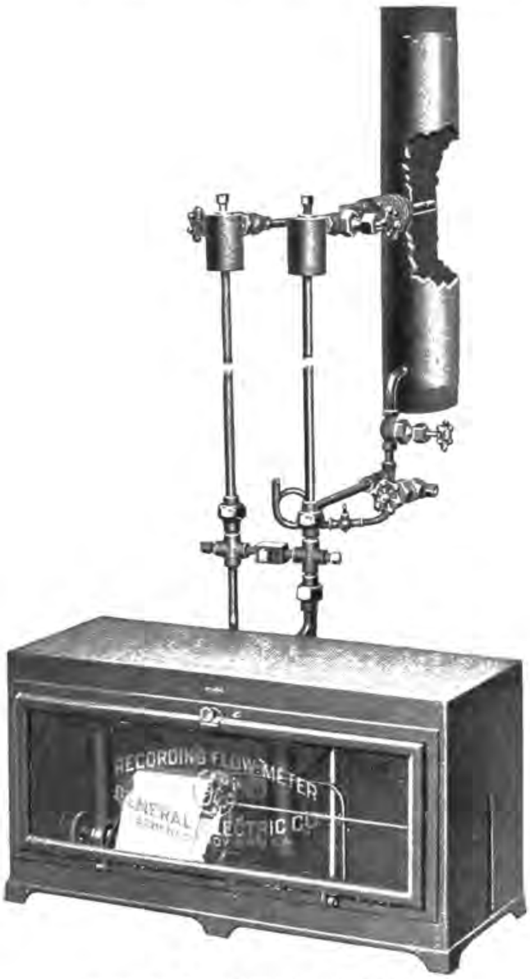
Units of Calibration

The G.E. steam flow meters are calibrated to read in pounds per hour. The readings obtained in these units may be reduced to equivalent boiler horse power by dividing by the proper constant.

Installation

To install the meters under normal conditions, the main steam piping is not interfered with whatsoever, it only being necessary to drill and tap a hole for inserting the nozzle plug in a straight vertical or horizontal run of pipe, at least 12 pipe diameters in length.

As there is no flow through the meters they always remain cool and can be placed in any desired position so long as they are below



TYPE RS RECORDING FLOW METER

the nozzle plugs to which they are connected by ¼ inch iron pipes filled with water.

G.E. RECORDING FLOW METER, TYPE RS, FOR MEASURING STEAM FLOW

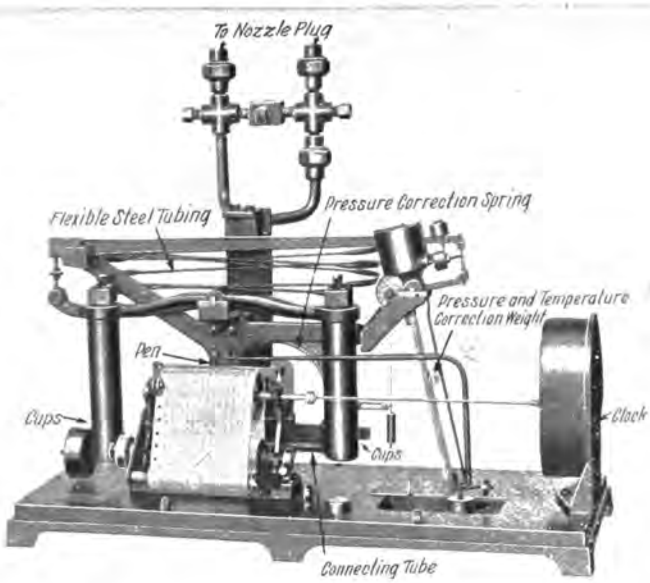
The G.E. recording flow meter, Type RS, is a curve drawing instrument giving an accurate record of the rate of flow of steam in pounds per hour.

Enabling determination of deterioration in efficiency of a boiler due to the formation of scale, etc.

Means of determining the efficiency in the method of stoking.

Description

The meter consists of two cylindrical hollow cups filled to about half their height



TYPE RS RECORDING FLOW METER WITH AUTOMATIC PRESSURE COMPENSATING DEVICE

Service for Which the Meter is Adapted

Recording the total amount of steam generated by a battery of boilers.

Recording the amount of steam delivered to any department of a manufacturing plant.

Recording the amount of steam sold for power, heating or manufacturing processes.

Enabling equalization of load on individual boilers of a battery.

Discovering losses originating from leaks between boilers and points of consumption; *e.g.*, defective traps, gaskets and valves, where the loss otherwise could not be detected.

Means of discovering internal leaks in boilers shown by difference in the water input and the steam output.

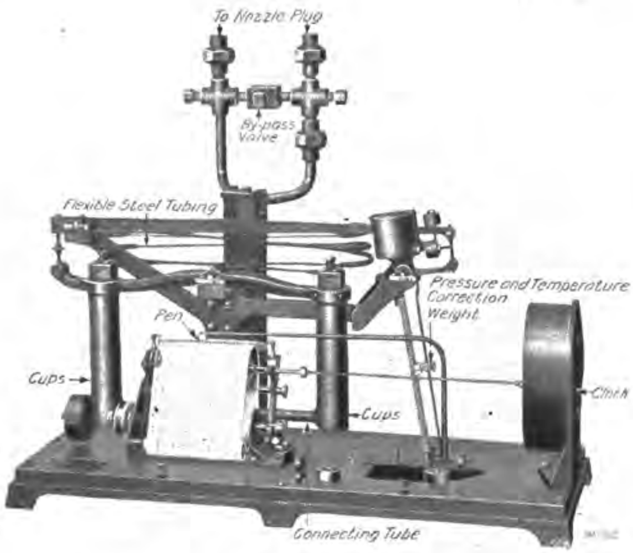
with mercury, and joined together at the bottom by a hollow tube. This arrangement of cups and connecting tube forms a "U" tube, which is supported on and free to move as a balance about a set of knife edges.

A difference of pressure in the nozzle plug is communicated to the cups by flexible steel tubing placed inside the case. This difference of pressure causes the mercury to rise in the left-hand cup and fall the same amount in the right-hand cup until the unbalanced columns of mercury exactly balance the difference in pressure.

By the displacement of the mercury, the beam carrying the cups moves downward on the left-hand side of the knife edges. This side will descend until the moment of the weights on the right of the knife edges exactly balances the moment caused by the displacement of the mercury into the left-hand cup. The motion of the beam is multiplied by levers and actuates the pen which moves in proportion to the amount of mercury displaced.

actual rate of flow in pounds per hour, it is necessary to compensate for pressure and temperature fluctuations.

Compensation is made automatically in the case of pressure variations. A hollow spring, similar to the pressure spring in a steam gauge, is connected so as to be influenced by the static pressure at the point



TYPE RS RECORDING FLOW METER WITHOUT AUTOMATIC PRESSURE COMPENSATING

where the flow is being measured. Any variation of the static pressure causes the spring to expand or contract, and this movement actuates a small correction weight in such a manner as to affect the deflection of the pen, so that the rate of flow recorded by the pen is correct for the pressure existing in the steam main at the point where the flow is being measured.

The time element of the meter consists of an eight day clock which drives the drum feeding the paper. The paper on which the record is made is so calibrated that the rate of flow in pounds per hour may be read at any instant or the average rate calculated for a given time.

Meters are equipped with a reroll device operated by a spring mechanism and this device is of sufficient capacity to accommodate one complete roll of paper.

Compensating Devices for Pressure and Superheat Variation

The velocity of the steam being measured may remain practically constant while the pressure and temperature vary over a considerable range. Therefore, to obtain the

Compensation for temperature variations is made by an independent hand adjustment of the same correction weight which corrects the reading for pressure fluctuations. This adjustment is made by increasing or decreasing the distance of the correction weight from its point of suspension and this distance is determined from a curve sent out with each meter.

Meters Suitable for Measuring Flow at Constant Pressure

In many stations, the temperature and pressure at which steam is delivered are held practically constant. To meet this condition, the recording flow meter will be furnished without the automatic pressure compensating device.

The meters can be adjusted by hand to give the true rate of flow at the existing pressure and temperature. If it is desired to measure the flow at any other temperature and pressure, the meter must be readjusted for these conditions. This adjustment is readily made by properly setting the compensating weight.

Flexibility of Operation

The Type RS meter may be used to measure the flow under normal conditions in any number of different pipe lines in the plant, it being necessary only to provide each pipe with a nozzle plug of the proper length to which plug the meter can be connected, and to place on the meter a chart of the proper range.

PRESSURE RANGE 25 TO 225 LB. GAUGE QUALITY RANGE 4 PER CENT. MOISTURE TO 260 DEG. F. SUPERHEAT

WITH AUTOMATIC PRESSURE CORRECTION DEVICE		WITHOUT AUTOMATIC PRESSURE CORRECTION DEVICE	
Cat. No.	Pipe Diam. in In.	Cat. No.	Pipe Diam. in In.
116151	2	116159	2
116152	3	116160	3
116153	4	116161	4
116154	6	116162	6
116155	8	116163	8
116156	10	116164	10
116157	12	116165	12
116158	14	116166	14

Cat. Nos. include meter complete with nozzle plug.

Meters can be furnished for pipes larger than 14 inches if desired.

Shipping weight 85 lb.

Paper Feeds

Meters are furnished with standard paper feed of three inches per hour, though one inch or six inches per hour feed can be supplied.

Finish

The interior and working parts of the meter are finished in dull black and nickel; the case is finished in dull black with glass front.

Weight

The meter weighs complete 55 lb.

Dimensions

23 in. by 9 in. by 13 in.

ADDITIONAL NOZZLE PLUGS FOR USE WITH THE TYPE RS RECORDING STEAM FLOW METER

Cat. No.	Diameter of Pipe in Inches
103541	2
103542	3
103543	4
103544	6
103545	8
103546	10
103547	12
103548	14

Cat. Nos. include two valves, two reservoirs and piping between nozzle plug and reservoirs.

Nozzle plugs can be furnished for pipes larger than 14 inches if desired.

Shipping weight 15 lb.

FLOW RANGE

The table on page 6 gives the maximum and minimum rates of flow in pounds per hour which can be *accurately* measured with different charts and at different pressures, and qualities, and in pipes of various diameters. If the existing steam pressure is other than that given in the table, the values for the maximum and minimum flow can be closely approximated by interpolation.

If the actual rate of flow of steam to be metered is more or less than can be accurately measured under the existing conditions of pressure, quality and pipe diameter, accurate results can be obtained by inserting in the steam line a section of pipe of greater or less diameter in which section the nozzle plug is installed. This section of pipe should be 12 pipe diameters or more in length.

FLOW RANGE TABLE

QUALITY OF STEAM—4 PER CENT. MOISTURE TO 80 DEG. F. SUPERHEAT

Pipe Diam. in Inches	STEAM PRESSURE — Flow in Pounds per Hour							
	50 Lb. Gauge		100 Lb. Gauge		150 Lb. Gauge		200 Lb. Gauge	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
2	2000	500	2000	500	2000	750	2000	750
					3000	750	3000	750
3	4000	1250	5000	1250	6000	2000	8000	2500
	5000	1250	6000	1250	8000	2000	10000	2500
4	6000	2500	10000	3000	10000	4000	12000	4000
	8000	2500	12000	3000	12000	4000	16000	4000
	10000	2500			16000	4000		
6	16000	5000	20000	6000	24000	7500	30000	10000
	20000	5000	24000	6000	30000	7500	40000	10000
8	30000	10000	40000	12500	50000	15000	50000	15000
	40000	10000	50000	12500	60000	15000	60000	15000
10	40000	15000						
	50000	15000	60000	20000	80000	25000	80000	25000
	60000	15000	80000	20000	100000	25000	100000	25000
12	60000	20000	100000	30000	100000	30000	120000	40000
	80000	20000	120000	30000	120000	30000	160000	40000
14	80000	30000	120000	40000	120000	40000	160000	50000
	100000	30000	160000	40000	160000	40000	200000	50000
	120000	30000						

QUALITY OF STEAM—80 DEG. F. SUPERHEAT TO 200 DEG. F. SUPERHEAT

Pipe Diam. in Inches	50 Lb. Max.	50 Lb. Min.	100 Lb. Max.	100 Lb. Min.	150 Lb. Max.	150 Lb. Min.	200 Lb. Max.	200 Lb. Min.
2	2000 *	500	2000	500	3000	750	3000	750
3	4000	1250	5000	1500	6000	1500	6000	2000
	5000	1250	6000	1500			8000	2000
4	6000	2000	8000	2500	10000	3000	12000	4000
	8000	2000	10000	2500	12000	3000	16000	4000
6	16000	5000	20000	6000	24000	7500	24000	7500
	20000	5000	24000	6000	30000	7500	30000	7500
8	30000	7500	40000	10000	40000	12500	50000	15000
					50000	12500	60000	15000
10	40000	12500	50000	15000	60000	20000	80000	25000
	50000	12500	60000	15000	80000	20000	100000	25000
12	60000	20000	80000	25000	100000	30000	100000	30000
	80000	20000	100000	25000	120000	30000	120000	30000
14	80000	25000	100000	30000	120000	40000	160000	50000
	100000	25000	120000	30000	160000	40000	200000	50000

* Special compensating weight necessary.

NOTE.—By using a special compensating weight the maximum flow ranges given in this table may be increased from 2 to 35 per cent. without changing the main steam piping.

G.E. INDICATING FLOW METER, TYPE TS

The Type TS flow meter will meet general commercial requirements where an indicating rather than a recording instrument is desired. Owing to its simplicity of construction and flexibility of operation it will be found especially useful for testing work, locating troubles due to leaks, etc.

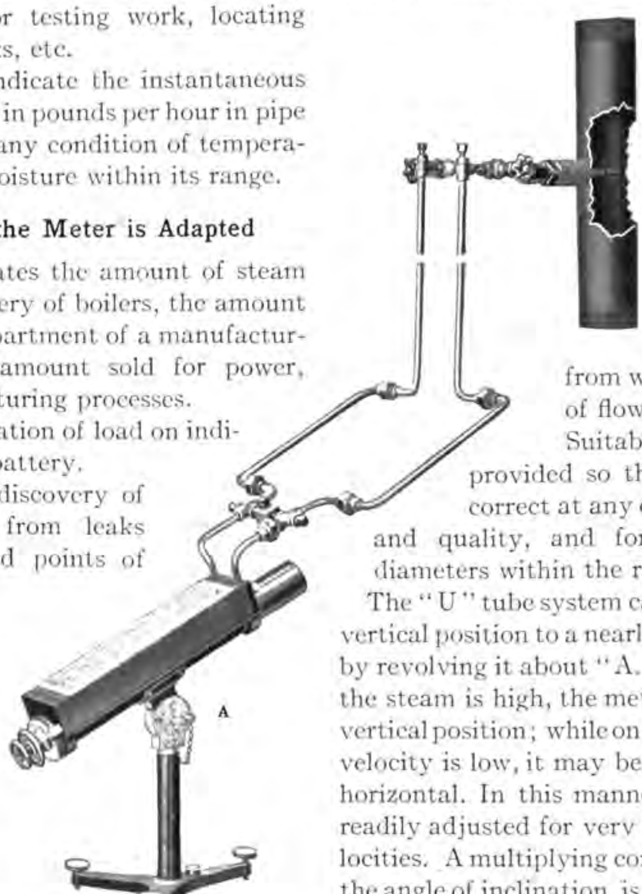
The meter will indicate the instantaneous rate of flow of steam in pounds per hour in pipe of any diameter at any condition of temperature, pressure, or moisture within its range.

Service for Which the Meter is Adapted

This meter indicates the amount of steam generated by a battery of boilers, the amount delivered to any department of a manufacturing plant, or the amount sold for power, heating or manufacturing processes.

It enables equalization of load on individual boilers of a battery.

It leads to the discovery of losses originating from leaks between boilers and points of consumption; *e.g.*, defective traps, gaskets and valves, where the loss otherwise could not be detected.



TYPE TS INDICATING FLOW METER

It affords a means of discovering internal leaks in boilers shown by the difference between water input and steam output.

It enables the determination of deterioration in efficiency of a boiler due to the formation of scale, etc.

It forms a means of determining the efficiency in the method of stoking.

Description

The meter consists of a "U" tube with glass legs, which are filled for part of their height with mercury. Located centrally with respect to the glass tube is a cylindrical chart from which is read the rate of flow in pounds per hour. Suitable auxiliary scales are provided so that the indication is correct at any condition of pressure and quality, and for pipes of various diameters within the range of the meter.

The "U" tube system can be inclined from a vertical position to a nearly horizontal position by revolving it about "A." If the velocity of the steam is high, the meter may be set in the vertical position; while on the other hand, if the velocity is low, it may be inclined toward the horizontal. In this manner the meter can be readily adjusted for very high or very low velocities. A multiplying constant, depending on the angle of inclination, is applied to the observation taken from the cylindrical chart.

The two legs of the "U" tube are connected with the two series of openings in the nozzle plug. There are no moving parts exposed to the fluid being metered, and consequently no wear or friction to be overcome. No foundation is necessary, as the meter is provided with leveling screws so that it may be mounted on any approximately level surface.

Method of Making Observation

After the meter has been filled and the piping connected, the level is adjusted and the steam turned on. It remains only to adjust the meter for the proper pipe diameter where the nozzle plug is inserted and for the pressure and temperature of the steam. This is done by rotating the inner handwheel at the lower end of the meter. The two sights are set to coincide with the meniscuses of the mercury in the glass "U" tube. The indication of the movable pointer on the chart multiplied by a constant depending upon the inclination of the meter from the vertical is the rate of flow in pounds per hour per square inch of pipe cross section.

Flexibility of Operation

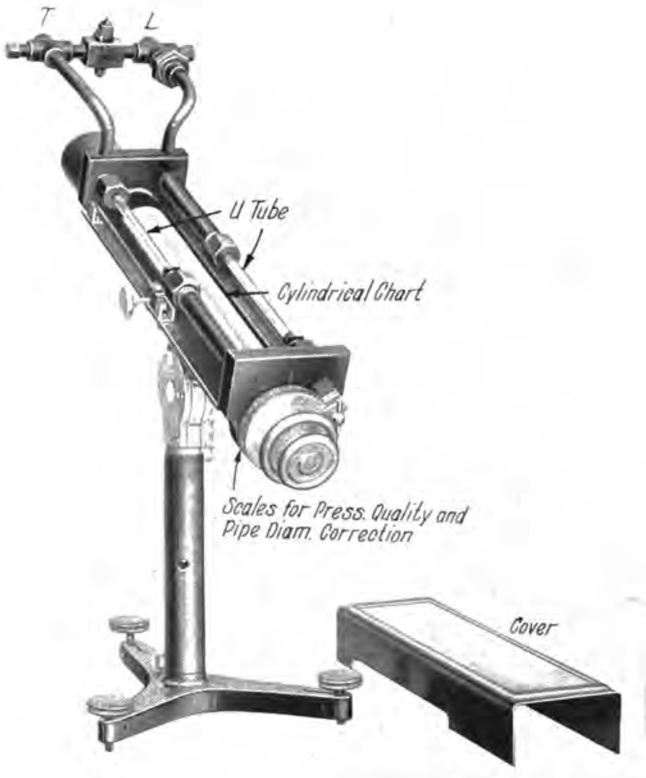
The Type TS meter may be used to measure the flow under normal conditions in any number of different pipe lines in the plant, all that is necessary being to provide the pipe with a nozzle plug of the proper length to which plug the meter can be connected. Its pressure, quality, pipe diameter, and flow range, together with its extreme simplicity, recommend this type of meter for general testing work.

Finish

The meter is finished in black japan and nickel.

Weight

The meter weighs complete 45 lb.



TYPE TS INDICATING FLOW METER

***PRESSURE RANGE, 75 TO 225 LB. GAUGE
QUALITY RANGE, 4 PER CENT. MOISTURE
TO 260 DEG. F. SUPERHEAT**

Cat. No.	Diameter of Pipe in Inches	Cat. No.	Diameter of Pipe in Inches
108198	2	108202	8
108199	3	108203	10
108200	4	108204	12
108201	6	108205	14

*If it is desired to operate the meter at pressures less than 75 lb. gauge, a correction curve will be furnished which will give the meter a pressure range of 0 to 225 lb. gauge.

Cat. Nos. include meter complete with nozzle plug.

Meters can be furnished for pipes larger than 14 inches if desired.

Shipping weight 70 lb.

ADDITIONAL NOZZLE PLUGS FOR USE WITH THE TYPE TS INDICATING FLOW METER

Cat. No.	Diameter of Pipe in Inches
103565	2
103566	3
103567	4
103568	6
103569	8
103570	10
103571	12
103572	14

Cat. Nos. include two valves, two tees and piping between tees and nozzle plugs. No reservoirs are necessary.

Nozzle plugs can be furnished for pipes larger than 14 inches in diameter if desired.

Shipping weight 15 lb.

FLOW RANGE

The following table gives the maximum and minimum rates of flow in pounds per hour which can be *accurately* measured at different pressures and qualities, and in pipes of various diameters. If the existing steam pressure is other than that given in the table, the values for the maximum and minimum flow can be closely approximated by interpolation.

If the actual rate of flow of steam to be metered is more or less than can be accurately measured under the existing conditions of pressure, quality and pipe diameter, accurate results can be obtained by inserting in the steam line a section of pipe of greater or less diameter in which section the nozzle plug is installed. This section of pipe should be 12 pipe diameters or more in length.

FLOW RANGE TABLE

QUALITY OF STEAM—4 PER CENT. MOISTURE TO 80 DEG. F. SUPERHEAT

Pipe Diam. in Inches	STEAM PRESSURE — Flow in Pounds per Hour: 2 Lb. Gauge		25 Lb. Gauge		50 Lb. Gauge		100 Lb. Gauge		150 Lb. Gauge		200 Lb. Gauge	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
2	1840 *	235 *	3000 *	385 *	3860 *	495 *	5090 *	660 *	6130	785	6990	942
3	4830 *	585 *	7900 *	955 *	10150 *	1230 *	13400	1770	16100	1950	18200	2100
4	8700 *	1040 *	14200 *	1700 *	18300 *	2190 *	24200	3150	29000	3470	33100	2300
6	19800 *	2340 *	32300 *	3820 *	41500 *	4900 *	55200	7080	65800	7800	75000	9200
8	35100 *	4170 *	57300 *	6820 *	73800 *	8760 *	98300	12600	117000	13900	133600	16400
10	55000 *	6500 *	90000 *	10600 *	115000 *	13700 *	153700	19700	183300	21700	209000	25600
12	79500 *	9300 *	130000 *	15300 *	167000 *	19700 *	222000	28300	265000	31200	303000	36800
14	108000 *	12700 *	176000 *	20800 *	227000 *	26700 *	303000	38500	360000	42400	412000	50000

QUALITY OF STEAM—80 DEG. F. SUPERHEAT TO 200 DEG. F. SUPERHEAT

2	1700 *	227 *	2780 *	370 *	3580 *	476 *	4720 *	627 *	5680 *	755 *	6360	854
3	4350 *	531 *	7100 *	870 *	9140 *	1120 *	12050 *	1470 *	14500	1770	16600	1950
4	7950 *	945 *	13000 *	1545 *	16700 *	1990 *	22000 *	2620 *	26500	3150	30000	3780
6	18000 *	2130 *	29300 *	3470 *	37700 *	4460 *	49600 *	5880 *	59800	7080	68000	8500
8	32100 *	3788 *	52500 *	6180 *	67400 *	7950 *	88800 *	10500 *	107000	12600	122000	15100
10	50300 *	5910 *	82200 *	9660 *	105500 *	12400 *	139000 *	16400 *	167500	19700	190000	27700
12	72300 *	8500 *	118000 *	13900 *	152000 *	17850 *	200000 *	23500 *	241000	28300	275000	34000
14	101000 *	11550 *	165000 *	18900 *	212000 *	24200 *	280000 *	32000 *	337000	38500	384000	46200

* Values are obtained by applying to the meter readings a constant derived from a correction curve.

G.E. INDICATING FLOW METER, TYPE FS

The Type FS meter is designed to meet the demand for a moderate priced indicating instrument for general testing work at normal velocities of steam flow.

This meter will indicate the instantaneous rate of flow of steam in pounds per hour in a pipe of any diameter and at any condition of temperature, pressure, or moisture within its range.

TYPE FS INDICATING FLOW METER

Service for Which the Meter is Adapted

The same results can be obtained with this meter as with the Type TS provided the rate of flow is within the accurate operating range of the meter.

Description

The meter consists of an iron casting which is cored out to form a "U" tube. This is filled for part of its height with mercury. (See Fig. A.) A difference of pressure in the nozzle plug causes a difference in level of the mercury in the "U" tube. A small float suspended by a silk cord actuates a pulley over which the cord passes. The pulley in turn moves a small magnet on the end of the shaft next to the dial in proportion to the change in level of the mercury in the "U" tube. (See Fig. A.)

The indicating needle is mounted in a separate cylindrical casing. This needle carries another magnet which is free to turn in the same plane as the magnet on the inside of the meter. The mutual attraction of these two magnets keeps them always parallel and the necessity of a packed joint in transmitting the motion of the pulley to the indicating needle is thus eliminated.

A by-pass valve is provided to prevent blowing out the mercury by excessive pressure in either leg of the "U" tube.

The piping, reservoirs and nozzle plugs are of the same general design as those used with the recording meter.

Method of Making Observations

The proper adjustments for pipe diameter, temperature, and pressure are readily made by setting the graduated cylinders (see Fig. A) which actuate the rack carrying the pointer. When these settings are made the rack is rotated by hand until the pointer coincides with the indicating needle. The point on the graduated scale at the intersection of the needle and pointer gives the true instantaneous rate of flow in pounds per hour per square inch of pipe cross section.

If the temperature and pressure of the steam remain practically constant, only a single adjustment of the graduated cylinders is necessary for making observations.

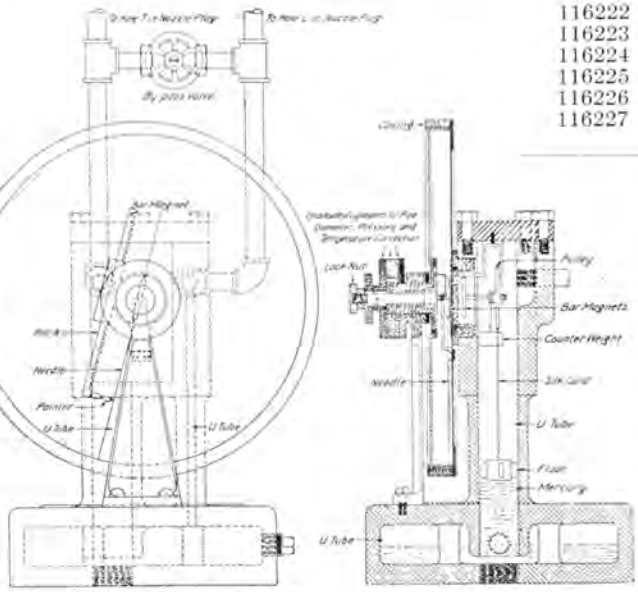


Fig. A—TYPE FS INDICATING FLOW METER

Flexibility of Operation

The Type FS meter may be used to measure the flow under normal conditions in any number of pipe lines in the plant; it being necessary only to provide the pipe with a nozzle plug of the proper length to which plug the meter can be connected. Since the meter is light and compact, it can be easily carried about and used as a portable instrument.

Finish

The meter is finished in black japan and nickel.

Weight

The meter weighs complete 25 lb.

G.E. INDICATING FLOW METER, TYPE FS, FOR MEASURING STEAM FLOW

CAT. NO.			
Low Pressure	Medium Pressure	High Pressure	
Steam Pressure Range 10 to 40 Lb. Abs. Quality Range 4% Moisture to 260° F. Superheat	Steam Pressure Range 20 to 80 Lb. Gauge Quality Range 4% Moisture to 260° F. Superheat	Steam Pressure Range 75 to 225 Lb. Gauge Quality Range 4% Moisture to 260° F. Superheat	Diameter of Pipe in Inches
116220	116228	116236	2
116221	116229	116237	3
116222	116230	116238	4
116223	116231	116239	6
116224	116232	116240	8
116225	116233	116241	10
116226	116234	116242	12
116227	116235	116243	14

Cat. Nos. include meter complete with nozzle plug.

Meters can be furnished for pipes larger than 14 inches if desired.

Shipping weight 40 lb.

ADDITIONAL NOZZLE PLUGS FOR USE WITH TYPE FS INDICATING FLOW METER

Cat. No.	Diameter of Pipe in Inches
103549	2
103550	3
103551	4
103552	6
103553	8
103554	10
103555	12
103556	14

Cat. Nos. include two valves, two reservoirs and piping between nozzle plug and reservoirs.

Nozzle plugs can be furnished for pipes larger than 14 inches in diameter if desired.

Shipping weight 15 lb.

FLOW RANGE

The following table gives the maximum and minimum rates of flow in pounds per hour which can be *accurately* measured at different pressures and qualities, and in pipes of various diameters. If the existing steam pressure is other than that given in the table, the values for the maximum and minimum flow can be closely approximated by interpolation.

If the actual rate of flow of steam to be metered is more or less than can be accurately measured under the existing conditions of pressure, quality and pipe diameter, accurate results can be obtained by inserting in the steam line a section of pipe of greater or less diameter in which section the nozzle plug is installed. This section of pipe should be 12 pipe diameters or more in length.

FLOW RANGE TABLE

LOW PRESSURE

QUALITY OF STEAM—4 PER CENT. MOISTURE TO 80 DEG. F. SUPERHEAT

Pipe Diam. in Inches	STEAM PRESSURE 10 Lb. Abs.		20 Lb. Abs.		30 Lb. Abs.		40 Lb. Abs.	
	Flow in Pounds per Hour							
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
2	304 *	210 *	475	320	585	400	680 *	465 *
3	795 *	525 *	1250	800	1530	1000	1780 *	1160 *
4	1450 *	940 *	2290	1440	2800	1800	3260 *	2100 *
6	3250 *	2100 *	5150	3200	6250	4000	7260 *	4650 *
8	5800 *	3780 *	9150	5750	11150	7200	13000 *	8380 *
10	9100 *	5880 *	14300	8950	17500	11200	20400 *	13000 *
12	13100 *	8400 *	20350	12800	25250	16000	29400 *	18600 *
14	17700 *	11600 *	28100	17600	34200	22000	39800 *	25600 *

QUALITY OF STEAM—80 DEG. SUPERHEAT TO 200 DEG. SUPERHEAT

Pipe Diam. in Inches	10 Lb. Abs. Max.	10 Lb. Abs. Min.	20 Lb. Abs. Max.	20 Lb. Abs. Min.	30 Lb. Abs. Max.	30 Lb. Abs. Min.	40 Lb. Abs. Max.	40 Lb. Abs. Min.
2	278 *	190 *	430	290	535	360	610	420
3	720 *	475 *	1140	725	1390	900	1600	1050
4	1310 *	850 *	2060	1300	2520	1620	2900	1890
6	2950 *	1900 *	4650	2900	5680	3600	6530	4200
8	5250 *	3420 *	8250	5230	10100	6480	11600	7550
10	8200 *	5320 *	12900	8130	15800	10100	18200	11800
12	11900 *	7600 *	18700	11600	22900	14400	26250	16800
14	16100 *	10500 *	25400	16000	31100	19800	36600	23100

MEDIUM PRESSURE

QUALITY OF STEAM—4 PER CENT. MOISTURE TO 80 DEG. F. SUPERHEAT

Pipe Diam. in Inches	STEAM PRESSURE 20 Lb. Gauge		35 Lb. Gauge		50 Lb. Gauge		80 Lb. Gauge	
	Flow in Pounds per Hour							
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
2	1100 *	433 *	1300 *	520 *	1490	590	1800	715
3	2900 *	1090 *	3420	1300	3900	1490	4750	1790
4	5230 *	1950 *	6200	2330	7060	2680	8560	3220
6	11850 *	4330 *	14100	5180	16100	5900	19400	7150
8	21000 *	7800 *	25000	9330	28500	10700	34500	12900
10	33000 *	12200 *	39200	14500	44700	16700	54200	20000
12	47500 *	17400 *	56500	20750	64300	23800	78000	28600
14	64500 *	23800 *	77000	28500	87600	32800	106000	39400

QUALITY OF STEAM—80 DEG. F. SUPERHEAT TO 200 DEG. F. SUPERHEAT

Pipe Diam. in Inches	20 Lb. Gauge Max.	20 Lb. Gauge Min.	35 Lb. Gauge Max.	35 Lb. Gauge Min.	50 Lb. Gauge Max.	50 Lb. Gauge Min.	80 Lb. Gauge Max.	80 Lb. Gauge Min.
2	990 *	370 *	1180 *	470 *	1340 *	535 *	1630	650
3	2620 *	925 *	3100	1170	3560	1340	4300	1630
4	4720 *	1670 *	5620	2100	6370	2420	7750	2930
6	10700 *	3700 *	12700	4700	14500	5350	17600	6500
8	19000 *	6650 *	22500	8430	25700	9650	31200	11700
10	29800 *	10350 *	35300	13100	40400	15000	49000	18200
12	43000 *	14800 *	50900	18700	58100	21400	70600	26000
14	58500 *	20400 *	69100	25700	79100	29500	96100	35800

FLOW RANGE TABLE (Cont'd)

HIGH PRESSURE

QUALITY OF STEAM—4 PER CENT. MOISTURE TO 80 DEG. F. SUPERHEAT

Pipe Diam. in Inches	STEAM PRESSURE — Flow in Pounds per Hour							
	75 Lb. Gauge		125 Lb. Gauge		175 Lb. Gauge		225 Lb. Gauge	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
2	2870 *	700 *	3580 *	870 *	4150	1000	4680	1150
3	7450 *	1750 *	9350	2200	10800	2500	12200	2800
4	13600 *	3150 *	17000	3920	19800	4500	22300	5050
6	30800 *	7000 *	38300	8700	44800	10000	50500	11300
8	54700 *	12600 *	68000	15700	79500	18000	89500	20300
10	86000 *	19600 *	106500	24400	124500	28000	140000	31600
12	123500 *	28000 *	155000	34900	180000	40000	203000	45000
14	167000 *	38500 *	209000	48000	243000	55000	275000	62000

QUALITY OF STEAM—80 DEG. F. SUPERHEAT TO 200 DEG. F. SUPERHEAT

Pipe Diam. in Inches	75 Lb. Max.	75 Lb. Min.	125 Lb. Max.	125 Lb. Min.	175 Lb. Max.	175 Lb. Min.	225 Lb. Max.	225 Lb. Min.
2	2600 *	630 *	3230 *	790 *	3770	920	4240	1050
3	6800 *	1580 *	8450	1980	9850	2300	11100	2550
4	12400 *	2840 *	15400	3560	17900	4150	20300	4600
6	28000 *	6300 *	34800	7900	40600	9200	45700	10500
8	49900 *	11400 *	61700	14300	72000	16500	81000	18400
10	78000 *	17700 *	97000	22200	113000	25700	127000	28600
12	113000 *	25200 *	140000	31700	164000	36600	184000	41000
14	153000 *	34700 *	190000	43500	222000	50500	249000	56200

* Values are obtained by applying to the meter readings a constant derived from a correction curve.

When Ordering Recording Steam Flow Meters, Type RS or Indicating Steam Flow Meters, Types TS or FS Always Give the Following Information:

Cat Nos. of meters desired.

Cat. Nos. of additional nozzle plugs desired.

Approximate maximum steam flow in pounds per hour through each pipe to be metered.

For what purpose is steam in each pipe metered used?

What is the maximum and minimum pressure in pounds gauge?

Continuous Flow Conditions

If steam is used for continuous flow conditions, heating systems or manufacturing processes, etc., can the nozzle plug be placed in a straight vertical or horizontal run of pipe at least 12 pipe diameters in length?

Periodically Intermittent Flow Conditions

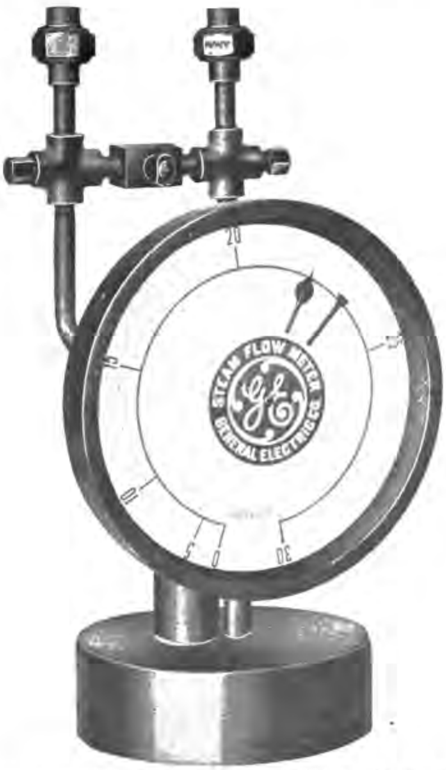
If the steam is to be used for engines, send a simple sketch showing the plan and elevation with dimensions of piping, including all branch mains, from engine to boilers.

G.E. INDICATING STEAM FLOW METER, TYPE FS2

The G.E. indicating steam flow meter, Type FS2, will show in pounds per hour or boiler horse power the amount of steam being generated at any instant by a boiler or battery of boilers; and this information is essential to secure high efficiencies and economical results.

Service for Which the Meter is Adapted

This meter indicates the total amount of steam generated by a boiler or battery of boilers in either pounds per hour or boiler horse power.



INDICATING STEAM FLOW METER, TYPE FS2

It enables the equalization of load on individual boilers or batteries.

It is a means of determining the efficiency in the method of stoking or correct feed water regulation.

It enables the determination of deterioration in efficiency of a boiler due to the formation of scale, etc.

It affords a means of discovering internal leaks in boilers shown by difference in the water input and steam output.

It indicates the amount of steam distributed to different departments of a manufacturing plant or amount used in various processes of manufacture.

Units of Calibration

The Type FS2 meter will be calibrated in pounds per hour or boiler horse power, whichever is preferred, for a given condition of pipe diameter, pressure and quality. It cannot be used on pipe of any other diameter or for any other pressure or quality than that for which it is calibrated.

If the meter is calibrated in boiler horse power the unit will be taken to represent 30 pounds of steam per hour.

Installation

To install the meter under normal conditions the steam piping is not interfered with whatsoever; it being necessary only to drill and tap a small hole for inserting the nozzle plug in a straight vertical or horizontal run of pipe at least 12 pipe diameters in length.

The meter may be located in any desired position so long as it is below the nozzle plug to which it is connected by 1/4 inch iron pipe filled with water. The distance between the nozzle plug and the meter is immaterial. A good location for the meter is on the front of the boiler near the steam gauge, or in any other conspicuous place, where it can be readily seen by the fireman or engineer.

DESCRIPTION OF THE METER

Body

The body of the meter consists of an iron casting which is cored out so as to form one leg and well of a U tube, the other leg of the U tube being formed by the pipe going into the well, which contains the mercury. A by-pass valve is provided at the top of the meter to equalize the pressure at any time on the two legs of the U tube system.

Movable Mechanism

A small float resting on the top of the mercury in one leg of the U tube is attached to a waterproof silk cord passing over a pulley, and this cord is kept taut by a counterbalance weight acting in the opposite direction on the pulley. The shaft on which the pulley is mounted carries a small horseshoe magnet with its pole faces near and parallel to the inside surface of a copper plug screwed into the body of the meter. The brackets supporting the pulley system are made of copper, and the pivots and bearings of a special non-corrosive metal.

Scale, Indicating Needle and Target

The scale is eight inches in diameter and is marked on a white surface with heavy flow lines and figures so as to be easily read.

The pivoted end of the indicating needle consists of a small magnet, with its faces near and parallel to the outside surface of the copper plug previously referred to, and with its axis of rotation in line with the shaft carrying the magnet inside the meter. The indicating needle is attached direct to this magnet.

A target is provided for designating a certain flow on the scale. This target is easily set from the outside and is of sufficient size to be conspicuous.

Operation of Meter

A difference of pressure in the leading and trailing set of openings in the nozzle plug, caused by the steam flow, is transmitted to the U tube system of the meter and causes the mercury in the well to rise into the leg of the U tube which contains the float, the height of the mercury in this leg being proportional to the difference of pressure in the two sets of openings in the nozzle plug.

By means of the float and cord the pulley carrying the magnet inside the body is rotated in proportion to the change of level of the mercury. Any motion of this magnet is transmitted to the outside magnet carrying the indicating needle, causing this needle to deflect in proportion to the change in level of the mercury in the leg of the U tube which contains the float.

Finish

The body of the meter is finished in black enamel and the case containing the scale and needle is in dull black.

INDICATING STEAM FLOW METER, TYPE FS2
CONNECTED TO PIPE

Dimensions

Diameter of base, 7 in.
Height of meter, 13 in.

Weight

The meter weighs complete 32 pounds.

G.E. INDICATING FLOW METER

TYPE FS2

PRESSURE FOR WHICH METER CAN BE CALIBRATED, 0 TO 250 LB. GAUGE; QUALITY FOR WHICH METER CAN BE CALIBRATED, 4 PER CENT. MOISTURE TO 260 DEG. F. SUPERHEAT

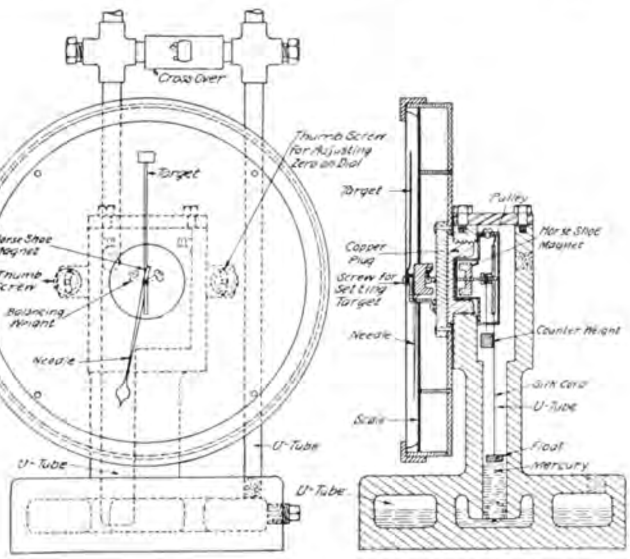
Cat. No.	Diameter of Pipe in Inches
119580	2
119581	3
119582	4
119583	6
119584	8
119585	10
119586	12
119587	14

Cat. Nos. include meter complete with nozzle plug.

Meters can be furnished for pipes larger than 14 inches if desired.

Shipping weight, 50 lb.

NOTE.—The Type FS2 meter is calibrated for a certain pipe diameter, pressure and quality and cannot be used for any other condition.



INDICATING STEAM FLOW METER, TYPE FS2, CROSS SECTIONAL VIEW

When Ordering G.E. Indicating Steam Flow Meters, Type FS2, for Measuring the Steam Output of Boilers Where the Nozzle Plug will be Installed in the Riser Between the Boiler and Header, Always Give the Following Information:

Measured internal pipe diameter at point of installing the nozzle plug for which meter is to be calibrated.

Pressure in lb. gauge for which the meter is to be calibrated.

Quality of steam in per cent. moisture or degree of superheat for which the meter is to be calibrated.

Maximum amount of steam flowing through the pipe in pounds per hour or b.h.p.) for which the meter is to be calibrated.

Shall the meter be calibrated in pounds per hour or b.h.p.? If in the latter unit, one b.h.p. will be equivalent to 30 lb. of steam per hour.

Can the nozzle plug be installed in a straight vertical or horizontal run of pipe at least 12 pipe diameters in length? If this cannot be done, send a simple sketch showing the plan and elevation of the piping with dimensions.

When Ordering G.E. Indicating Steam Flow Meters, Type FS2, Where the Nozzle Plug will be Installed Between the Header and Apparatus Consuming the Steam, Always Give the Following Information:

Measured internal pipe diameter at point of installing the nozzle plug for which the meter is to be calibrated.

Pressure in pounds gauge for which the meter is to be calibrated.

Quality of steam in per cent. moisture or degree superheat for which the meter is to be calibrated.

For what purpose is steam used?

Maximum amount of steam flowing through the pipe (in pounds per hour or b.h.p.) for which the meter is to be calibrated.

Shall the meter be calibrated in pounds per hour or b.h.p.? If in the latter unit, one b.h.p. will be equivalent to 30 lb. of steam per hour. If the steam is used for engines, send a simple sketch showing plan and elevation of piping with dimensions from engine to boilers, including all branch mains.

Can the nozzle plug be installed in a straight vertical or horizontal run of pipe at least 12 pipe diameters in length?

General Electric Company
Schenectady, N.Y.

May, 1911

**Bulletin No. 4847*

BELT-DRIVEN ALTERNATORS, FORM B

The lower first cost of belted generators compared with direct connected units is sufficient to create a large demand for such machines where space is not a serious consideration in the selection. To meet this demand the General Electric Company manufactures a standard line of belt-driven alternating current generators known as "Form B." These machines are built with two bearing housings forming part of the bearing brackets which are securely bolted to the frame, as shown in illustrations. The bearing brackets are substantially made and hold the self aligning bearings securely in position. Provision is thus made for perfect alignment between the revolving field, bearings and stationary armature, and cool running and a long life for the bearings is insured. Economy of space and material is also obtained by this form of construction and the generators are lighter and occupy less floor space for the same rating than machines arranged with separate pillow blocks and bearings. These generators are designed for both power and lighting service and for operation at any power-factor from 0.8 to unity. They are built in sizes from 50 kw. to 200 kw. (For complete ratings, see table on page 5.)

150 KW. ALTERNATOR WITH DIRECT CONNECTED EXCITER

Attention is called to the fact that these machines can be furnished with either direct connected or belted exciters, and further, that all machines are so designed that a direct connected exciter can be substituted for a belted exciter without any change of generator parts and without any machine

NOTE.—The data in this publication are for the convenience of customers, and every effort is made to avoid error, but this Company does not guarantee their correctness, nor does it hold itself responsible for any errors or omissions in this publication. Subject to change without notice.

work on the generator. It should also be noted that all pole pieces are slotted to receive a squirrel cage winding, so that at any future date the machine may be changed to a

STATOR FRAME SHOWING BEARINGS

synchronous motor or synchronous condenser by the simple addition of this winding which can be readily assembled by any station operative.

ARMATURE

The frame of the Form B alternator is a substantial iron casting provided with large ventilating holes. The armature core is built up of sheet iron laminations mounted on the inner periphery of the frame and

REVOLVING FIELD OF GENERATOR

properly lapped to make a practically continuous magnetic circuit. These laminations are secured to the frame by dovetail construction and after assembly are held in place by a clamping ring and supporting fingers as shown in the illustration. Suitable space blocks provide core ventilation and the open construction of the bearing brackets allows ample circulation of air for cooling the interior parts of the machine.

The armature coils are of standard General Electric construction, form wound and held in the slots by wooden wedges. The superiority of this and other features of the General

ARMATURE AND BEARINGS, EXCITER END

Electric alternator is clearly demonstrated by the fact that the aggregate capacity of General Electric alternators sold during the past ten years is in excess of 4,000,000 kw.

REVOLVING FIELD

The construction of the revolving field is well shown in the accompanying illustrations. The field spools, except on the largest size machine, are wire wound and treated with a special insulating heat conducting compound (the fields of the 200 kw. alternator are supplied with edgewise wound copper strip); these spools are so shaped as to present a maximum radiating surface. These features assist in maintaining a low temperature, especially when operating on low power-factor loads or as synchronous condensers.

The pole pieces are built up from laminated iron sheets riveted together and re-enforced by stiff end plates as shown in the illustration. The illustrations indicate the method of securing the pole pieces to the spider by dovetails and slots.

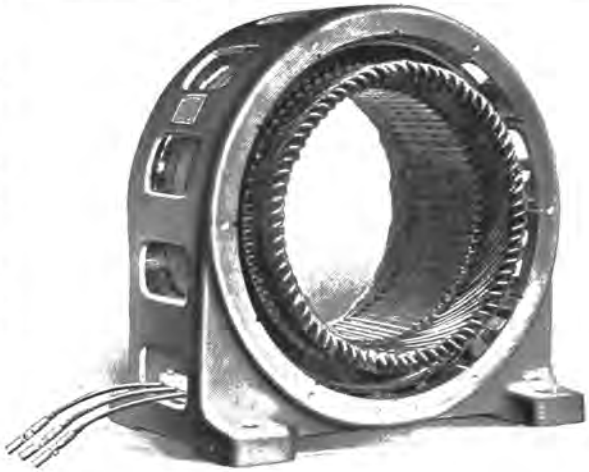
The field spider also is built up from sheet iron laminations, the whole being riveted together and pressed on the shaft.

The collectors are bolted to a cast iron ring which is pressed on the shaft. This construction insures good ventilation, high insulation and allows easy access in case of injury.

POLE PIECE FOR REVOLVING FIELD

EXCITATION

As previously stated, these generators can be furnished with either direct connected or belted exciters. The excitation cited on page 5 is sufficient to excite the generator when operated at any power-factor from 0.8 to unity with the guaranteed overload in kv-a. All fields are wound for 125 volt excitation. A Type TA voltage regulator as described in Bulletin No. 4601 is recommended for use with these generators as a means of maintaining practically constant voltage under all conditions of load. The listed excitation will also be sufficient for the machines when operating as synchronous condensers at the ratings given below.



STATOR FRAME SHOWING WINDINGS

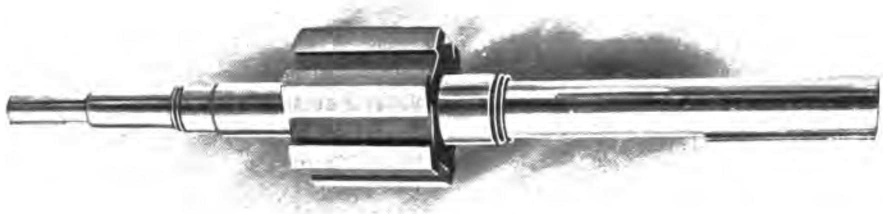
PULLEYS

The driving pulleys have cast iron centers and compressed paper rims. This construction makes a considerably lighter pulley and one able to transmit more power per inch of face than an iron pulley with diminished strain on bearings and shaft. These machines are supplied with an improved sub-base for belt tightening, the main features of which are shown in the accompanying cut.

FIELD OF SYNCHRONOUS MOTOR WITH SQUIRREL CAGE WINDING

BEARINGS

The bearings are self-oiling by means of oil rings and have ample surface to insure cool running. The lower part of the bearing forms a large oil reservoir and convenient



FIELD SPIDER AND SHAFT

gauges are provided for indicating the height of the oil.

The use of three-arm bearing brackets increases the ventilating air available for cooling the working parts of the machine, and all bearings are split so that both halves may be removed without removing the rotating element from the frame.

SYNCHRONOUS MOTORS AND CONDENSERS

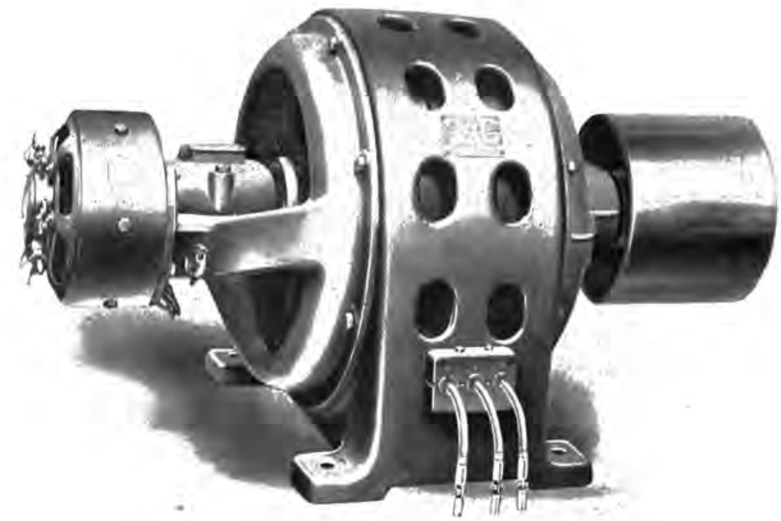
As mentioned in the first part of this bulletin, these generators can be changed to synchronous motors or synchronous condensers by the addition of squirrel cage windings. This winding increases the starting torque so that the machine may be started through a starting compensator or from starting taps on transformers. It is also the most effective anti-hunting device on the market and will keep the motor in step if it is possible to operate a synchronous motor on the system.

The machines may be operated as synchronous condensers at the ratings given below with temperature rise not exceeding 40 deg. C. on the armature and 50 deg. C. on the field.

PHASES AND VOLTAGES

The standard designs are adapted to three-phase or two-phase windings without change except in the armature coils and terminal blocks, the exciters and all accessories being the same for both. No single-phase windings have been standardized, the intention being to use three-phase windings for cases where single-phase machines would ordinarily be required, the load being carried by any two of the three legs. Designs have been made for the following potentials: 240, 480, 600, 1150 and 2300 volts.

SLIDING BASE AND BELT TIGHTENER



100 KW. ALTERNATOR WITH DIRECT CONNECTED EXCITER

TEMPERATURES

The rating of the Form B alternator is based on continuous operation at full rated kv-a. load. Under these conditions the temperature rise at 1.0 power-factor is guaranteed not to exceed 35 deg. C. The maximum temperature rise at 25 per cent. overload under continuous operation at this power-factor will not exceed 40 deg. C. At 0.8 power-factor the maximum temperature rise will not exceed 40 deg. C. under full load continuous operation, while at 25 per cent. overload operation for two hours 0.8 power-factor, the temperature rise will not exceed 55 deg. C.

The temperatures are measured by thermometer and based upon a room temperature of 25 deg. C. and barometric pressure of 30 inches, in accordance with the Standardization Rules of the A.I.E.E.

RATINGS

The weights and rating of the standard Form B alternators are given in the following table.

The single-phase kv-a. rating of Form B machines at both 1.0 power-factor and 0.8 power-factor is 65 per cent. of the three-phase kv-a. rating at 0.8 power-factor. In case the power-factor is less than unity this rating must be multiplied by the power-factor to give the kw. or energy rating.

CLASSIFICATION							APPROXIMATE SHIPPING WEIGHT		DIMENSIONS IN INCHES			
Type	Poles	Kw. Capacity		Speed R.P.M.	Synchronous Condenser Rating in Kv-a.	Exciter Kw. at 125 Volts	With Exciter	Without Exciter	Length Overall		Pulley	
		1.0 P-F.	0.8 P-F.						With Exciter	Without Exciter	Diam.	Face
ATB or AQB	6	50	50	1200	50	2.25	2870	2665	56 7/8	52	16	11
ATB or AQB	6	75	75	1200	75	2.25	3785	3580	63 3/4	58 7/8	16	14
ATB or AQB	8	100	100	900	125	3.0	5215	4830	73 3/4	68 3/4	21	17
ATB or AQB	10	150	150	720	187	5.5	7895	7500	88 1/16	81 3/4	26 1/2	23
ATB or AQB	12	200	200	600	250	7.5	11230	10450	95 9/16	87 3/4	32	28

GENERAL ELECTRIC COMPANY

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