THE ELECTRIFICATION OF THE MOUNTAIN DISTRICT OF THE CHICAGO, MILWAUKEE & ST. PAUL RAILWAY

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The author gives a brief description of the physical characteristics of the Chicago, Milwaukee & St Paul Railway electrification and comments briefly on the principal features involved. Detailed description of the locomotives, substation layout, motor generator sets, switchboards, etc. is contained in other articles in this issue.—Editor.

The Chicago, Milwaukee & St. Paul Railway is the most recent transcontinental line to cross the western states to the Pacific Coast, its lines being extended about seven years ago from Mobridge, South Dakota to Seattle and Tacoma in the state of Washington. This step was accomplished by building 1420 miles of road across the Rockies, the Bitter Root and the Cascade Mountain ranges. Unlike the earlier transcontinental railroads, this project received no grants of public land or other governmental aid. The engineers and financial backers, however, did not fail to profit by the mistakes of earlier roads and the route chosen is the shortest line from Chicago to the Pacific North Coast and the roadbed is of the most permanent character. The Milwaukee system now includes over 10,000 miles of track and is one of the most extensive systems in the United States. This progressive railway company owns and operates all train equipment including parlor, sleeping and dining cars and runs over its own rails the entire distance from Chicago to the Pacific Coast.

The Electrified Divisions

The tracks of the mountain district of the Chicago, Milwaukee & St. Paul Railway, in surmounting the obstacles imposed by the Rocky Mountain and coastwise ranges, represent the solution of one of the most difficult problems ever mastered by railway engineers. Out of this section of rugged mountain railway, including many long grades and short radius curves, four steam engine divisions were selected for electrification aggregating 440 miles in length. Steam engines were first abandoned on the Three Forks—Deer Lodge Division, 115 miles long and crossing the main Continental Divide, thus giving the electrical equipment its initial tryout under the severest service conditions of the entire system. The first electric locomotives were placed in regular service on December 9, 1915, and during the month of April 1916, service was extended to Harlowton, making a total of 226 miles of electrically operated road. By the beginning of 1917, it is expected that steam engines will be superseded over the entire distance from Harlowton, Montana, to Avery, Idaho.

This project is the most extensive steam railway electrification in the world, the length of haul being nearly six times as great as any trunk line now operating with electric locomotives. The length of track to be electrified is approximately equal to that from New York to Buffalo or from Boston to Washington.

In crossing the three mountain ranges included in the electric zone, there are several grades of one per cent or more, the most difficult being the 21 mile two per cent between Piedmont and Donald, and the longest the 49 mile one per cent grade on the west slope of the Belt Mountains.

The curvature is necessarily heavy, the maximum being ten degrees. There are also numerous tunnels in the electric zone, 36 in all, the longest being the St. Paul Pass Tunnel, over a mile and a half in length piercing the ridge of the Bitter Root Mountains.

Passenger and Freight Traffic

The passenger service consists of two all-steel finely equipped transcontinental trains in each direction, the "Olympian" and "Columbian" and a local passenger train in each direction daily between Deer Lodge and Harlowton.

Freight traffic through the electric zone comprises from four to six trains daily in each direction. Westbound, the tonnage is made up of manufactured products and merchandise for Pacific Coast points and foreign shipment. Eastbound tonnage includes grain, lumber, products of the mines and live stock.

The larger part of the traffic is through freight. Trains are made up of an assortment of foreign cars, including box and flat cars, coal and ore hoppers, stock cars, refrigerators, etc., varying in weight from 11 to 25 tons empty and as high as 70 tons loaded. These cars being owned by many different railway systems are equipped with air brakes adjusted for different conditions of operation, and in accordance with different standards as to braking power and type of equipment, thus making the problem of holding the long trains on the heavy down grades by air brakes, a most difficult undertaking.

Electrical Operation

Electrification promises a material reduction in running time. It has been found, for example, that on the 21 mile two per cent. grade from Piedmont to Donald, the electric locomotive can reduce the running time of passenger trains from an hour and five minutes to approximately 40 minutes. On the run from Deer Lodge to Butte which, under the steam locomotive schedule, required one hour and 20 minutes, a saving of approximately 30 minutes can be made.

In the freight service, it has been found that on the first division where the steam locomotives have required 10 to 12 hours to make 115 miles, electric locomotives can meet a schedule of from 7 to 8 hours for the same distance. The heavy grades and frequent curves at certain points offer serious obstacles to steam locomotive operation even in the summer time, but with winter temperatures as low as 40 deg. F. below zero and heavy snowfalls in the Bitter Root Mountains, serious delays have occurred owing to engine failures or to inability to make steam. The capabilities of the electric locomotive are in no way impaired by cold weather or by inability to obtain fuel or water in case of snow blockades. During a series of record-breaking temperatures in December 1915, Mallet engines were frozen up at different points on the system and the new electric equipment was rapidly pressed into service to replace them. On several occasions electric locomotives hauled in disabled steam engines and trains which would otherwise have tied up the line.

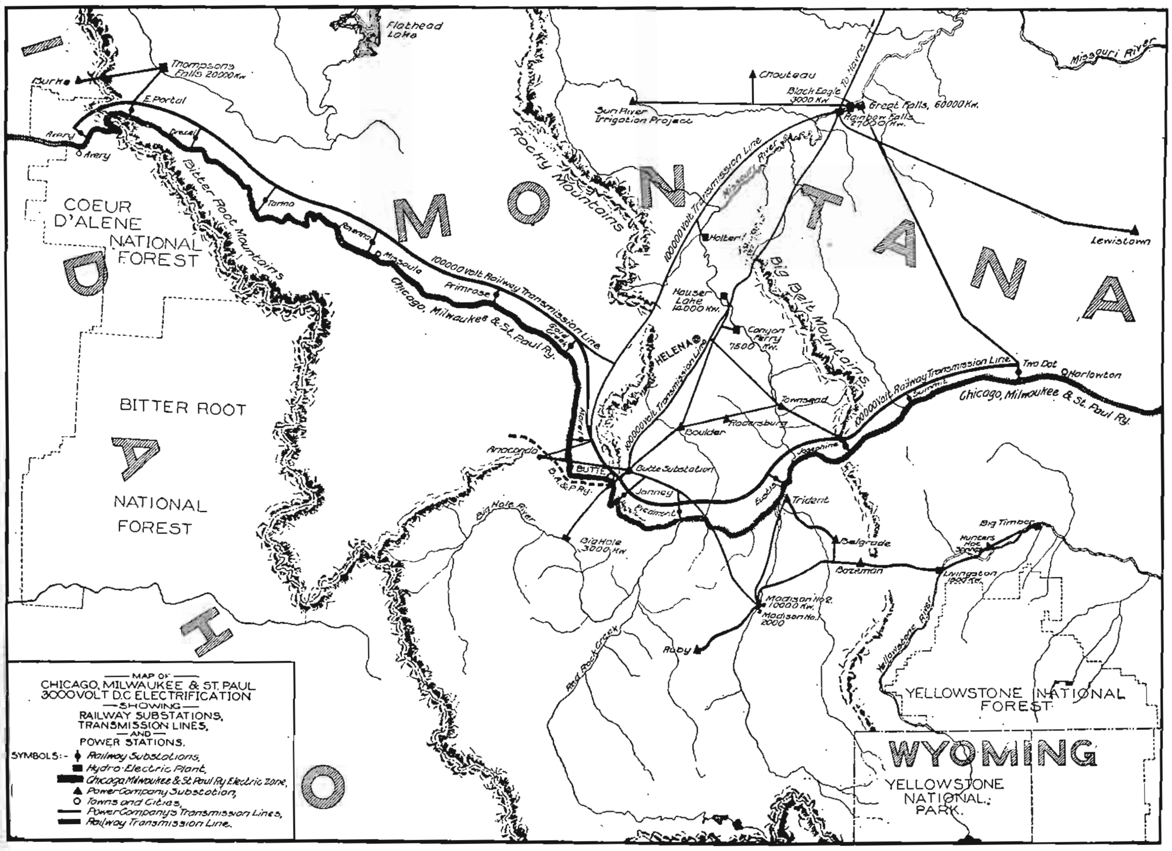

Fig. 1. Map of the Chicago, Milwaukee & St. Paul Electric Zone

During initial operation on the Rocky Mountain Division, the capacity of the new locomotives has been thoroughly tested. Trains of 3000 tons trailing have been hauled east and 2800 tons west, using a helper on the heavy grades. From the operating data obtained on the first division, it is evident that much heavier trains can be hauled with the electric locomotives than with steam engines and all passing tracks are being lengthened to one mile to take advantage of longer trains. On some of the runs where the grades are less than one per cent trains of as many as 130 cars and as heavy as 4000 and 5000 tons are hauled with a single locomotive.

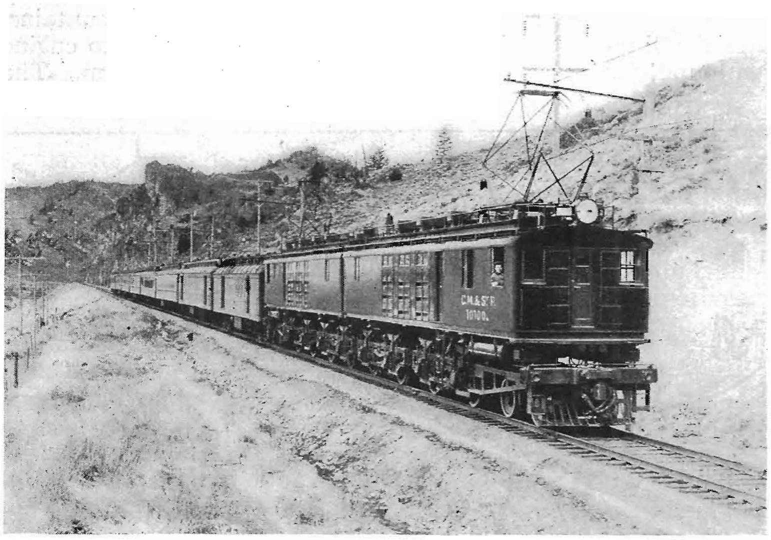

Fig. 2. All-steel Passenger Train "Olympian" in Silver Bow Canyon

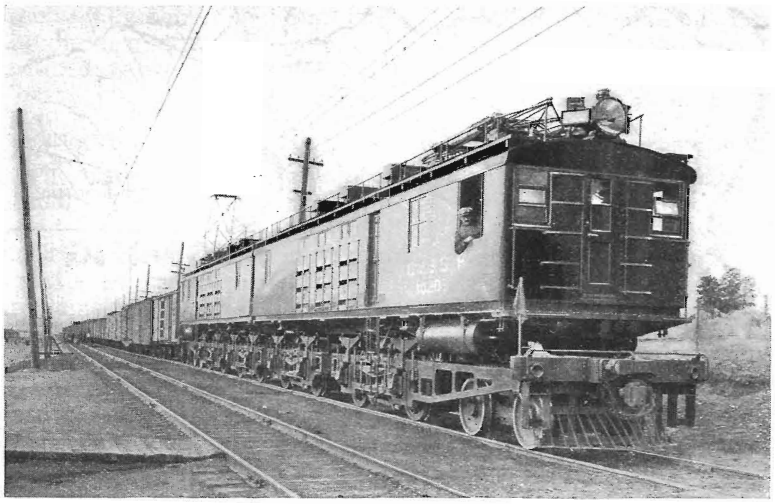

Fig. 3. Electric Locomotive and Freight Train on 2 Per Cent Grade at Grace

The four through passenger trains "Olympian" and "Columbian" are taken across the two mountain ranges by a single passenger locomotive. These trains at present consist of nine full vestibuled steel coaches weighing approximately 650 tons. Instead of changing locomotives at Three Forks as has been the practice under steam operation, the same locomotive is run through the 226 miles from Deer Lodge to Harlowton, changing crews midway. Passenger trains will travel over the entire electrified division in approximately 15 hours including all stops and the tourist thus will have an opportunity of traversing by daylight some of the most beautiful scenic regions in the United States and without suffering the annoyance of cinders and smoke incident to the use of steam locomitives. The local passenger trains operating in the electric zone between Deer Lodge and Harlowton are handled by half units weighing about 150 tons with equipment similar to the main line locomotives.

Regeneration

Regeneration or the recovery of energy on descending grades by reversing the function of the motors reduces the cost of operation and furnishes a ready solution of the difficult braking problem. On the long sustained grades encountered in crossing the three mountian ranges, great skill is required to handle either the heavy and varied freight or the high speed passenger trains with the usual air brakes.

The stored energy due to gravity which must be dissipated by the friction of the brake shoes on the wheels approximates 3500 kw. or 4700 h.p. for a 2500-ton train running at 17 miles per hour on a 2 per cent grade. This explains why it frequently happens that brake shoes become red-hot and other serious damage is done since all of the potential energy stored in the train at the summit of the grade must be dissipated during the descent.

With regenerative braking, the motors become generators which absorb the energy of the descending train and convert it into electricity, thus restricting the train to a safe speed down the grade and at the same time returning electric power to the trolley for use by other trains. The strain on drawbars and couplings is reduced to a minimum since the entire train is bunched behind the locomotive and held to a uniform speed. The electric-braking mechanism automatically controls the speed by regulating the amount of energy fed back to the line. This smooth and easy descent is in marked contrast to the periodical slowing down and speeding up of a train controlled by air brakes.

In case there are no other trains between the substations to absorb the power generated by a descending train, this power passes through the substation machinery, is converted from direct to alternating current and fed into the distribution system connecting all substations. The Power Company's lines are so extensive and the load of such a diversified character that any surplus power returned by regenerating locomotives can readily be absorbed by the system, credit being given for all energy returned.

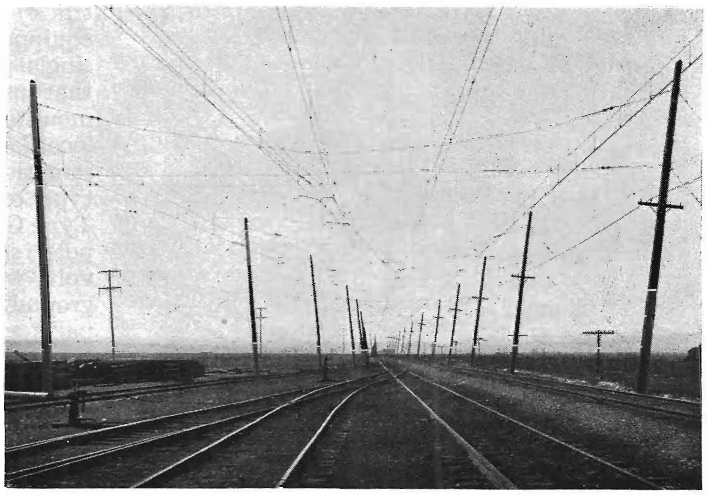

Fig. 5. Typical Overhead Work at the Entrance of Three Forks Yards

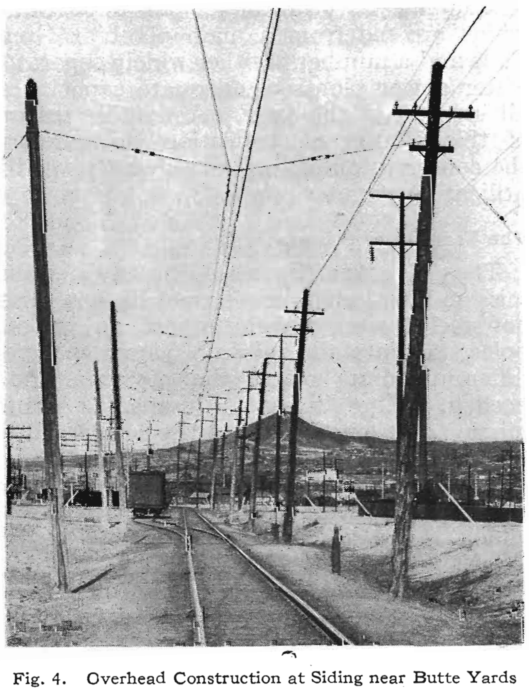

Fig. 4. Overhead Construction at Siding near Butte Yards

Electrical Equipment

The scheme of electrification includes the generation of electricity from the several water power plants of the Montana Power Company; transmission at 100,000 volts, three-phase, 60 cycles; conversion in substations to 3000 volts direct current and distribution over catenary overhead construction to electric locomotives.

Electric Locomotives

The development of the electric locomotive is primarily the achievement which has made electrification of trunk lines feasible. There are 42 of these main line locomotives (30 freight and 12 passenger) and two switching locomotives. The locomotives are the first to be used for railroad service with direct current motors operating at a potential as high as 3000 volts* and the first to use direct current regeneration.

Control

The control equipment is the well-known Sprague General Electric Type "M" arranged for multiple unit operation. The main control switches are mounted in steel compartments inside the locomotive cab with convenient aisles for inspection and repairs. A motor-generator set in each half of the locomotive furnishes low voltage current for the control circuits, headlights, cab lighting and for charging the storage batteries on the passenger coaches. Under steam operation, the charging current for these batteries is furnished by a steam turbo-generator set located in the baggage car. The blower for ventilating the traction motors is also direct connected to one end of the motor-generator set.

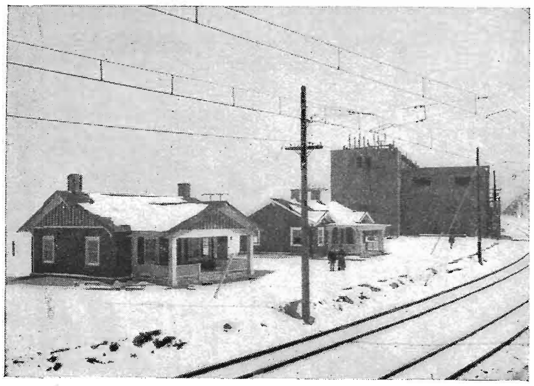

Fig. 6. Janney Substation showing Bungalows for Housing Substation Operators

The pantograph collectors, one of which is mounted on each half of the locomotive, are of the double pan type with a working range of from 17 ft. to 25 ft. above the rail. The contact elements are of the same metal as the trolley wire, so that current passes from copper to copper.

The air brake equipment is practically the same as that used on steam locomotives except that motor-driven air compressors are used to furnish compressed air. Aside from the air brakes, compressed air is also used for signals, whistles, bell-ringers, sanders, flange oilers, pantograph trolleys, part of the control equipment, and on the passenger locomotives for the oil fired steam boilers.

* It is of interest to note that this is the first direct current installation to use a potential as high as 3000 volts and this equipment was adopted after a careful investigation of all systems available for electrification. The Butte, Anaconda & Pacific Railway in the immediate vicinity of the Chicago, Milwaukee & St. Paul electrification has been in operation with 2400-volt direct current locomotives since May, 1913, and has furnished an excellent demonstration of the entire practicability of high voltage direct current operation.

Switching Locomotives

The switching locomotives are of the swivel truck type weighing 70 tons each and equipped with four geared motors. A single pantograph of construction similar to that used on the main line locomotives is mounted on the cab and in other ways the locomotive represents the standard construction commonly used with the steeple cab type of switcher. The motors (known as Type GE-255) are of box frame, commutating pole, single geared type designed for 1500 volts with an insulation of 3000 volts to the ground. Many of the switching locomotive parts are interchangeable with those used on the main line locomotives; for example, the air compressors, small switches, headlights and cab heaters.

Source of Power

Utmost precautions were taken by the Railway Company in making plans for this electrification to insure a reliable source of power. The Montana Power Company, with whom the contract was closed for electric power, operates a network of transmission lines covering a large part of Montana which are fed from a main plant at Great Falls and a number of other widely separated water power plants of adequate capacity at all seasons of the year. A notable feature of this pioneer electrification is, therefore, the conservation of fuel consequent upon the utilization of water powers.

The Transmission Lines

The Montana Power Company's transmission lines, which are carried in some cases on steel towers and in others on wooden poles, tap into the railway system at seven different points where the power is most needed. The Railway Company's transmission line extends the entire length of the system on wood poles. In most cases this line is built on the Company's right-of-way, although at several points there are cutoffs which make a considerable saving in the length of line.

With this completely interconnected transmission system, each substation may be fed from either direction and also at the tie-in points from a third source of power.

Substations

Fourteen substations are equipped for converting the 100,000-volt alternating-current to 3000 volts direct-current. They are distributed along the route at an average distance apart of 32 miles. Each station contains step-down transformers, motor-generator sets, switchboard and the necessary controlling and switching equipment. The transformers receive the line current at 100,000 volts and supply the synchronous motors at 2300 volts. Each synchronous motor drives two 1500-volt direct-current generators connected permanently in series, thus supplying 3000-volt current for the locomotives.

Overhead Construction

The overhead construction employs the principle of the flexible twin catenary originated by the General Electric Company. The details of construction and installation were entirely under the supervision of the Railway Company's engineers. With this quite novel but remarkably successful construction, the current is collected in both high speed passenger service and heavy freight service without any sparking.

Cost

Electric locomotion has been undertaken with the expectation of effecting a sufficient reduction in the cost of operation to return an attractive percentage on the investment required, as well as to benefit by all the operating advantages of electric locomotives. According to statements made by the Railroad officials, about $12,000,000.00 will be expended, and with the work more than half completed there is every reason to believe that the cost of construction will come inside the estimates.

THE MECHANICAL FEATURES OF THE LOCOMOTIVES OF THE CHICAGO, MILWAUKEE & ST. PAUL MAIN LINE SERVICE

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The author gives a concise statement of the most important mechanical features of the St. Paul locomotives. He describes the make-up of the frames and superstructure and gives the arrangement of apparatus. The article is profusely illustrated, many of which show considerable detail.—Editor.

Much has already been said about the operation of the electrified portion of the Chicago, Milwaukee & St. Paul Railway in the Rocky Mountains, it having been in operation now approximately a year, including an extremely severe winter, when many steam operated roads were unable to keep their trains moving regularly enough to prevent congestion at points even where the natural conditions are not considered severe. This electric division, through a most difficult section of the Rockies, with long grades both up and down and with severe cold weather and bad storms operated with its new equipment without any apparent difficulty, not only keeping the road clear of congestion, but almost universally making up time that had been lost on the adjoining steam operated portions of the road. It, therefore, seems fitting at this time to give a more detailed description of the mechanical part of the electric locomotives that were making such a remarkable record in the hauling and braking of the enormous trains that were handled up and down these mountain grades so effectively. The principal dimensions and features of these locomotives are as follows:

GENERAL DATA

Gage	4 ft. 8½ in.
Service	Freight
Voltage	3000 volts d-c.
Wheel arrangement	4-4-4-4-4-4
Maximum tractive effort	132,500 lb.
Continuous tractive effort	71,000 lb.
Length over all	112 ft. 0 in.
Total wheel base	102 ft. 8 in.
Width over all	10 ft. 0 in.
Height, trolley locked down	16 ft. 8 in.
Rigid driving wheel base	10 ft. 6 in.
Rigid guiding wheel base	6 ft. 0 in.
Diameter driving wheels	52 in.
Diameter guiding truck wheels	36 in.
Size main driving journals	8 by 14 in.
Size guiding truck journals	6½ by 12 in.
Total weight	576,000 lb.
Weight on drivers	450,000 lb.
Weight per driving axle	56,250 lb.
Spring borne weight per driving axle	40,000 lb.
Dead weight per driving axle	16,250 lb.
Weight on guiding truck wheels	126,000 lb.
Weight per guiding axle	31,500 lb.
Spring borne weight per guiding axle	27,274 lb.
Dead weight per guiding axle	4,226 lb.
Maximum tractive effort in per cent of weight on drivers	30 per cent
Continuous tractive effort in per cent of weight on drivers	16 per cent
Normal braking power in per cent of weight on drivers	89 per cent
Normal braking power in per cent of total weight	69 per cent