Extensive Electrification on the St. Paul

First Step Toward the Equipment of 440 Miles for Electric Operation; 3,000 Volts, Direct-Current Adopted

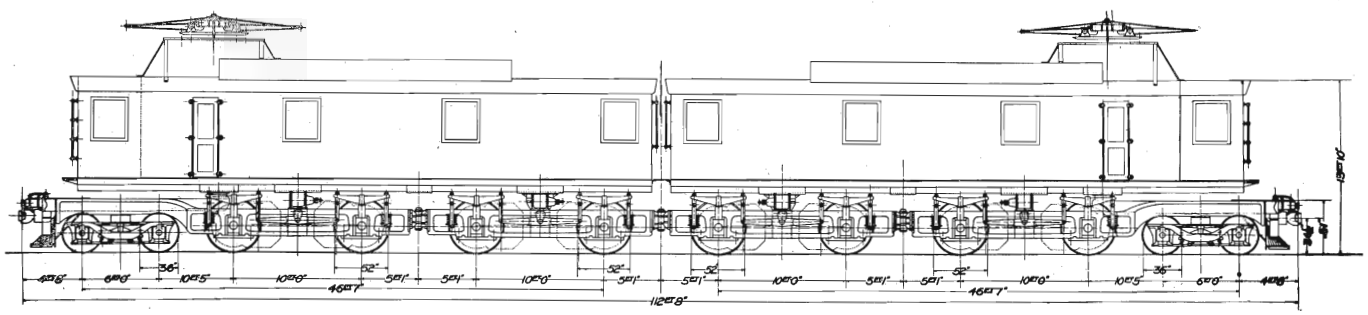
Plans for the electrification of the first engine division of the Puget Sound lines of the Chicago, Milwaukee & St. Paul* have been completed and contracts let to the General Electric Company for the electric locomotives, substation apparatus and line material, and to the Montana Power Company for the construction of the transmission and trolley lines. The work is under the direction of C. A. Goodnow, assistant to the president, in charge of construction. This initial electrification of 113 miles of main line between Three Forks and Deer Lodge is the first step toward the electrification of four engine divisions extending from Harlowton, Mont., to Avery, Idaho, a total distance of approximately 440 miles, aggregating about 650 miles of track, including yards and sidings. While this comprises the extent of track to be equipped in the near future, it is understood that plans are being made to extend the electrification from Harlowton to the coast, a distance of 850 miles, should the operating results of the initial installation prove as satisfactory as anticipated.

The plans for this work are of special interest, as this is the first attempt to install and operate electric locomotives on tracks extending over several engine divisions, under which conditions it is claimed the full advantage of electrification can be secured. The various terminal and tunnel installations have been made necessary, more or less, by reason of local conditions; but the electrification of this road is undertaken purely on economic grounds, with the expectation that superior operating results with electric locomotives will effect a sufficient reduction in the present cost of steam operation to return an attractive percentage on the large investment required. If the anticipated savings are realized in the electric operation, this initial installation will constitute one of the most important milestones in electric railway progress.

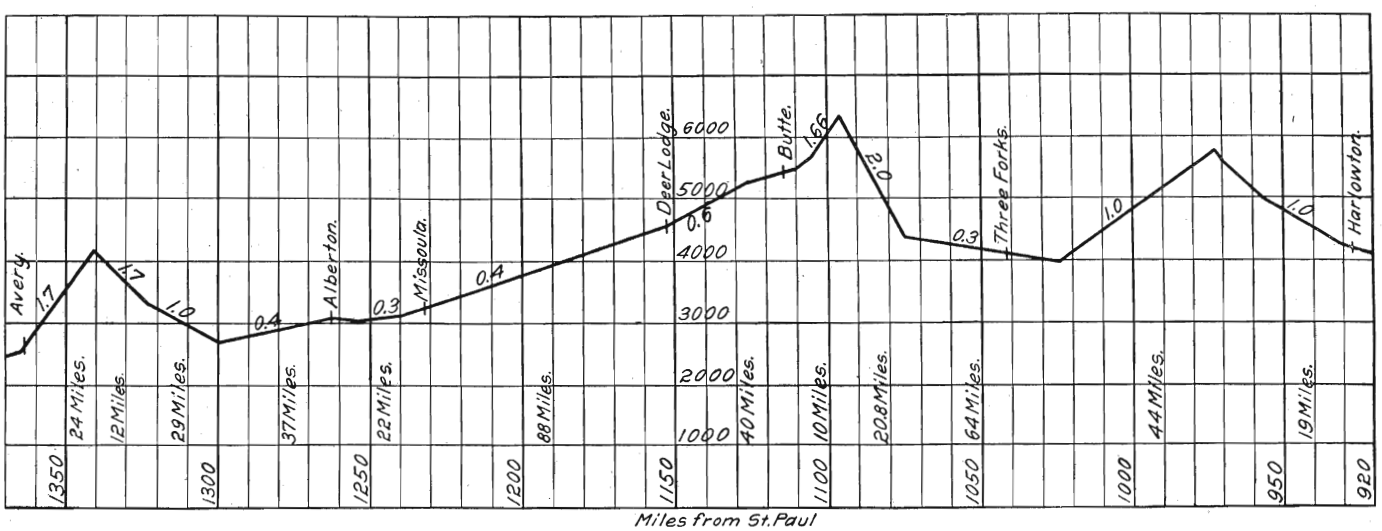
Due to the facilities available and the low cost of construction under the favorable conditions existing, the railway company will purchase power at a contract rate of $0.00536 per kilowatt-hour, based on a 60 per cent load factor. It is expected under these conditions that the cost of power for locomotives will be considerably less than is now expended for coal. The contract between the railway and power companies provides that the total electrification between Harlowton and Avery, comprising four engine divisions, will be in operation January 1, 1918.

In order to connect the substations with the several feeding-in points of the Montana Power transmission lines, a tie-in transmission line is being built by the railway company that will permit feeding each substation from two directions and from two or more sources of power. This transmission line will be constructed with wooden poles, suspension type insulators, will operate at 100,000 volts, and will follow, in general, the right of way of the railway company, except where advantage can be taken of a shorter route.

The immediate electrification of 113 miles will include four substations containing step-down transformers and motor-generator sets with necessary controlling switchboard apparatus to convert 100,000-volt 60-cycle three-phase power to 3,000 volts



Elevation of the Locomotives to Be Used on the St. Paul's Electrified Lines



Chicago, Milwaukee & Puget Sound from Harlowton, Mont., to Avery, Idaho

*See *Railway Age Gazette*, January 2, 1914, page 19.

direct current. This is the first direct current installation using such a high potential as 3,000 volts, and this system was adopted in preference to all others after a careful investigation extending over two years. The 2,400-volt direct current installation of the Butte, Anaconda & Pacific in the immediate territory of the proposed electrification has furnished a demonstration of high voltage direct current locomotive operation during the past year and a half, and the selection of 3,000 volts direct current for the St. Paul was due in a large measure to the satisfactory performance of the Butte, Anaconda & Pacific installation.

The substation sites of the Chicago, Milwaukee & Puget Sound electrified zone provide for an average intervening distance of approximately 35 miles, notwithstanding that the first installation embraces 20.8 miles of 2 per cent grade westbound and 10.4 miles of 1.66 per cent grade eastbound over the main range of the Rocky Mountains. With this extreme distance between substations and considering the heavy traffic and small amount of feeder copper to be installed, it becomes apparent that such a high potential as 3,000 volts direct current permits of a minimum investment in substation apparatus and considerable latitude as to location sites. The substations will be of the indoor type, transformers being three-phase, oil cooled, and reducing from 100,000 volts primary to 2,300 volts secondary, at which potential the synchronous motors will operate. The transformers will be rated 1,900 and 2,500 kv-a. and will be provided with four 2½ per cent taps in the primary and 50 per cent starting taps in the secondary.

The motor-generator sets will comprise a 60-cycle synchronous motor, driving two 1,500-volt direct current generators connected permanently in series for 3,000 volts. The fields of both the synchronous motor and direct current generators will be separately excited by small generators direct connected to each end of the motor-generator shaft. The direct current generators will be compound wound, will maintain constant potential up to 150 per cent load and will have a capacity for momentary overloads up to three times their normal rating. To insure good commutation on these overloads, the generators are equipped with commutating poles and compensating pole-face windings. The synchronous motors will also be utilized as synchronous condensers, and it is expected that the transmission line voltage can be so regulated thereby as to eliminate any effect of the fluctuating railway load.

The location and equipment of the several substations is as follows:

Station	Miles from Deer Lodge	No. of units	Kw. per unit	Total
Morel	17.1	2	2,000	4,000
Janey	50.5	3	1,500	4,500
Piedmont	77.9	3	1,500	4,500
Eustis	120.6	2	2,000	4,000

The trolley construction will be of the catenary type, in which a 4/0 trolley wire is flexibly suspended from a steel catenary supported on wooden poles, the construction being bracket wherever track alinement will permit and cross-span on the sharper curves and in yards.

As the result of careful investigation and experiments, a novel construction of trolley will be installed, composed of the so-called twin-conductor trolley. This comprises two 4/0 wires suspended side by side from the same catenary by independent hangers alternately connected to each trolley wire. This form of construction permits the collection of very heavy current by reason of the twin contact of the pantograph with the two trolley wires, and also insures sparkless collection under the extremes of either heavy current at low speed or more moderate current at very high speeds.

Including sidings, passing and yard tracks, the 113 miles of route mileage is increased to approximately 168 miles of single track to be equipped between Deer Lodge and Three Forks in the initial installation.

The locomotives to be manufactured by the General Electric Company are the first to be constructed for railroad service with direct-current motors designed for so high a potential as 3,000 volts. They will weigh approximately 260 tons and will have a continuous capacity greater than any steam or electric locomotive yet constructed. Perhaps the most interesting part of the equipment is the control, which is arranged to effect regenerative electric braking on down grades. This feature as yet has never been accomplished with direct-current motors on so large a scale.

The Chicago, Milwaukee & Puget Sound, from Harlowton to the coast, crosses four mountain ranges, the Belt mountains at an elevation of 5,768 ft., the Rocky mountains at an elevation of 6,350 ft., the Bitter Root mountains at an elevation of 4200 ft. and the Cascade mountains at an elevation of 3,010 ft. The first electrification between Three Forks and Deer Lodge calls for locomotive operation over 20.8 miles of 2 per cent grade between Piedmont and Donald at the crest of the main Rocky mountain divide.

The initial contract calls for nine freight and three passenger locomotives having the characteristics given below and similar in all respects, except that the passenger locomotives will be provided with a gear ratio permitting the operation of 800-ton trailing passenger trains at approximately 60 m. p. h., and will be equipped with an oil-fired, steam-heating outfit for the cars.

The eight motors for the complete locomotive will be type GE-253-A. This motor has a normal one-hour rating of 430 horsepower, with a continuous rating of 375 horsepower. The eight motors will thus give the locomotive a one-hour rating of 3,440 horsepower and a continuous rating of 3,000 horsepower. The drawbar pull available for starting trains will approximate 120,000 lb. at 30 per cent coefficient of adhesion.

Each motor will be twin-geared to its driving axle in the same manner as on the Butte, Anaconda & Pacific, the Detroit River Tunnel and the Baltimore & Ohio locomotives, a pinion being mounted on each end of the armature shaft. The motor is of the commutating pole type and has openings for forced ventilation from a motor-driven blower located in the cab.

The freight locomotives are designed to haul a 2,500-ton train on all grades up to 1 per cent at a speed of approximately 16 m. p. h., and this same trainload unbroken will be carried over the 1.66 and 2 per cent ruling grades on the west and east slopes of the Rocky mountain divide with the help of a second similar freight locomotive acting as pusher. Track provision is being made at Donald, the summit of the grade, to enable the pusher locomotive to run around the train and be coupled to the headend to permit electric braking on the down grade. In this case the entire train will be under compression and held back by the two locomotives at the headend, the entire electric braking of the two locomotives being under the control of the motorman in the operating cab of the leading locomotive. It is expected that electric braking will prove valuable, as in addition to providing the greatest safety in operation, it also returns a considerable amount of energy to the substations and transmission system. In this connection, the electric locomotives will have electric braking capacity sufficient to hold back the entire train on down grade, leaving the air brake equipment to be used only in emergency and when stopping the train.

With the completion of the remaining engine divisions, it is proposed to take advantage of the possibilities afforded by the introduction of the electric locomotive by combining the present four steam engine divisions into two locomotive divisions of approximately 220 miles length, changing crews, however, at the present division points.

The general characteristics of the locomotives are given below:

Total weight	260	tons
Weight on drivers	200	tons
Weight on each guiding truck	30	tons
Number of driving axles	8	
Number of motors	8	
Total length of locomotive	112	ft.
Rigid wheel base	10	ft.
Voltage	3,000	
Voltage per motor	1,500	
Horsepower rating, one hour, each motor	430	
Horsepower rating, continuous, each motor	375	
Horsepower rating, one hour, complete locomotive	3,440	
Horsepower rating, continuous, complete locomotive	3,000	
Trailing load capacity, 2 per cent grade	1,250	tons
Trailing load capacity, 1 per cent grade	2,500	tons
Approximate speed at these loads and grades	16	m. p. h.