General Electric Company
Schenectady, N.Y.

November, 1920 Bulletin No. IGE-44484

GENERAL ELECTRIC MODERN RAILWAY CAR EQUIPMENT

VENTILATED COMMUTATING-POLE D-C. RAILWAY MOTORS

The great improvements that have been made in the design and manufacture of electric railway motors have been important factors in the rapid growth of electric railways in the United States, and in the electrification of existing steam railroads.

The development of the railway motor since the early days of electric railroads has been rapid. Not only has progress been made by important steps, such as the general adoption of the box frame, commutating poles and the feature of self-ventilation, but also by improvements in detail of design, in lubrication and insulation, and in manufacturing processes, resulting in the production of railway motors which have enabled railway companies to meet the demand for rapid and safe transportation at a low cost.

The special features of the modern, ventilated, box frame, commutating-pole railway motor are shown in the sectional view (Fig. 1), of one of this line of motors, and attention is drawn by the notes to points wherein improvements have been made over the earlier types of motors.

Box Frame Motors

There are many advantages inherent in the box type of frame, and it is now so generally used in the United States that it is considered standard, and most of the latest motors are built with this type of frame only.

NOTE.—Data subject to change without notice.

Advantages

The advantages possessed by the box frame motor as compared with the split frame are briefly these:

For a given weight and space, a greater output can be obtained, or for a given output the motors can be made both lighter and smaller owing to the unrestricted ventilation obtained.

The absence of the joint in the frame gives an unbroken magnetic circuit and prevents oil from the axle bearings creeping into the motor.

All connections between the field coils are inside the frame and are, therefore, well protected.

There is a greater freedom of design for armature, pole pieces and coils, and a better design of axle bearings and oil boxes is possible. The lower half of the malleable iron gear cases can be supported in a more substantial manner.

The box frame possesses greater structural strength and durability, a fewer number of parts and has a very low maintenance cost.

If repairs become necessary, the entire motor with armature in place is removed from the car and the motor opened on the floor, permitting a more thorough examination of the interior than is possible when repairs are made from the pit as is usual with split frame motors. The better working conditions thus obtained insure better workmanship. Repairs effected in this manner take no longer to perform than with the split frame motor, and inspection for worn bear-

ings, loose armature bands, worn brushes, etc., can be made through the hand holes provided in the frame as conveniently as with the split frame.

Ventilation

The self-ventilated type of railway motor is the greatest advance in design that has been made up to the present time. The success of these motors has been phenomenal. There are now upwards of 40,000 ventilated railway motors in the United States and other countries. These are operating successfully in all classes of service and under all weather conditions. In these motors a number of longitudinal ducts are provided in the armature core and in the commutator shell through which cooling air is drawn by a fan mounted on the armature. Air is drawn in through screened openings and follows either one of two courses depending on the design of the motor. Figs. 2 and 3 show the general course of the air for these two methods of ventilation. In addition to greatly increasing the service capacity of the motor by the greater dissipation of heat thus obtained, the air blast tends to prevent the accumulation of dust and the particles of carbon in the frame.

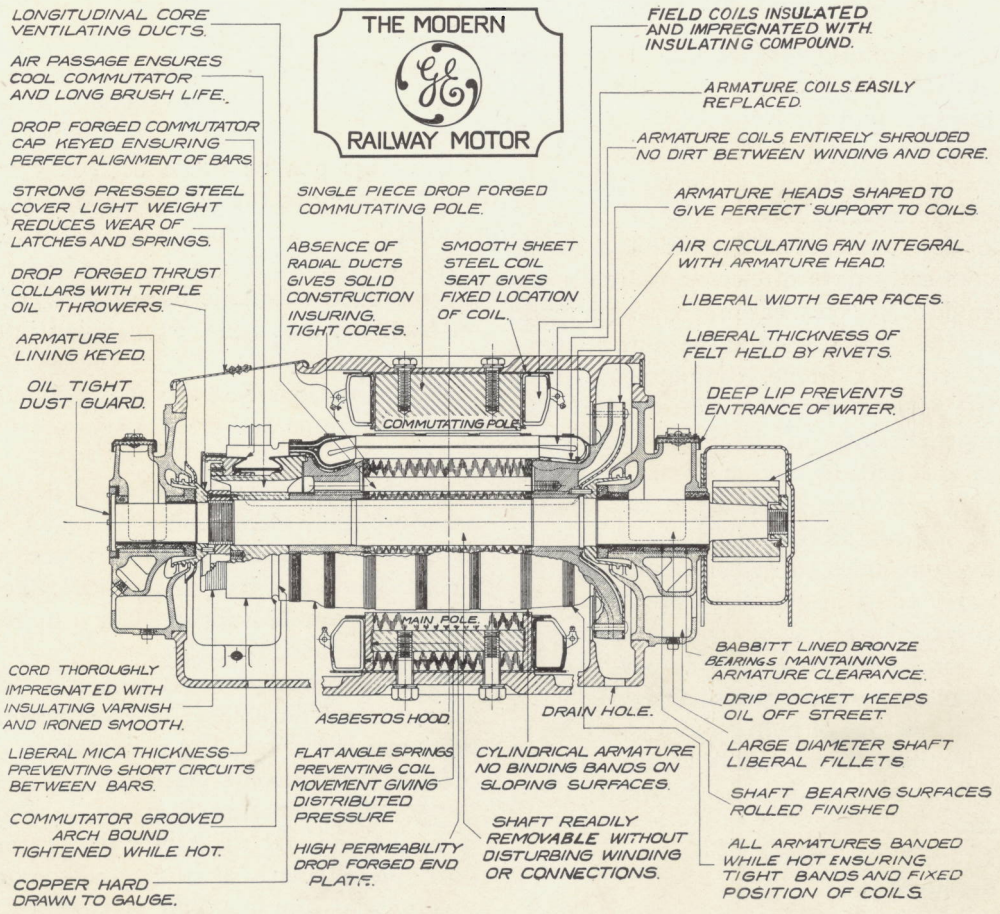


Fig. 1

DIAGRAM OF COMMUTATING-POLE RAILWAY MOTOR WITH CONSTRUCTION DETAILS

Rating of Ventilated Motors

There has been in the past a practice of supplying motors, especially those for service outside of the United States, entirely on a basis of rated horse power for one hour, the manufacturer being given only the horse power that is considered necessary for the proposed service, and no information furnished on the service to be performed by the motors. This horse power rating is that which is obtained during a stand test of one hour's duration. In a test of this length of time, much of the heat generated is absorbed in the mass of the motor itself, and the greater ability of the ventilated motor to dissipate heat, which is the real measure of its service capacity, is not apparent. For this reason the horse power rating is less of an indication of service capacity of the ventilated than of the non-ventilated motor, and the continuous ampere rating should be considered in comparing the two types of motors.

The high continuous capacity of the ventilated motor frequently permits the recommendation of one of this type for a proposed service, having a considerably smaller one-hour horse power rating than would be necessary if the non-ventilated motor were used. In order, therefore, to avoid supplying motors which are unsuitable, full information relative to service conditions rather than the estimated horse power rating should be furnished to the General Electric Company. A form has been prepared outlining the information that is required on propositions. A copy of this form is shown on Pages 12 and 13.

By reference to Table I a comparison of the relative service capacities of old type and the modern, ventilated commutating-pole motors can be made. All propositions for the substitution of a modern motor for one of the old type should be referred to the engineers of the General Electric Company with full information as to truck dimensions and service data, although a tentative choice can be made from the table.

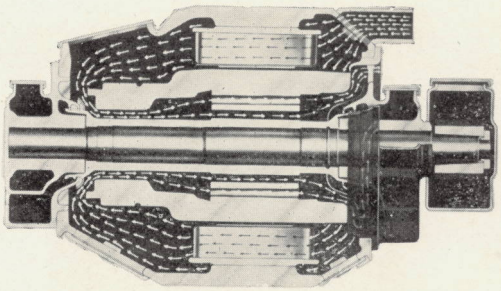


Fig. 2. SERIES-VENTILATED MOTOR

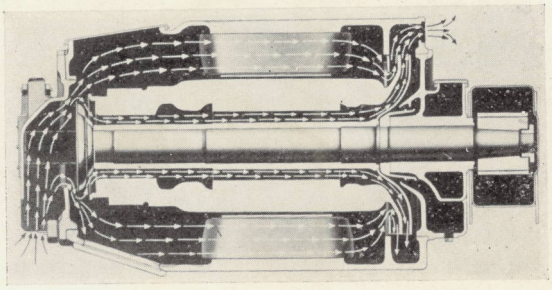


Fig. 3. MULTIPLE-VENTILATED MOTOR

UNDER ORDINARY CONDITIONS THE FOLLOWING MODERN VENTILATED MOTORS HAVE CAPACITIES SUFFICIENT TO PERFORM ANY SERVICE NOW BEING OPERATED BY THE OLD TYPE OF MOTORS AS INDICATED.

TABLE I

GE-247-A-D	GE-800, 1000, 52, 54, 60, 62, 78, 81
GE-249-A	GE-58, 67, 70, 80, 90
GE-203-P	GE-53, 67, 70, 80, 90, 1200
GE-263-A	GE-57, 75, 90, 98
GE-240-A	GE-73, 74

SUBSTITUTIONS OF MOTORS AS INDICATED MAY NOT BE POSSIBLE IN ALL CASES BECAUSE OF MECHANICAL DIFFERENCES WHICH SHOULD BE CHECKED CAREFULLY.

WHEN A CHANGE IS CONTEMPLATED, THE SUITABILITY OF THE MOTOR WILL BE DEFINITELY DETERMINED BY THE GENERAL ELECTRIC COMPANY'S ENGINEERS IF SERVICE DATA IS FURNISHED AS SPECIFIED ON DATA SHEETS PAGES 12 AND 13.

Operation and Maintenance

The general practice of railway companies in the United States to keep an account of

the cost of inspection and repairs of various motors they operate has given reliable figures on maintenance costs from many sources. These records show that because of the superior design and construction of these

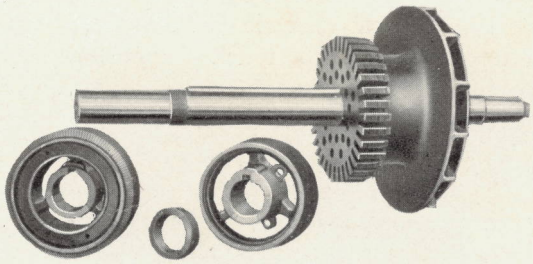


Fig. 4. CONSTRUCTION DETAILS OF VENTILATED MOTOR ARMATURE

motors, their average cost of maintenance has been approximately 20 to 50 per cent of the cost of maintaining the older non-ventilated types, such as GE-800, 52, 54, 57, 58, 67, 70, 73, 74, 80, 81, 90, etc.

These figures are based on conditions existing in the United States and will vary according to the cost of labor and materials in other countries.

Construction Details

The General Electric Company during its many years experience in the manufacture

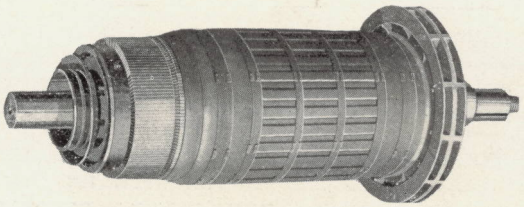


Fig. 5. COMPLETE ARMATURE OF MULTIPLE-VENTILATED MOTOR

of railway equipments has incorporated in the design of ventilated commutating-pole motors the most modern and practical features known. The principal details and most important features of the construction are illustrated in the accompanying photographs.

Fig. 4 shows the method of building up the armature. The ventilating fan in this photograph is that used in motors having the type of ventilation indicated in Fig. 2 which is known as series ventilation. Fig. 5 is a complete armature with the type of fan used for what is known as multiple ventilation as shown in Fig. 3.

Fig. 6 illustrates the method of insulating and mounting commutator segments.

Fig. 7 shows the frame heads with a section of one in Fig. 8 giving an illustration of the

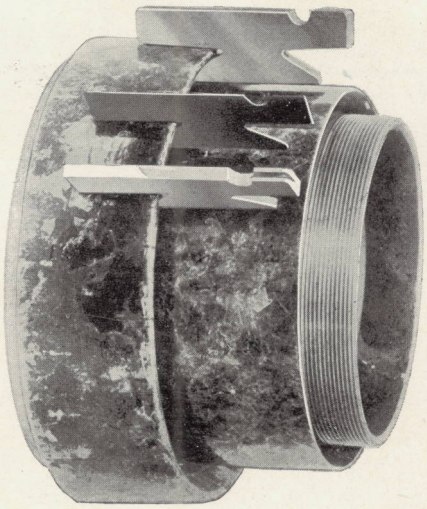


Fig. 6. COMMUTATOR BARS AND INSULATION

oil and waste lubricating system for the armature bearings. The frame heads are made a driving fit in the ends of the frame and tapped holes, diametrically opposite, are provided for jack screws to facilitate the removal of the heads.

Axle bearings are lubricated in a manner similar to that of the armature bearings.

Grease is not used for a lubricant in the latest types of motors.

Fig. 9 shows the method of winding exciting field coils, with the method usually employed of mounting and holding the completed coil in Fig. 10. Commutating coils are supported in a similar manner.

All coils after being well insulated are thoroughly impregnated with insulating varnish by a vacuum process.

All armature windings are form wound and assembled in groups or polycoils which are carefully insulated and pressed to shape

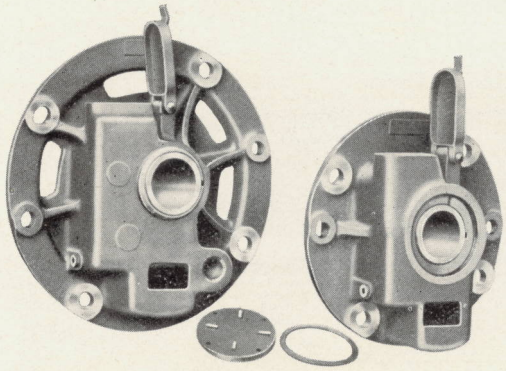


Fig. 7. FRAME HEADS

in steam moulds. This insures uniform and interchangeable coils.

One of the very important improvements incorporated in the modern motors is that the armature shaft can be replaced when necessary without disturbing the armature windings or connections to the commutator. This method of removing the shaft is illustrated in Fig. 11.

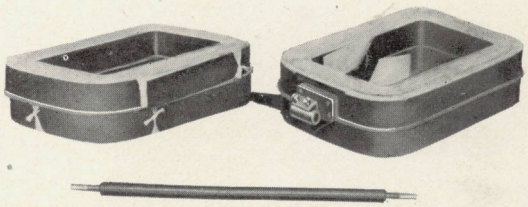


Fig. 9. RIBBON WOUND FIELD COILS BEFORE INSULATING

Fig. 12 shows one of the series-ventilated motors and Fig. 13 one of the multiple-ventilated type both complete with gear case.

Table No. 2 (Page 10) gives data on some of the G-E ventilated motors which will enable a tentative choice for the particular service under consideration. Under ordinary conditions some one of these motors will be found suitable for almost any normal average service. For extra severe or special services

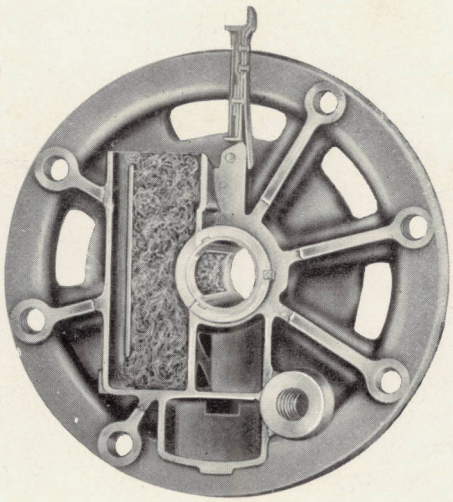


Fig. 8. FRAME HEAD SECTION SHOWING METHOD OF LUBRICATING BEARINGS

it may be necessary to use one of the many other ventilated motors which the General Electric Company manufactures.

Handling Box Frame Motors

Examples are given of some of the methods

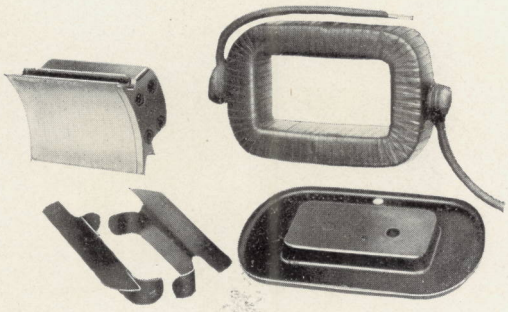


Fig. 10. FINISHED EXCITING FIELD COIL, POLE PIECE AND SUPPORTS

in use in the United States of opening the box frame type of motor for inspection and repairs.

To remove the armature, the motor is first taken from the truck. With double-truck cars, it is a simple matter to support one end of the car by chain blocks, while the truck at that end is run out where easy access to the motor can be had.

With single-truck cars, the motor can be lowered into the pit without removing the truck from the car. To do this the gear case and axle linings are removed and the suspension unbolted from the truck. The motor should be supported by a jack from the pit and moved over horizontally sufficiently far to enable the axle bearing housings to clear the axle. The motor may then be lowered into the pit. If there is sufficient clearance under the car body to clear the axle caps when swung up, it may be more convenient to leave the axle caps in position and allow the motor to swing down around the axle. It may then be supported, the axle caps removed and the motor lowered into the pit. This method, however, necessitates the removal of lubricant from the motor. With single truck cars (the only type on which this method of removal may be necessary) the motors are generally such that the weight to be handled is not

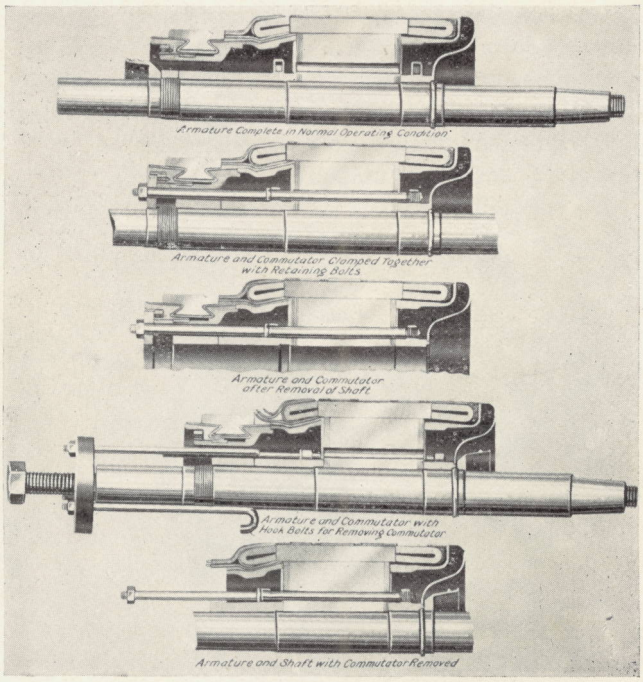


Fig. 11. REMOVAL OF SHAFT AND COMMUTATOR FROM VENTILATED MOTOR ARMATURES

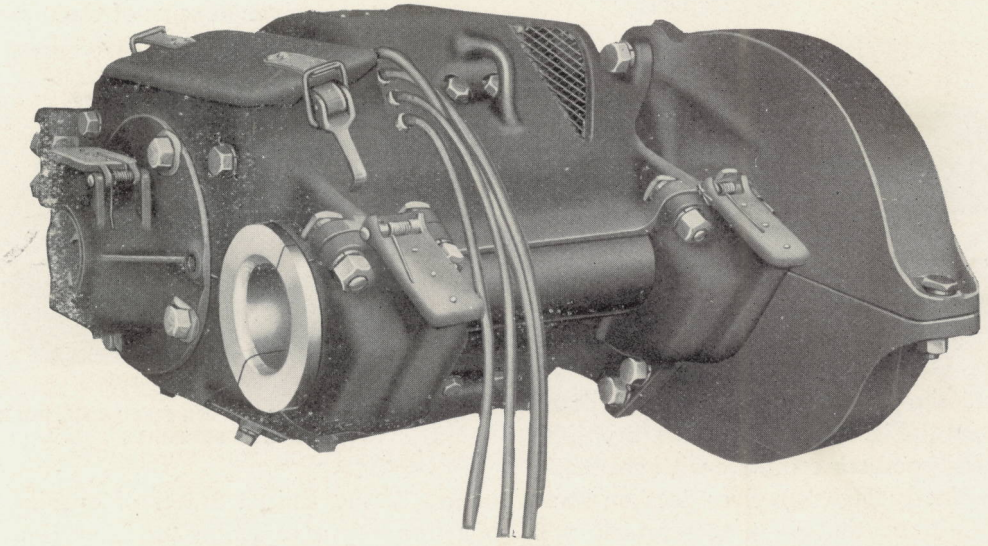


Fig. 12. SERIES-VENTILATED COMMUTATING-POLE RAILWAY MOTOR

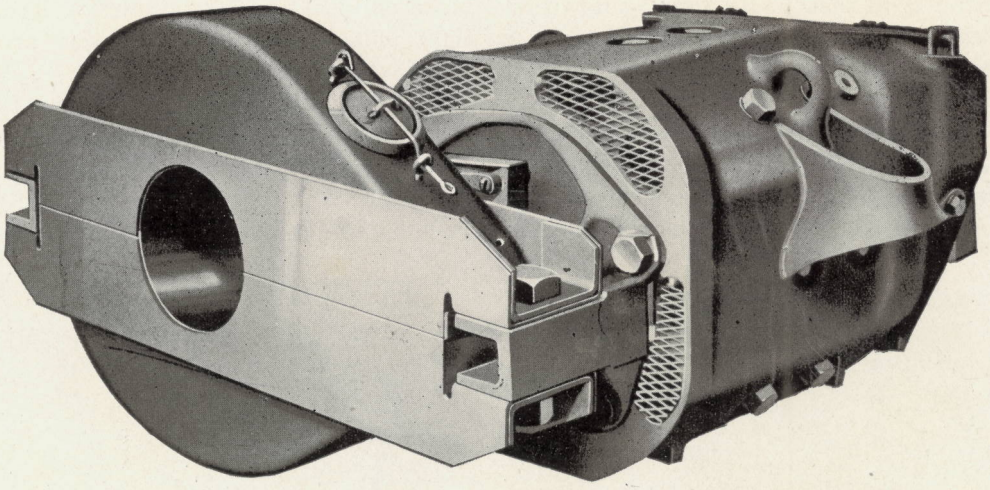


Fig. 13. MULTIPLE-VENTILATED COMMUTATING-POLE RAILWAY MOTOR

great, and the small amount of equipment that it is necessary to provide to successfully handle the box frame motor is more than compensated for by the advantages of this type of frame.

The removal of the armature from the motor is greatly facilitated by the provision of some simple appliances, their design depending on the method adopted and the facilities of individual car barns and shops. A method which has been used successfully is shown in the accompanying illustration (Fig. 14). The frame head is removed, and a lever having a collar at one end, which fits over and is clamped to the pinion, is used to support that end of the armature shaft. The armature is then pulled out sufficiently far to permit a wide lifting strap to be put in position. The bearing at the commutator end supports that end of the armature until

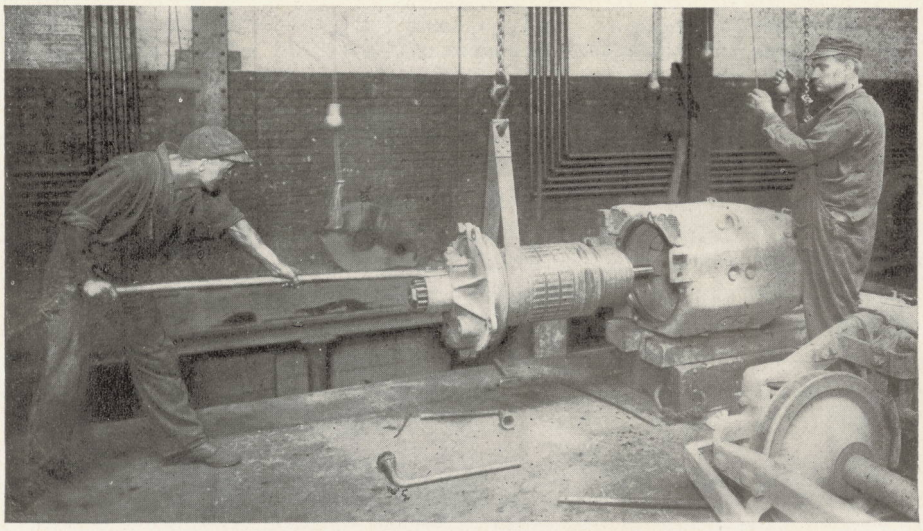


Fig. 14. REMOVING ARMATURE FROM A BOX FRAME MOTOR. METHOD NUMBER ONE

the strap is in place. By bearing down on the lever the weight of the armature is balanced and it may be withdrawn without difficulty.

A second method is also shown in Fig. 15 in which the armature shaft is supported at one end by a tube which slips over it. A rope sling is used to support the other end, and the armature moved horizontally by means of an overhead traveler.

An example is also given of the method sometimes employed in removing the armatures from large interurban box frame motors. In this case the motor is turned on end and the armature removed vertically by means of scissor-like clamps which fit under the pinion. (See Fig. 16.) The armature is then stood on blocks and the clamps replaced by a light chain before laying the armature down.

Another method very much used is to place the motor on a truck, and after removing the frame heads, the armature is supported by two adjustable jacks, one under the pinion and one under a tube slipped over the shaft at the other end, the necessary circular supports or clamps first having been attached to the head of the jacks. The armature is then raised to clear the pole pieces and the motor frame on the truck moved along the line of the shaft until the armature is out of the frame.

Other methods are in use which may be better suited to the requirements of individual car barns and shops.

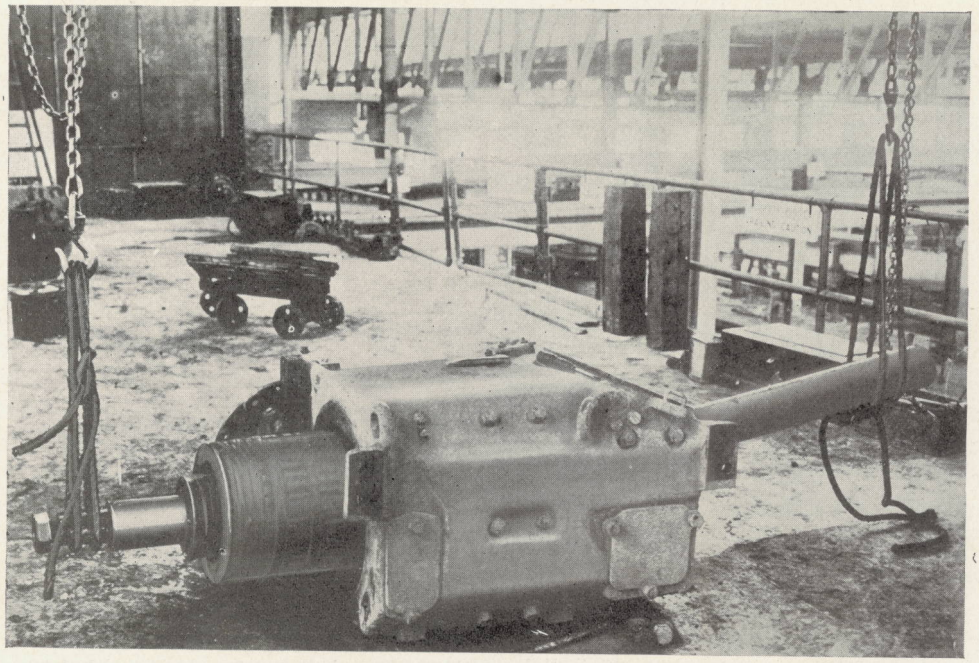


Fig. 15. REMOVING ARMATURE FROM A BOX FRAME MOTOR. METHOD NUMBER TWO

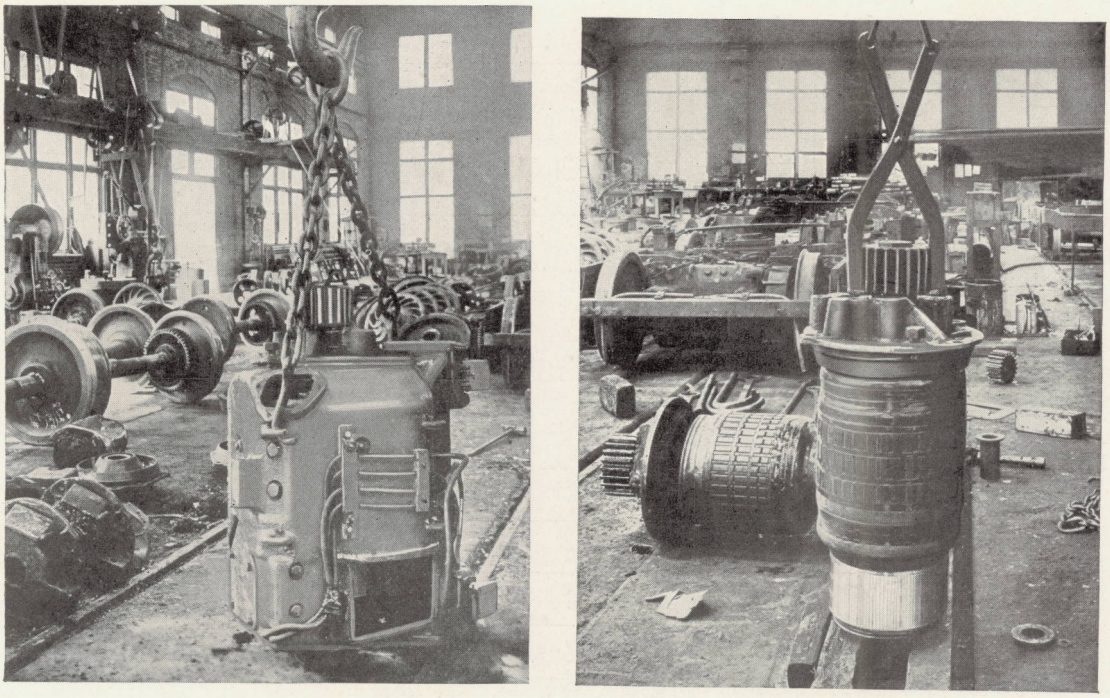


Fig. 16. REMOVING ARMATURE FROM A BOX FRAME MOTOR. METHOD NUMBER THREE

TABLE NO. 2

PARTIAL LIST OF VENTILATED RAILWAY MOTORS

Motor	Hourly Horse Power Rating on 600 Volts for 75 Deg. C. Rise by Thermometer	Continuous Amp. Rating on 600 Volts for 65 Deg. C. Rise by Thermometer	Type of Service for which Suitable	Wheel Diameter Inches	Clearance Above Track in Inches Under—		Wheel Diameter Millimeters	Clearance Above Track in Millimeters Under—		Maximum Diam. of Axle		Approximate Maximum Allowable Load Per Motor with Seated Load		Overall Dimension of Motor Along Shaft		Approximate Weight Complete with Gear, Pinion, Gear Cover, Axle Linings		Cubical Space Occupied in Shipment		General Description and Characteristic Curves
					Gear Cover	Motor Frame		Gear Cover	Motor Frame	Inches	Millimeters	Pounds	Kilograms	Inches	Millimeters	Pounds	Kilograms	Cubic Ft.	Cubic Meters	
GE-264-A	25	35.2	City	24	$2\frac{23}{32}$	$3\frac{5}{16}$	610	69	84	4	100	10,000	4,550	$34\frac{7}{8}$	886	1005	456	23	.65	Bulletin 44470
GE-264-B	25	35.2	City	30	$2\frac{5}{8}$	$6\frac{5}{16}$	770	70	165	$4\frac{1}{2}$	115	10,000	4,550	$34\frac{7}{8}$	886	1130	513	23	.65	Bulletin 44470
GE-247-A	40	36.6	City and Suburb.	24	$3\frac{5}{32}$	$3\frac{5}{16}$	610	80	84	4	100	18,000	8,150	41	1041	1740	790	24	.68	Bulletin 44406-A
GE-247-D	40	36.6	City and Suburb.	30	$3\frac{13}{16}$	$4\frac{9}{16}$	770	101	120	$4\frac{1}{2}$	115	18,000	8,150	$41\frac{3}{8}$	1051	1870	849	24	.68	Bulletin 44406-A
GE-249-A	40	38.0	City and Suburb.	33	$4\frac{1}{8}$	$5\frac{1}{8}$	850	110	136	$4\frac{1}{2}$	115	20,000	9,110	$36\frac{5}{16}$	922	2320	1053	37	1.05	Bulletin IGE-44408
GE-203-P	50	46.0	City, Suburban and Light Interurb.	33	$3\frac{7}{8}$	$5\frac{3}{8}$	850	104	142	5	125	20,000	9,110	$42\frac{15}{16}$	1091	2280	1035	46	1.30	Bulletin 44424
GE-263-A	65	70.5	City, Suburban and Light Interurb.	33	$3\frac{13}{16}$	$4\frac{1}{4}$	850	102	114	5	125	22,000	10,000	$48\frac{3}{4}$	1238	3060	1388	50	1.42	General Specification No. 14397
GE-240-A	105	88.5	Interurb.	33	$3\frac{1}{2}$	$3\frac{11}{16}$	850	94	99	6	150	30,000	13,600	$50\frac{13}{16}$	1291	3840	1742	51	1.45	Bulletin 44409

Note.—The allowable weight per motor depends on the service operated, varying according to the number and duration of stops, schedule speed, and average voltage.

All of the above motors are built with the box frame except the GE-249 which was developed to supply a demand for a modern motor of the split frame type for meter gauge.

INFORMATION REGARDING DATA REQUIRED IN FOLLOWING "INFORMATION SHEET"

By filling in this Information Sheet accurately, the General Electric Company is in a better position to determine the most suitable size of motor, ratio of gearing, winding, etc., which affect not only the energy consumption, but also maintenance costs.

In order that the temperatures of motors in service may not be excessive, it is important that the conditions under which motors are to operate be carefully studied and correct data as regard running time, stops, distances, slow downs, etc., be given on this data sheet.

Care should be taken to give the number of stops as counted in actual service in the distances and corresponding running times designated and not the number of possible stopping places.

The "average service" may generally be taken as occurring between one and five p.m., and the "rush service" from five to seven p.m.

The average passengers per car during a round trip may be determined by counting all the passengers in the car at 5 minute intervals and dividing the sum of the passengers counted each time by the number of times the count is made.

It frequently happens that during the "rush service," the schedule speed, number of stops and slow downs, as well as passenger load is greatly different from the average conditions, and is of such a character as to be limiting as regards motor capacity.

The average voltage should not be given as an average of the maximum and minimum, but the average voltage maintained at the car only during the time power is applied to the motors and not including the time of coasting, braking, or standing.

Unsatisfactory operation of motor equipment has resulted, owing to incorrect service data having been given, and customer and agents are requested to give as accurate and complete information as possible,

The General Electric Company will assume, in making engineering recommendations, that the motor equipment will be handled in a careful and proper manner when performing the service specified. Brakes will be adjusted so that they will not drag and will be in the released position while power is on.

INFORMATION SHEET (English Units)

DATA REQUIRED BY THE GENERAL ELECTRIC COMPANY FOR RAILWAY MOTORS

on the ..... Railway

MOTOR CARS: Seating capacity..... Capacity with standing load..... Length of car over all.....
Weight of empty cars and trucks not including electrical equipment..... lb.
Have cars single or double trucks?..... No. of motors per car..... Diam. of car wheel..... in.

TRAIL CARS: Seating capacity..... Capacity with standing load..... Length of car over all.....
Weight of empty cars and trucks..... lb.

LINE POTENTIAL: Maximum voltage is..... Minimum voltage is..... Average voltage is.....

TOTAL DISTANCE round trip..... miles.
Distance round trip in city service..... miles. Suburban..... miles. Interurban..... miles.

AVERAGE SERVICE: Time, excluding layovers required to make round trip..... minutes.
Time excluding layovers, to make round trip, city service..... minutes. Suburban service..... minutes. Interurban service..... minutes.
No. of stops in round trip, city service..... Suburban..... Interurban.....
No. of slow downs, round trip, to approx. half speed, city service..... Suburban service ..... Interurban service.....
No of trail cars handled by motor car..... No. of consecutive round trips with trail cars.....
Average passengers during round trip, motor car..... Trail cars.....

RUSH SERVICE: Time excluding layovers required to make round trip..... minutes
Time required to make round trip, city service..... minutes. Suburban service ..... minutes. Interurban service..... minutes.
No. of stops in round trip, city service..... Suburban..... Interurban.....
No. of slow downs, round trip, to approx. half speed, city service..... Suburban service..... Interurban service.....
No. of trail cars handled by motor car.....
No. of consecutive round trips per car, motor car only..... Motor car and trail cars.....
Average passengers during round trip, motor car..... trail cars.....

DURATION OF STOPS: For average city service..... seconds. Suburban..... seconds. Interurban..... seconds.
For rush city service..... seconds. Suburban..... seconds. Interurban.....

LAYOVERS: Round trip, number and duration.....

GRADES
Underscore grades which cars both ascend and decend in round trip.

Length in ft.	%	Length in ft.	%	Length in ft.	%	Length in ft.	%	Length in ft.	%

MOTOR: Motor frame box or split?..... MOTOR LEADS: Axle or suspension side?.....

AXLE DIAMETER: In motor axle bearings..... inches. In gear..... inches. In axle collar ..... inches. Should gear be split or solid?..... If solid give *exact* bore..... inches.
Distance between wheel hubs..... inches. Style of axle..... Track gauge..... inches.

REMARKS:

Dated..... 192..... Signed.....

By.....

(READ PAGE 11 BEFORE FILLING IN THIS SHEET)

INFORMATION SHEET (Metric Units)

DATA REQUIRED BY THE GENERAL ELECTRIC COMPANY FOR RAILWAY MOTORS

on the ..... Railway

MOTOR CARS: Seating capacity..... Capacity with standing load..... Length of car over all.....
Weight of empty cars and trucks not including electrical equipment.....kg.
Have cars single or double trucks?..... No. of motors per car..... Diam. of car wheel.....mm.

TRAIL CARS: Seating capacity..... Capacity with standing load..... Length of car over all.....
Weight of empty cars and trucks.....kilograms.

LINE POTENTIAL: Maximum voltage is..... Minimum voltage is..... Average voltage is.....

TOTAL DISTANCE round trip.....kilometers.
Distance round trip in city service.....km. Suburban.....km. Interurban.....km.

AVERAGE SERVICE: Time, excluding layovers required to make round trip.....minutes
Time excluding layovers, to make round trip, city service.....minutes. Suburban service.....minutes. Interurban service.....minutes.
No. of stops in round trip, city service.....Suburban.....Interurban.....
No. of slow downs, round trip, to approx. half speed, city service..... Suburban service ..... Interurban service.....
No. of trail cars handled by motor car..... No. of consecutive round trips with trail cars.....
Average passengers during round trip, motor car..... Trail cars.....

RUSH SERVICE: Time excluding layovers required to make round trip.....minutes.
Time required to make round trip, city service,.....minutes. Suburban service .....minutes. Interurban service.....minutes.
No. of stops in round trip, city service.....Suburban.....Interurban.....
No. of slow downs, round trip, to approx. half speed, city service,.....Suburban service..... Interurban service.....
No. of trail cars handled by motor car.....
No. of consecutive round trips per car, motor car only..... Motor car and trail cars.....
Average passengers during round trip, motor car.....trail cars.....

DURATION OF STOPS: For average city service.....seconds. Suburban..... seconds. Interurban.....seconds.
For rush city service.....seconds. Suburban.....seconds. Interurban..... seconds.

LAYOVERS: Round trip, number and duration.....

GRADES	Length in km.	%	Length in km.	%	Length in km.	%	Length in km.	%	Length in km.	%
Underscore grades which cars both ascend and descend in round trip.										

MOTOR: Motor frame box or split?..... MOTOR LEADS: Axle or suspension side? .....

AXLE DIAMETER: In motor axle bearings.....mm. In gear.....mm. In axle collar.....mm.
Should gear be split or solid?..... If solid gear give *exact* bore.....mm.
Distance between car wheel hubs..... mm. Style of axle..... .....
Track gauge.....mm.

REMARKS:

Dated.....192..... Signed .....
By.....

(READ PAGE 11 BEFORE FILLING IN THIS SHEET)

AIR BRAKE EQUIPMENTS

The General Electric Company, during the many years it has been connected with the electric traction industry, has given special attention to the brake problem. Experience has proved that the air brake is the most durable, satisfactory and positive of all brakes, and best meets the severe requirements of the modern electric railway. Practically all electric cars in the United States are now equipped with air brakes. None of the various types of electric brakes are used except in rare instances, the air brake being considered more reliable and quicker in action than any form of electric brakes for emergency as well as service stops.

The use of air brakes permits the installation of a motor approximately 15 to 20 per cent smaller in continuous capacity for a given service than would be allowed if electric brakes were used for all stops.

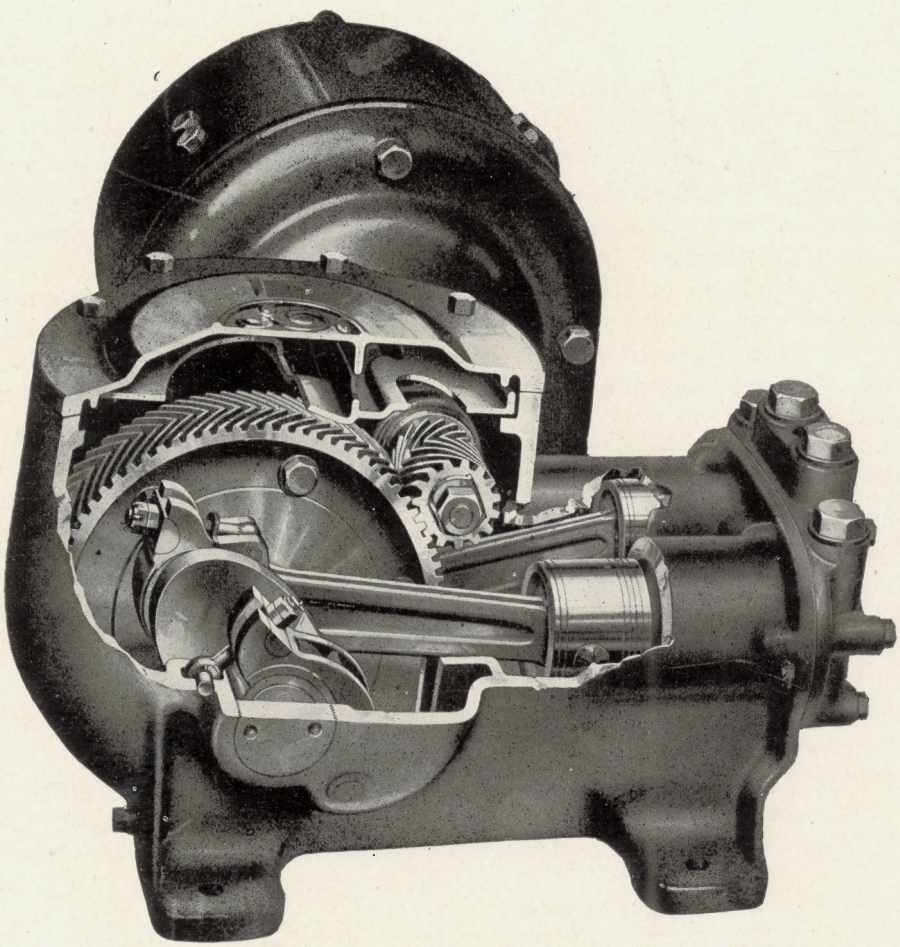


Fig. 17. AIR COMPRESSOR SECTION SHOWING MECHANICAL DETAILS

Where it is required to use electric brakes for making emergency stops only, this can be accomplished with the standard cylinder control equipment. However, where foreign practice requires all service stops to be made by electric braking, a rheostatic braking controller can be supplied.

The compressed air supply for the operation of the air brakes is furnished by a center geared, motor driven compressor. A standard

compressor with working parts exposed is shown in Figs. 17 and 18. A complete description of air compressors is given in Bulletin 44591.

At the present time there are approximately 17,000 machines of this type in operation, many of them having been installed for several years. The cost of operation and maintenance is extremely low.

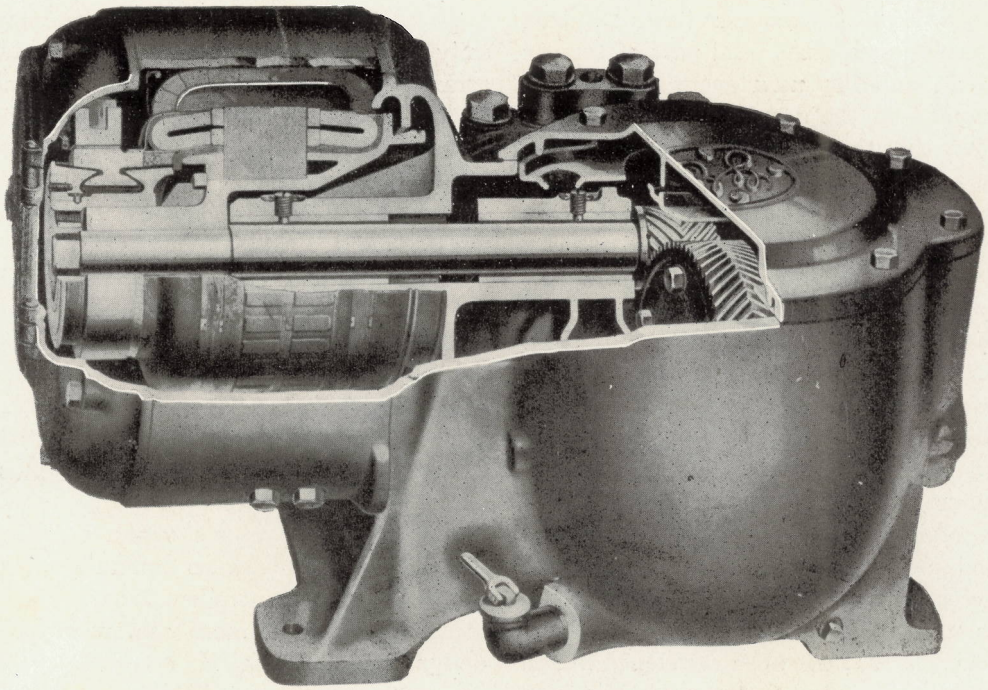


Fig. 18. AIR COMPRESSOR SECTION SHOWING ELECTRICAL DETAILS

Air compressors of various sizes are furnished with suitable brake equipment for every type of service. Each equipment in every detail is made with a view to giving the most durable, efficient and reliable apparatus which many years of experience has shown is possible to produce. A complete description of the various types of brake equipments can be found in the following bulletins:

Bulletin No. 4798:

Straight Air Brake Equipment for single car operation only.

Bulletin No. 44555:

Straight Air Brake Equipment with Emergency Feature for city service where a simple form of emergency equipment is desired for cars operating singly or in trains of not more than **two** cars.

Bulletin No. 4701:

Emergency Straight Air Brake Equipment for city and suburban cars operating singly or in trains of not more than **five** cars.

Bulletin No. 44565:

Automatic Variable Release Air Brake Equipment for interurban cars which run both singly and in trains but where trains are operated a greater part of the time.

Bulletin No. A-4127:

Combined Straight and Automatic Variable Release Air Brake Equipment for interurban cars which run both singly and in trains but where single cars are operated a greater part of the time.

This equipment is also used on electric locomotives.

RAILWAY CONTROL EQUIPMENTS

CONTROLLERS FOR RAILWAY SERVICE

The series parallel controller has been almost universally used with railway motor equipments for the past twenty-five years, and during this period the General Electric Company has manufactured over 200,000 of these controllers.

From the inception of electric railroading the General Electric Company has recognized the controller as a most vital part of the car equipment, and has used every resource at its command in the development of railway controllers that they should be as reliable and efficient as possible.

The high merit of this apparatus at the present time has been made possible only by the unequalled manufacturing facilities of the General Electric Company, and the ability and resource of its corps of experienced engineers.

Although the chief characteristics of these controllers have remained practically unchanged for many years, there has been a continuous improvement in details such as the magnetic blowout, the use of hexagonal insulated shafts, the style of contact, and circuit connections. Other improvements are due to the production of new insulating materials, such as have been developed within recent years by the Company's Research Laboratory.

The series parallel controller as is well known, is used to control two motors, or two pairs of motors, and serves to connect these motors in series or in parallel relation. By means of these connections a car may be run economically at a medium speed, as well as at full speed, and can be accelerated to full speed more efficiently than is possible with a simple rheostatic controller; hence, the practically universal adoption of the series parallel controller in railway service.

The General Electric Company manufactures two distinct types of series parallel controllers for railway service. They are the cylinder or drum controllers for single car operation and the Sprague General Electric multiple unit control for train operation.

CYLINDER CONTROLLERS

There are two general kinds of cylinder controllers for railway service: the type K, and type B, each with a distinguishing characteristic of its own.

The type K controller is the one universally used in the United States. It is arranged to series-parallel either two motors or two pairs of motors and maintains an unbroken power circuit during the transition from series to parallel.

The type B controllers have the usual power circuit connections, and besides these they have connections to enable the motors to be run as generators to provide a dynamic braking action. This type of controller is applicable for conditions where more than emergency braking with the motors (which can be obtained on all "K" type of controllers) is required as when service stops must be made by electric braking.

In addition to above types, the General Electric Company also manufactures for railway service, controllers for the rheostatic control of one or more motors, which are designated as type R controllers. These do not provide for series-paralleling the motors, but control the speed by resistance in series only.

Certain features are common to all railway cylinder controllers. These are:

(a) Separate power and reverse cylinders with their handles mechanically interlocked to prevent improper operation.

(b) Magnetic blowouts and arc resisting shields to promptly disrupt arcs formed when breaking circuits.

(c) Cutout switches for disconnecting a damaged motor or pair of motors and still permitting the operation of the remaining motors.

(d) Asbestos-lined wood covers, which can be removed quickly.

(e) Easy removal and replacement of parts subjected to wear, such as fingers and segments, at a minimum expense.

(f) When the power has been lost, an emergency stop can be made with either the four-motor or two-motor controllers by using the motors as generators. In the case of the four-motor controllers it is necessary only to throw the reverse switch to the position which would give the opposite direction of motion with power on. In the case of two-motor controllers, in addition to turning the reverse switch as above, the controller must be turned to some parallel position.

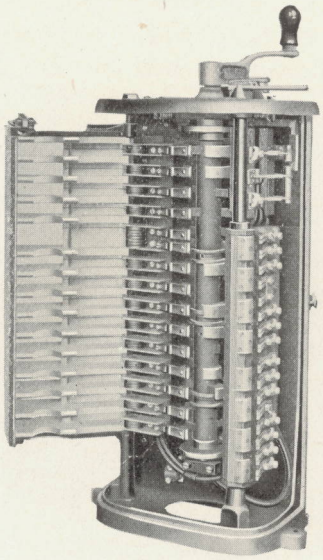


Fig. 19

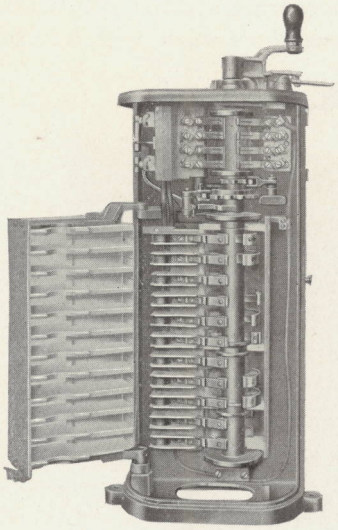


Fig. 20

STANDARD CYLINDER CONTROLLERS

STANDARD CYLINDER CONTROLLERS

With the advent of the commutating pole motor and the consequent use of higher operating voltages, a new line of cylinder controllers was developed. The present standard forms of these controllers with ratings, etc., are given in the accompanying tables, and Figs. 19 and 20 show the general appearance of these controllers. The type for electric braking is shown in Fig. 21.

Each finger is supplied with a separate magnetic blowout, consisting of a complete magnetic circuit, blowout coils and arc deflecting chutes. In order to extend the pole pieces to a point where arcing occurs, between the finger and segment, iron plates are imbedded in the insulation of the arc chutes. The arc chutes are made of a special moulded insulation compound, which does not carbonize under the influence of an arc.

Individual magnetic blowouts are provided for each main finger or group of fingers. These are so located that the arc is blown away from the cylinder.

The wiring has been greatly simplified by omitting the connection board and providing terminals at the finger bases to which incoming leads are directly connected. This eliminates a number of soldered connections and short pieces of cable. The cable is clamped firmly in position by tightening one screw.

Fig. 22 shows the construction of the main finger and magnetic blowout used in the later forms of cylinder controllers. This finger is built up of a straight strip of phosphor bronze re-enforced with laminated copper, and is furnished with a renewable drop forged copper tip riveted to the spring. The drop of the finger when leaving the segments is governed by an adjusting screw provided with a locking spring. This construction gives the finger

a large current carrying capacity with the desired flexibility and permits a perfect adjustment.

The cylinder shafts are made of hexagonal steel, which is covered with a tough insulating material illustrated in Fig. 23. This material is in the form of thin sheets, wrapped around the shaft, with a waterproof cementing binder between the layers, until the requisite thickness is obtained. This method of construction and the material used provide an insulation of high dielectric strength, and one which is not easily injured or affected by heat.

The cylinder castings for supporting the contact segments are made with a hexagonal hole to fit the insulation upon the shaft, and are held firmly in place by keys and set screws. The resulting structure affords great strength and permanence, and permits the ready removal and replacement of any part.

The segments are made of rolled copper bent accurately to shape, and secured by screws to the drum castings. Burning tips are provided at the ends of all but the shorter segments, so that when they are badly worn or burned by the constant breaking of heavy arcs they can be readily replaced. This eliminates the necessity for replacing an entire segment, as has heretofore been the practice.

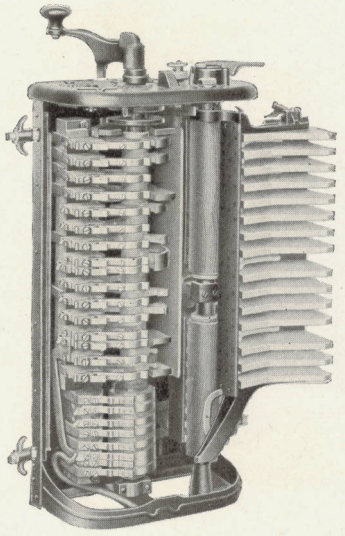


Fig. 21 RHEOSTAT BREAKING CONTROLLER

All standard railway cylinder controllers are furnished with wooden covers lined with asbestos. By this construction, flashovers, which sometimes occur, due to the arc jumping to a grounded metal cover and burning through it, are eliminated. With wooden covers lined with asbestos, even if the asbestos should become damaged, the wood is still a non-conductor and will not hold the arc.

CYLINDER CONTROLLERS FOR 1200 VOLTS

In most cases where high voltages are used, operating conditions are such that some type of remote control is the most suitable, but where the platform type of control is desired the R-200 and K-47 controllers have been developed for use on 1200 volt lines.

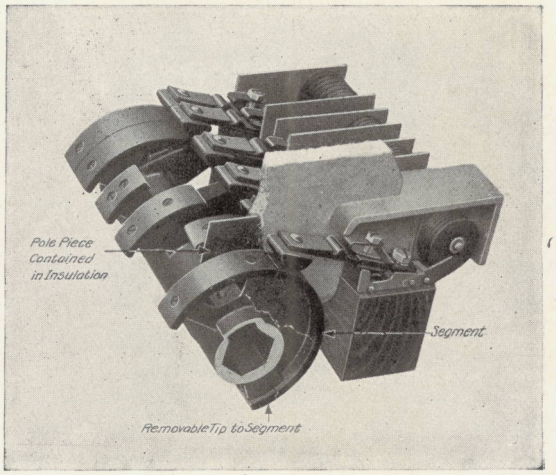


Fig. 22. DETAILS OF CONTROLLER FINGERS AND MAGNETIC BLOWOUT

LIST OF STANDARD CYLINDER CONTROLLERS

The ratings in Tables No. 3 and No. 4 are based on the hourly rating of the motors at normal voltage, and the continuous rating at three quarters normal voltage. When selecting controllers for a given motor equipment do not exceed the hourly rating in horse power or the continuous rating in amperes.

LINE BREAKER EQUIPMENTS FOR DRUM CONTROLLERS

The General Electric Company has recently developed a line breaker for use with drum controllers shown in Fig. 24. This line breaker has been designed primarily for the purpose of eliminating severe arcing from the controller fingers by breaking the main circuit by a line breaker located under the car body. It has the further advantage of eliminating the hand-operated circuit breakers usually mounted in the vestibule of the car, thereby making it practically impossible for objectionable flashing to occur on the car platform where it may be seen by passengers.

The new line breaker equipment consists essentially of a ratchet switch in the controller, combined switch and fuse for the protection of the line breaker circuit, and a box containing one line breaker and overload relay.

The ratchet switch closes when the controller handle is turned to the first point and remains closed throughout all succeeding positions of the operating handle. When the controller is notched back in the "off" direction the ratchet switch immediately opens, thus de-energizing the line breaker, causing it to open the main circuit regardless of the position of the operating handle. It is then necessary to turn the controller completely off, and on again to the first point, before the line breaker will close.

In case of overloads, the relay in the line breaker box trips out the line breaker, opening the main circuit. The relay is then held open until it is automatically reset by turning the controller to the off position.

The fact that the ratchet switch contacts open immediately on any backward movement of the controller handle, regardless of its position, insures a considerable reduction of the arcing in the controller and materially reduces the cost of maintenance.

The line breaker used is of the latest magnetically operated type and is provided with contact tips which may be easily renewed when necessary. A powerful magnetic-blow-out coil with large arc chute insures the disrupting of the arc under all service conditions.

The line breaker and overload relay, together with two enamel resistor tubes, are enclosed in a sheet metal box. This box with its contents weighs one hundred and sixteen pounds, and its small dimensions and the design of the cover permit its installation on cars having small wheels. Porcelain insulators are furnished for insulating the box from the car body.

The ratchet switch parts are small and compact allowing it to be installed in a large number of the older types of drum controllers. With the more recent designs space has been provided for the ratchet which makes its installation and maintenance much simpler. The controllers arranged in this latter manner include the letter R in the type symbol as K-36-JR.

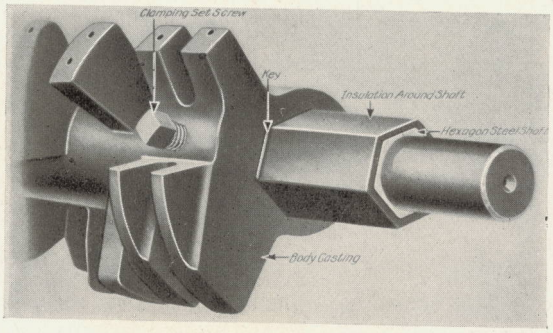


Fig. 23. HEXAGONAL SHAFT CONSTRUCTION OF CYLINDER CONTROLLERS

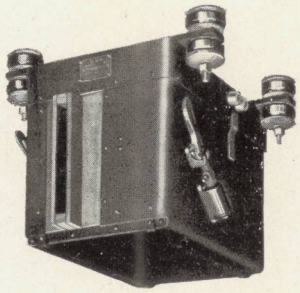


Fig. 24. LINE BREAKER

TABLE NO. 3

TYPE K CONTROLLERS FOR 600-VOLT SERVICE WITH MAXIMUM PEAKS OF 750 VOLTS

Type	No. of Motors	MAX. ALLOWABLE CAPACITY OF EACH MOTOR (NEITHER TO BE EXCEEDED)		Series	Parallel	Approximate Weight Lbs.	Weight Kilograms	Vol. Cu. Met.	Remarks
		Hourly Rated H.P. on 600 V.	Continuous Rating Amperes						
K-35-GR-2	4	65	60	5	3	270	122	48	
K-36-JR	2	70	66	4	4	225	102	43	
K-39-C	2	70	66	4	4	230	104	53	For Metallic return cir.
K-40-AR-2	4	65	60	5	5	280	127	55	For Metallic return cir.
K-51-A	2	70	66	5	4	250	113	49	For tapped field motors
K-63-BR	2	40	38	4	3	135	61	27	Single coil blowout
K-64-BR	4	110	105	6	4	450	204	70	Cont. furnished only with line breaker attachment

TABLE NO. 4

TYPE B CONTROLLERS FOR 600-VOLT ELECTRICAL BRAKING SERVICE WITH MAXIMUM PEAKS OF 750 VOLTS

Type	No. of Motors	MAX. ALLOWABLE CAPACITY OF EACH MOTOR (NEITHER TO BE EXCEEDED)		NO. OF POINTS			Approx. Weight Lbs.	Weight Kilograms	Vol. Cu. Met.	Remarks
		Hourly Rated H.P. on 600 V.	Continuous Rating Amperes	Series	Parallel	Brake				
B-54-A	2	75	75	4	3	7	270	122	51	Individual blowout coils
B-50-B	4	60	53	5	4	9	492	223	70	Individual blowout coils
B-51-B	2	120	105	5	4	9	492	223	70	Individual blowout coils

SPRAGUE GENERAL ELECTRIC MULTIPLE UNIT CONTROL

The Sprague General Electric multiple unit control system was designed primarily to permit a train of motor cars, when coupled in any combination, to be operated as a single unit from either end of any car of the train. The system has been very generally used on individual equipments.

Fundamentally, the system for each motor car may be considered as consisting of a motor controller and a master controller. The motor controller comprises a set of apparatus, which handles directly the current for the motors, while the master controller merely governs the operation of the motor controller, and consequently, does not handle the larger currents necessary in the motor circuit.

The best known form of multiple unit control is the Sprague General Electric type M. Its salient characteristic is the individual electro-magnetic operated contactors or switches that comprise the motor controller. Several thousand equipments of this control are in successful operation throughout the world. It has been, however, largely superseded by the type PC.

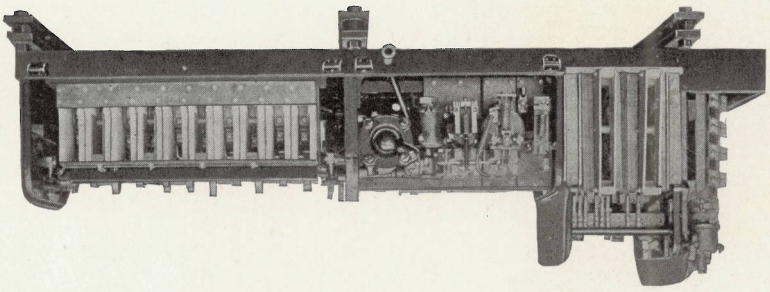


Fig. 25. LARGE 600-VOLT PC CONTROLLER (Front view)

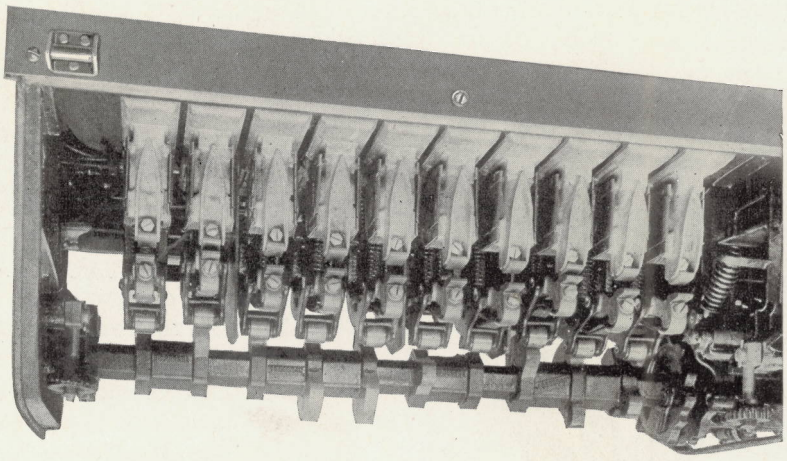


Fig. 26. TYPE PC CONTROLLER SHOWING CAMS

This latest development in the Sprague General Electric multiple unit control system is a cam operated motor controller. Before designing this controller, a thorough analysis of all existing control systems was made. As a result there has been

incorporated in this new control the following features:

1st. A definite sequence of contactor operation, preventing the trouble sometimes

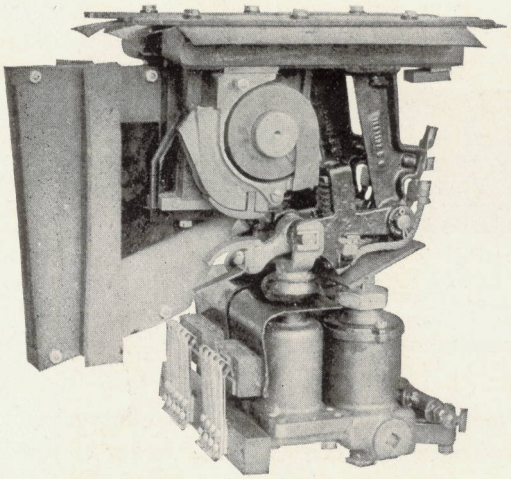


Fig. 27. LARGE PC MOTOR CONTROLLER LINE BREAKER—ONE ARC CHUTE REMOVED

encountered from improper functioning of independently operated contactors.

2nd. Interlocks on individual contactors eliminated.

3rd. Automatic acceleration with resulting power saving, improved passenger comfort, and low maintenance.

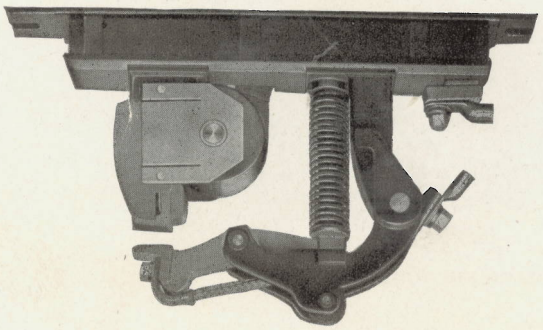


Fig. 28. LARGE PC CONTROLLER CONTACTOR UNIT

4th. Provision on the master controller by means of an advance lever so that the rate of acceleration may be increased or decreased for emergency conditions of operation.

5th. The master controller has a dead man's release. The fingers are self-adjusting and non-stubbing. The reverse handle has a safety catch, and is interlocked with the main drum.

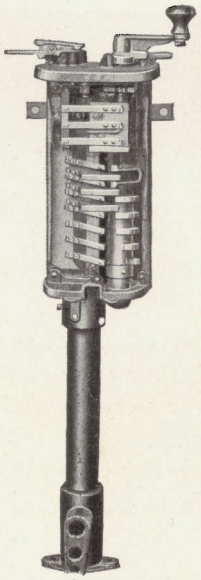


Fig. 29. MASTER CONTROLLER

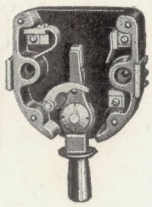


Fig. 30. CONTROL AND RESET SWITCH

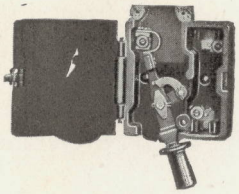


Fig. 31. MAIN CONTROL SWITCH AND FUSE

6th. Simplicity of electric control circuits.

7th. The simplicity and compactness of the apparatus, which permits the assembly of the contactors, reverser, line breaker, relays, etc., in one box.

8th. Installation cost reduced by all parts assembled in one box.

9th. Line breaker and contactors have powerful blowout coils, insuring positive arc rupturing with low maintenance.

10th. The overload relay trips line breaker before excessive currents can harm the equipment.

11th. The reverser is interlocked with the line breaker, so that the former cannot be thrown unless the latter is open.

12th. Should the power fail, the motor controller returns automatically to the "off"

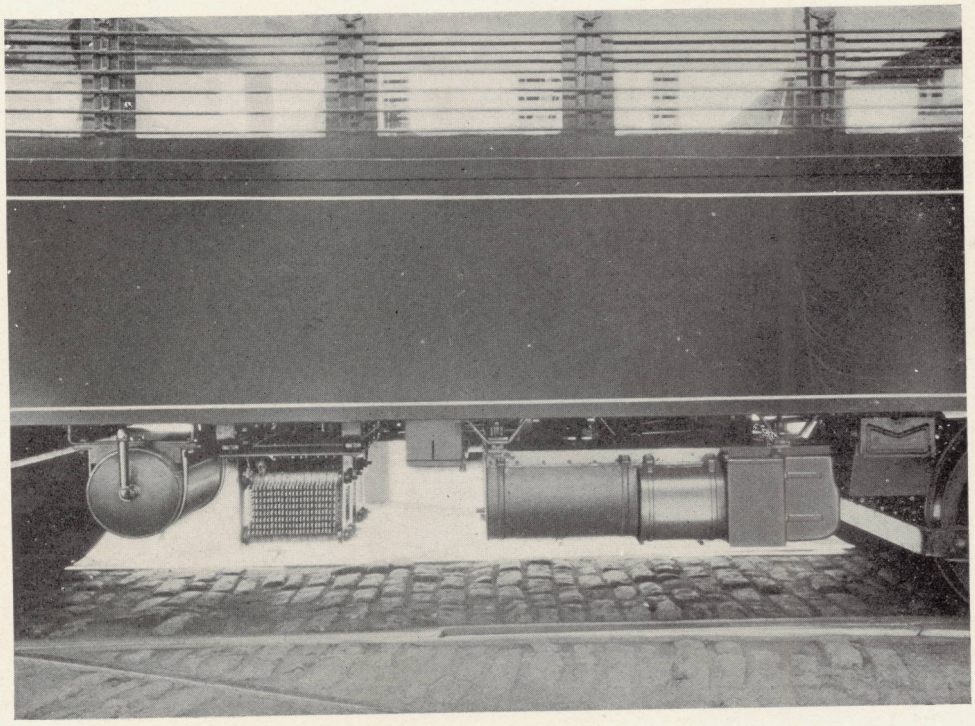


Fig. 32. PC CONTROL AND RHEOSTATS INSTALLED UNDER CAR

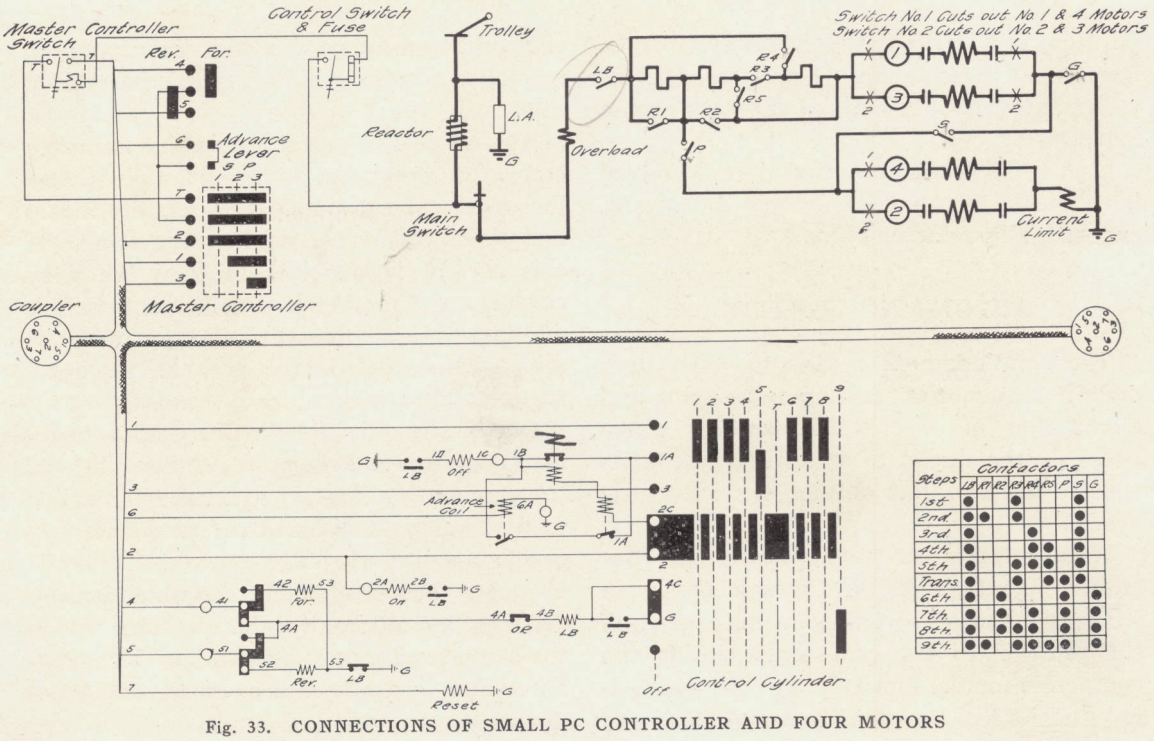


Fig. 33. CONNECTIONS OF SMALL PC CONTROLLER AND FOUR MOTORS

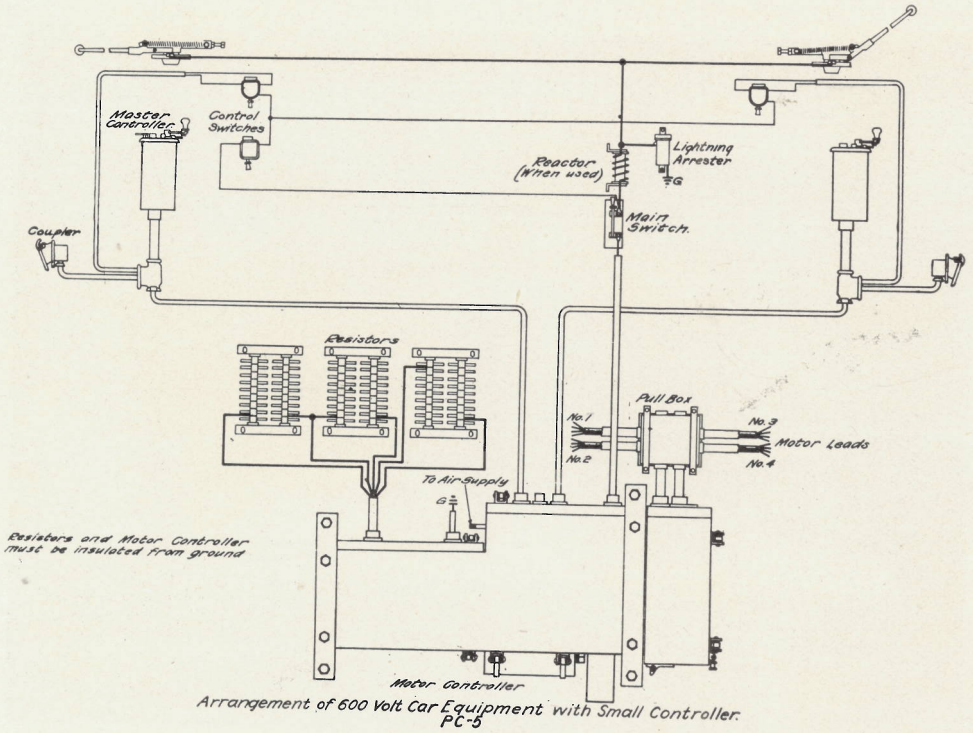


Fig. 34. CONNECTIONS FOR LARGE PC CONTROLLER FOR FOUR MOTORS

position, and if the master controller handle is retained in an operating position, the car starts automatically without jar when power is restored.

13th. The contactor arc chutes assembled in a single group that swings downward, exposing all contactor parts.

AUTOMATIC CONTROL

The cam operated contactors with their definite sequence of opening and closing and elimination of electrical interlocks make posssible the design of an automatic control that is simpler than former non-automatic types.

With automatic control, the master controller operates directly through the train wires, the motor reverser, line breaker and the rotation of the cam shaft closing the contactors for the first step, but the succeeding positions of the cam shaft and closing of the contactors are controlled indirectly by the master controller through the accelerating relay.

The scheme of operation is that, as each section of resistance is cut out of circuit, an increased current passes through the motor and series coil of the accelerating relay. If this current is sufficient to open the relay contacts, the progression of the cam shaft is arrested until the current falls to a predetermined value, and, in this manner, the automatic accelerating feature is secured.

One of the objections in the past to automatic control has been the inflexibility of the accelerating limit in so far as overcoming grades, pulling a disabled car or other emergency conditions. The General Electric Company has overcome these objections by devising an automatic control from which the same results may be obtained as a non-automatic control under emergency conditions.

TABLE NO. 5

LIST OF STANDARD TYPE PC CAM-OPERATED CONTROLLERS

Controller	No. of Motors	RATING OF EACH MOTOR, NEITHER TO BE EXCEEDED				Weight Kilo-grams	Volume Cubic Meters
		Hourly H.P. at 600 Volts	Amperes at 75% of Rated Voltage	Full or Tapped Field	Weight Lb.		
SMALL CONTROLLER—600 VOLTS							
PC- 5	4	70	75	Full	525	238	82
PC- 6	2	140	135	Full	530	240	82
PC- 9	2	70	75	Tapped	530	240	82
LARGE CONTROLLER—600 VOLTS							
PC-10	2	250	200	Full or Tapped	1027	466	156
PC-12	4	150	140	Full	985	447	206

When a car will not accelerate with the current at which the accelerating relay is set, the operator moves the advance lever on the controller cap plate. This advances the motor controller one point. The operation is repeated if necessary. By this means the motor controller may be notched up to and held on any point desired. Likewise if the acceleration is too rapid, as a slippery rail, a lower rate than the accelerating limit is obtained by holding the advance lever closed. From this it is evident that under emergency conditions the accelerating rate is as flexible as with a non-automatic control.

The line breaker, reverser and contactors are actuated by air pressure controlled by magnet valves. The line breaker and reverser are provided with individual magnet valves and air cylinders, while a cylinder with a double piston and two valves is used for the operation of all the contactors. The contactors are actuated by cams mounted on a shaft, which is rotated by a rack and pinion. Air is admitted to, or exhausted from, the air cylinder by means of magnet valves, controlled by the master controller.

Figs. 25 to 31 show the general features of these controllers, line breakers and switches, and Fig. 32 indicates the appearance of the equipment mounted under a car. Figs. 33 and 34 are connection diagrams of the small and large type controllers, and Table No. 5 gives ratings and other data.

CURRENT COLLECTORS

The current collectors furnished by the General Electric Company are of the trolley base type.

This collector is universally used throughout the United States on both high and low speed cars.

It consists of a malleable iron support fastened to the car (Fig. 35) with a pole, harp and wheel swiveling around the support on an anti-friction bearing. The wheel is held in contact with the wire by spring pressure and lowered by pulling down with a rope.

The contact surfaces of the wheels are made of an alloy found by practice to be particularly suitable for its purpose.

CIRCUIT BREAKERS

The circuit breakers used with cylinder control equipments are especially designed for railway service. They will automatically break the main circuit in case of excessive

overload or short circuits and can be used as hand operated main circuit switches. The contacts are held closed by a powerful spring held in position by a latch. When an overload occurs the latch is tripped and the contacts

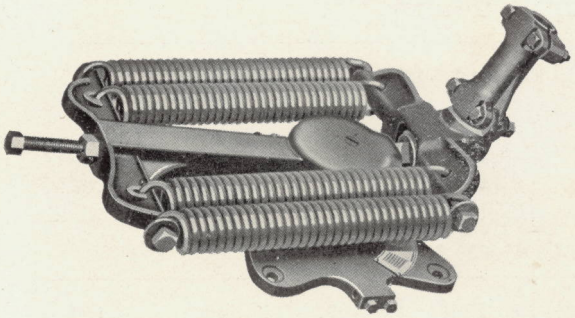


Fig. 35. U. S.-13 CURRENT COLLECTOR BASE

forced open while the arc is extinguished by a very effective magnetic blowout.

By means of a thumb screw and spring the circuit breaker can be adjusted to trip automatically at any point between its calibration limits.

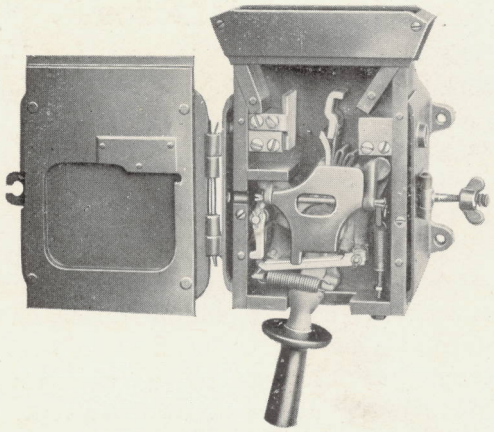


Fig. 36. TYPE MP-12-D AUTOMATIC CIRCUIT BREAKER

The cover over the working parts is easily removed. This construction makes them readily accessible for inspection.

The complete circuit breaker (Fig. 36), is arranged for easy installation in the hood or canopy of the car adjacent to the controller.

LIGHTNING ARRESTERS

Since the beginning of electrical railway work the General Electric Company has studied the problem of protecting car equipments with the result that actual experience shows conclusively that modern G-E arresters do protect.

The arrester used for railway cars consists of a small spark gap in series with a limiting resistance between line and ground, and an electro magnet arranged to extinguish the flow of generator current in the spark gap and thus restore normal conditions after

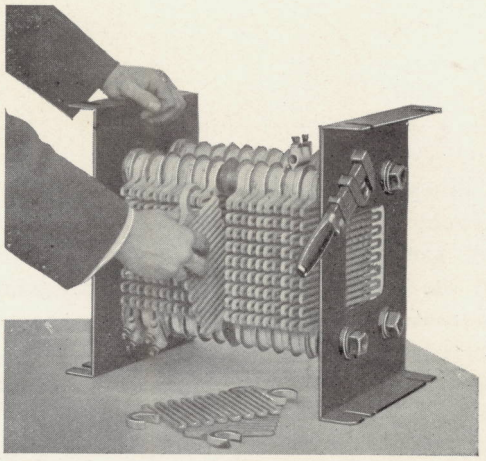


Fig. 37. METHOD OF REPLACING RESISTORS

a lightning discharge. The arrester is mounted in a suitable wood case so that it may be readily installed.

MOTOR RESISTORS

Years of experience with railway apparatus shows that the motor resistor must be made with short convolution of the resistor element to withstand the vibration received in service as well as to prevent sagging when overheated.

From the maintenance view point the grids must be readily replaceable in case of breakage and under these conditions the insulation should not be damaged. The slotted lugs make removal and replacement easy (Fig. 37), and the metal spool over the mica

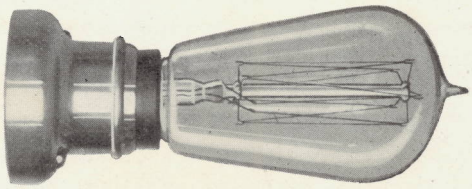
insulating tube prevents abrasion of it when replacements are made.

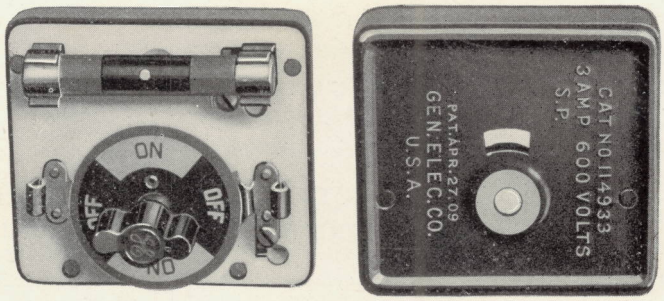
The resistors (Fig. 38), have two insulations in series between the grids and ground. The insulation between the grids and frame is mica while that between the frame and ground consists of porcelain collars held in place by the bolts supporting the resistor. The use of porcelain has been found particularly advantageous as it does not carbonize if current passes over its surface when damp, or covered with a layer of conducting material like dust from the brake shoes.

CAR WIRING CABLE

Car wiring cable, made by the General Electric Company, is stranded of high conductivity, tinned copper wire and insulated with a high grade of rubber compound which was developed after many years of experience and a long series of tests both in the electrical and chemical laboratories. The resulting compound is noted for its durability and high insulating qualities.

The finished cables are subject to a high potential test, from two and one-half to five times the working pressure at which the cables are rated; tests being made after not less than twelve hours immersion in water.





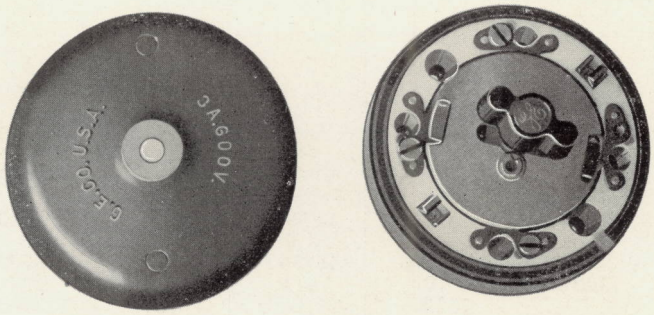


Fig. 39. A 23-WATT LAMP AND SWITCHES FOR STANDARD LIGHTING EQUIPMENT

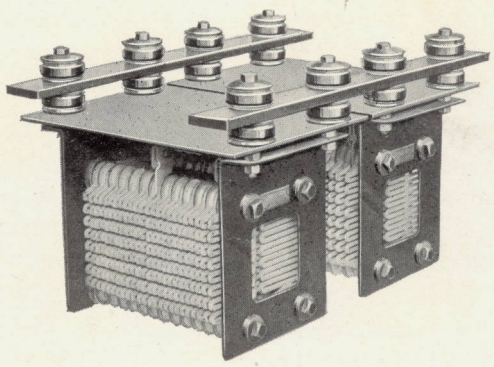


Fig. 38. METHOD OF MOUNTING RG RESISTOR WITH 600-VOLT PORCELAIN BOLT INSULATORS

To facilitate the making of splices and attaching terminals to the cables, all cables have a separator between the conductor and rubber jacket thus making it easier to strip off the insulation and leaving the conductor clean for soldering.

The rubber insulation is protected with either a double braid of cotton or a rubber filled cotton tape and a cotton braid. The cotton braids are filled with a black weatherproof compound. These compounds preserve the cotton from deterioration caused by moisture and other atmospheric conditions.

The cables are made with seven individual

strands for sizes of No. 2 B&S and smaller. The larger sizes have nineteen individual strands.

Table No. 6 shows the cross section of cables used with railway motors on car equipments.

LIGHTING

Fig. 39 shows the lamp, socket and switches furnished with standard lighting equipments.

All of these devices have been made particularly strong and sturdy for car service.

With two motor cars an 18-lamp equipment is furnished consisting of:

18-23-watt Lamps
16 Sockets
3 Switches
300 Ft. Cable

While with four motor cars a 29-lamp equipment is furnished. This consists of:

29-23-watt Lamps
27 Sockets
3 Switches
450 Ft. Cable

TABLE NO. 6

CROSS SECTION OF CABLE FOR CAR EQUIPMENTS

CROSS SECTION IS INDICATED BY BROWN AND SHARPE GAUGE NUMBERS AND CIRCULAR MILS.

Normal Motor H.P. at 600 Volts	TROLLEY AND GROUND		MOTOR		RESISTOR		
	2-Motor	4-Motor	1-Motor	2-Motor	4-Motor	2-Motor	1-Motor
25	5 33100	2 66370	7 20790	5 33100	6 26250	7 20790	7 20790
40	4 41740	1 83690	6 26250	4 41740	4 41740	6 26250	7 20790
50	4 41740	0 105500	6 26250	3 52630	3 52630	6 26250	7 20790
65	3 52630	2/0 133100	5 33100	1 83690	2 66370	5 33100	7 20790
75	1 83690	3/0 167800	4 41740	0 105500	2 66370	4 41740	6 26250
100	0 105500	4/0 211600	3 52630	2/0 133100	0 105500	3 52630	6 26250
110	0 105500	 250000	3 52630	2/0 133100	0 105500	3 52630	6 26250
125	2/0 133100	 300000	2 66370	3/0 167800	2/0 133100	2 66370	5 33100
140	3/0 167800	 350000	1 83690	4/0 211600	2/0 133100	1 83690	5 33100