eighty-two teeth in the gear, and for the passenger locomotives there are twenty-nine teeth in the pinion and seventy-one teeth in the gear. Both gears and pinions are made of high-carbon oil-treated stock, having an elastic limit of 85,000 pounds per square inch.

The gear cases are made of sheet steel with rim and sides securely riveted together. The supporting brackets extend over the rim of the case and are securely riveted to the rim and sides. The magnet frame is made of cast steel and, except in size, differs but little in general appearance from standard box frame railway motors.

The front of the motor is carried on the truck through an improved spring suspension. The design is such that both the downward and upward thrust is taken through springs. This form of suspension largely reduces the shock on the motor in passing over switches, crossings or other rough places in the track. The spring gears, and to a less extent the motor suspension, relieves the teeth of the gears of "hammer blows," a equalizes the load on the pinion and g teeth at each end of the motor.

The brush-holder design is of stand construction. The holders are suppor and protected from the ground through m insulated studs.

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THE CONTROL EQUIPMENT, WITH REGENERATIVE ELECTRIC BRAKING FEATURE, ON THE LOCOMOTIVES OF THE CHICAGO, MILWAUKEE & ST. PAUL RAILWAY

By R. Stearns

Railway Equipment Department, General Electric Company

The author describes the control features of the St. Paul locomotives in great detail. The article profusely illustrated which greatly helps an understanding of the text. Special attention is paid to t regenerative control.—Editor.

The engineer of a single 282-ton St. Paul electric locomotive has an enormous concentration of power at his command. The ease, efficiency, reliability and safety with which this power is made to serve the purpose of the engineer, while he maintains his train schedule involving wide variations in locomotive speeds, up and down grade, over the rugged profile of the Rocky Mountains, depends in a large measure upon the motor control equipment.

Owing to the great power needed in this exacting transcontinental service, the control design, both mechanically and electrically, includes many interesting departures. Particularly owing to the economic and safety requirements of definite speed regulation by electrical means down grades, the novel feature of regenerative electric braking has been provided in addition to the air brakes.

COLLECTION OF CURRENT

The system of current collection, which must be capable of handling unusually heavy currents at high speeds, has the distincti feature of using two parallel adjacent cop conductors supported alternately and ind pendently, by loop hangers from the sa messenger wire. A continuously flexi contact surface, for the most part double area, is thus obtained. In additio each pantograph is equipped with two sl ing contacts. Ordinarily, therefore, there a four points of contact between the collect and the trolley wires. With this very fle ible combination a single pantograph, (a there are two on all locomotives for eme gencies) can easily collect the heavy cu rents obtaining in the St. Paul servi Sparking is entirely eliminated. The curre required for a single locomotive at the co tinuous rating of the motors is 840 amper In the passenger service, speeds up to m.p.h. and over are attained.

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The front of the motor is carried on the truck through an improved spring suspension. The design is such that both the downward and upward thrust is taken through springs. This form of suspension largely reduces the shock on the motor in passing over switches, crossings or other rough places in the track. The spring gears, and to a less extent the motor suspension, relieves the teeth of the gears of "hammer blows," and equalizes the load on the pinion and gear teeth at each end of the motor.

The brush-holder design is of standard construction. The holders are supported and protected from the ground through mica insulated studs.

In service the motors have operated with most excellent results. The commutators take on a bright, smooth polish, with no indications of etching at the edges of the segments. The effect of the spring gears and spring suspension is to make the motors run with unusual quietness. There is no noticeable gear noise while the locomotives are in motion. The absence of vibration is also noticeable. This is quite a marked contrast to heavy twin geared motors when operating without spring gears and spring nose suspension. The motors run at a comparatively low temperature in service, the capacity of the motors being sufficient to handle heavier trains than originally contemplated.

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Owing to the great power needed in this exacting transcontinental service, the control design, both mechanically and electrically, includes many interesting departures. Particularly owing to the economic and safety requirements of definite speed regulation by electrical means down grades, the novel feature of regenerative electric braking has been provided in addition to the air brakes.

COLLECTION OF CURRENT

The system of current collection, which must be capable of handling unusually heavy currents at high speeds, has the distinctive feature of using two parallel adjacent copper conductors supported alternately and independently, by loop hangers from the same messenger wire. A continuously flexible contact surface, for the most part of double area, is thus obtained. In addition, each pantograph is equipped with two sliding contacts. Ordinarily, therefore, there are four points of contact between the collector and the trolley wires. With this very flexible combination a single pantograph, (and there are two on all locomotives for emergencies) can easily collect the heavy currents obtaining in the St. Paul service. Sparking is entirely eliminated. The current required for a single locomotive at the continuous rating of the motors is 840 amperes. In the passenger service, speeds up to 60 m.p.h. and over are attained.

Figs. 8 and 9 are characteristic curves based on 3000 volts line showing the amperes per motor obtained, at different locomotive speeds, in the freight and passenger service respectively. The current input through the collector as required by the eight traction motors is four times the ampere per motor reading as indicated.

The engineer controls the operation of his pantographs by means of an air valve. To raise the pantograph, air from the main reservoir is admitted to a pair of cylinders. The pistons of these cylinders energize powerful springs which in turn raise the collector and at the same time regulate the pressure against the trolley wire. The raising springs are energized at all times while the collector is in use, by maintaining air pressure in the cylinders. To lower the pantograph, air is exhausted from the cylinders, thus de-energizing the springs. The pantograph will then drop to its minimum collapsed height. The range of action of the trolley is between 17 feet and 25 feet above the rail.

As air is necessary to raise the pantographs, an auxiliary trolley pole with swivel base is supplied to collect current for the air compressor whenever the locomotive is first put into service. Fifty pounds is the minimum operating air pressure.

Fig. 1 shows one of the St. Paul locomotives equipped with two pantograph trolleys and also the auxiliary pole trolley used for starting purposes. It may be noted that the locomotive has two cabs. The pantographs installed on these cabs are connected by a bus line, so the duplex electrical equipments can be supplied from either trolley.

3000-VOLT PROTECTIVE APPARATUS

When 3000 volts was chosen as the desirable line potential for transmitting the great energy required by the locomotives of this extensive railway system, a further innovation was introduced into the design of the control equipment. It was appreciated from experience that, provided the protective devices in the main trolley circuit are reliable, short circuits clear themselves more quickly with high than with low voltages, and there is less attendant damage. The design of the main emergency switches and fuses was considered of great importance and these devices were accordingly mounted in a single high tension compartment of ample dimensions. Figs. 2 and 3 show this compartment.

The trolley lead starting from the pantograph trolley first enters the high tension compartment and is divided into two circuits, —main and auxiliary. A combination switch and fuse shown at the left in Fig. 3 is in the main circuit. An identical combination switch and fuse (except that a lower capacity fuse is used) is shown at the right of the picture. From the main switch and fuse, the main power lead goes directly to the controlling apparatus of the traction motors.

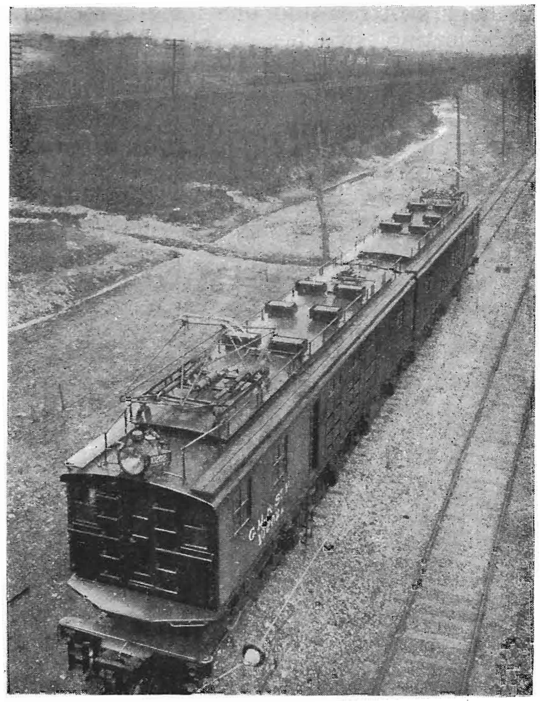

Fig. 1. St. Paul Locomotive Showing Twin Shoe Sliding Pantograph Trolley and Auxiliary Pole Trolley

The auxiliary lead passes to the four disconnecting switches shown at the top of the compartment and from there separate supply leads run to the motor generator set, air compressor and cab heater.

The compartment is made of sheet steel strongly reinforced with angle and channel irons and is thoroughly lined with insulation. A great saving in space has been effected by using for each combination switch and fuse a single arc chute containing two stationary contacts to which the incoming and outgoing leads are attached. The feature which combines the functions of switch and fuse consists in a cradle pivoted at one end carrying, on high voltage insulators, the supports for a copper ribbon fuse. These supports also carry spring contacts which complete the function of a switch. When the cradle is raised or lowered by a handle external to the compartment, the pair of spring contacts engages with the two stationary contacts and in this way closes or opens the switch. When the switch is closed the fuse is in circuit and automatically protects the circuit against overload.

The high tension compartment is equipped with three doors; one each for the main and auxiliary switches and one for the separate disconnecting switches. These doors are interlocked with the external operating handles so that no conducting parts can be approached without first opening its circuit by dropping the switch cradle. When either switch cradle is dropped it will be noted its fuse is entirely disconnected from the circuit.

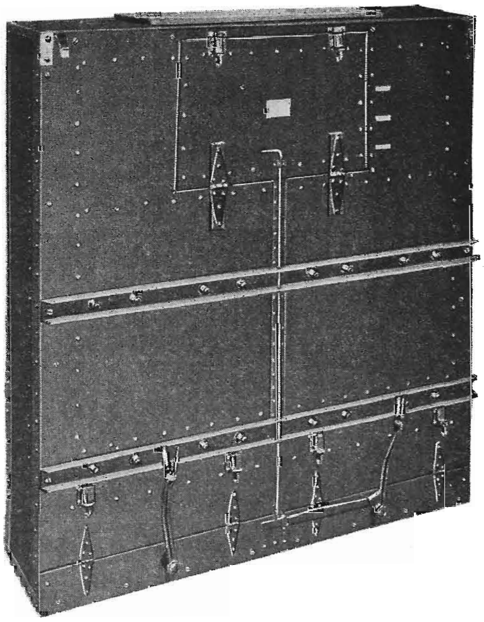

Fig. 2. 3000-volt Switch and Fuse Compartment

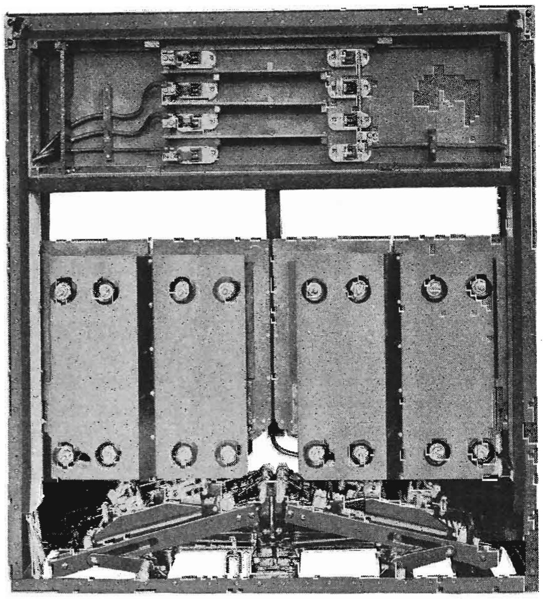

Fig. 3. 3000-volt Switch and Fuse Compartment with Sheet Steel Front Removed Showing Arc Chutes and Contact Mechanism

In addition to the protective apparatus in the high tension compartment, a 3000-volt aluminum cell lightning arrester is tapped into the main lead near the collectors. The lightning arrester, installed in a grounded sheet iron box, is mounted on the back of the high tension compartment.

3000-VOLT CONTACTOR COMPARTMENT

Aside from the apparatus already mentioned, the 3000-volt equipment of a locomotive consists of eight traction motors; two air compressor motors; two cab heaters; two driving motors for the motor generator sets; and the control equipment for all these devices. Since all this 3000-volt equipment is in duplicate, the following description will cover only that portion located in one of the two cabs which is entirely independent in operation. This controlling apparatus is grouped in a sheet iron compartment located near the center of the cab. Allowing for aisles on either side, the space occupied by this compartment, extends from the floor to the roof of the cab.

The complete set of rheostats used in regulating the current in the four traction motors is assembled at the bottom of the compartment along the floor of the cab. Each rheostat is mounted upon 3000-volt insulators as shown in Fig. 4. The rheostat is of the cast grid type shaped to effectively meet the space limitations of locomotive service. The remaining controlling apparatus is located in four groups directly above the rheostats. The rheostats are separated from the equipment groups above by a partition. The bottom of the rheostat compartment is open, and complete ventilation of the rheostats is obtained through six chimneys leading up to ventilators at the top of the cab. The control groups are installed between the chimneys. An idea of the space occupied by all this part of the equipment may be obtained by reference to Fig. 1 which shows clearly the location of each chimney.