VOL. XVI, NO. 3 JULY, 1920

# THE UNIVERSITY OF COLORADO

# JOURNAL OF ENGINEERING

CONTENTS



PUBLISHED QUARTERLY
BY THE ASSOCIATED ENGINEERING SOCIETIES
OF THE UNIVERSITY OF COLORADO
BOULDER, COLORADO

SUBSCRIPTION PRICE, $1.00 PER VOLUME OF FOUR NUMBERS
SINGLE NUMBER, 35 CENTS. BACK NUMBERS, 50 CENTS EACH



Entered as second-class matter March 9, 1916, at the postoffice at Boulder, Colo., under the Act of March 3, 1879.

# Electrification of the Chicago, Milwaukee and St. Paul Railway Between Harlowton, Montana, and Avery, Idaho

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The purpose of this paper is to give a brief history of the trunk line electrification of the Chicago, Milwaukee & St. Paul Railway from Harlowton, Montana to Avery, Idaho; some changes brought about by electric operation; and a general description of electrical equipment.

The Chicago, Milwaukee & St. Paul Railway was the last of the present transcontinental lines to cross the western states to the Pacific Coast. Up until about 1909 its western terminus was at Mobridge, South Dakota. When the extension was made across the Rockies, the Bitter Root and the Cascade Mountains, the shortest possible route was chosen and a roadbed of the most permanent character was built. It was not long after train service had been established between Chicago, and Seattle and Tacoma on the Pacific Coast that the railway officials began to seriously consider the tremendous advantages of main line electrification in mountainous districts together with the possibilities of regenerative electric braking down the long mountain grades. It is a recognized fact that steam locomotives are operated mainly from the standpoint of service rather than that of fuel economy. This represents a considerable item of maintenance in mountain railroading, especially with severe winter weather conditions such as exist in the northwest. The electrification of the Butte, Anaconda and Pacific Railroad in 1913 with a trolley potential of 2400 volts d. c. left no doubt as to the superiority of electric motive power over steam motive power. Operating results from this and other electrifications were studied and on November 25, 1914, the contract was closed for all electrical equipment which included that necessary for the installation of fourteen substations, transmission, distributions, and contract systems, and forty-one locomotives. The first electric locomotive was shipped September 25, 1915, and placed on exhibition on the Milwaukee between Chicago and the Pacific Coast. By December 1, 1915, nearly 200 miles of main line, yards and sidings were ready for electric operation extending from Deer Lodge east, also four substations. On December 9, 1915, the first electric train was operated between Deer Lodge and Three Forks, a distance of 115 miles and crossing the Continental Divide. During the month of April, 1916, electric service was extended east to Harlowton making a total of 226 miles electrically operated. The regular steam locomotive engineers were instructed to operate the electric locomotives. This was accomplished by having some five men who assisted in locomotive tests at the manufacturers' plant spend all their time riding locomotives hauling regular scheduled trains and explaining all details to the engineers. It required an average of three weeks to make an electric locomotive engineer out of a steam locomotive engineer. The complete change to electric operation was governed entirely by the rate at which the locomotives were delivered by the manufacturer.

During the latter part of October, 1916, electric operation was extended to Alberton and finally on February 1, 1917, to Avery, Idaho, covering the entire distance of 440 miles from Harlowton, Montana, to Avery, Idaho. All classes of service, both freight and passenger, were then under electric operation and over this strip of 440 miles the steam engine was only thereafter to be seen on the emergency trolley crew.

Under steam operation the total distance of 440 miles was divided into two passenger divisions known as the Rocky Mountain Division and the Missoula Division. Each passenger division was composed of two freight divisions, with Three Forks as the subdivision point in the Rocky Mountain Division, and Alberton as the subdivision point in the Missoula Division. Harlowton, Montana, was the eastern terminus of the Rocky Mountain Division and Avery, Idaho, the western terminus of the Missoula Division, with Deer Lodge, Montana, as the intermediate terminus. Engines were changed at Harlowton, Three Forks, Deer Lodge, Alberton and Avery, thus making an average run of 110 miles for each steam engine. At the end of each run it was necessary to put the engine in the shop or roundhouse for cleaning, washing the boilers, general inspection and for any light repairs. The railroad company maintained a large roundhouse and shop force at Deer Lodge, and all the heaviest repairs were made at that place. Passenger train and engine crews changed only at the through division points, Harlowton, Deer Lodge, and Avery. Freight train and engine crews changed at each through division and subdivision point.

Those who are more familiar with steam railroading over mountainous stretches of country realize that a large and detailed maintenance organization is essential to successful operation and that heavy operating losses occur. Briefly summarized, these include extra train and engine crews due to smaller tonnage, freight trains and helper service; helper service on through passenger trains; numerous water stations and coaling station; larger roundhouses and shop forces; a yard full of locomotives under steam with the heavy stand-by losses incident thereto; repair tracks and forces; and finally and by no means unimportant is the brake shoe inspection and heavy replacement necessary due to consequent braking over long periods on mountain grades. Freight engines and cabooses were assigned which of course made it necessary for the train to go into the yards at division points for switching. This often resulted in long tie-ups and costly delays. Other delays incident to steam motive power which are also costly and often require extra track facilities in order to carry on satisfactory through traffic, are stops for water, test of air brakes, etc.

Trunk line electrification can eliminate practically all of these losses. The extent to which they have been eliminated in the case of the Chicago, Milwaukee & St. Paul Railway has been remarkable, even surpassing the expectations of the Railway Company officials. Naturally all coaling and water stations with their maintenance forces have been eliminated. So far as the railroad is concerned, Three Forks and Alberton have been taken off the map. The roundhouses and shops are entirely closed down and nearly all the tracks have been removed. All this has been replaced by the electrician and helper at each of these two points who make a hasty "main line inspection" and more particularly of the bearings and pantographs. All changes of locomotives and crews are made on the main line. Through freight trains do not leave the main line unless a very large amount of switching is necessary. In the electrified zone, all locomotives and cabooses are pooled, which further eliminates switching. At Harlowton and Avery the locomotives are given a rough inspection and any repairs made that are of a nature not requiring engine delays or repair shop equipment. The locomotives remain in main line service for a determined average number of engine-miles when they are brought in for detailed inspection and maintenance work. This is all done at Deer Lodge which is about the mid-point of this electrified section and here the railway company has established its large electrical repair shops.

A further advantage from an operating standpoint is that of increased carrying capacity of the same trackage previously under steam operation. It has been conservatively estimated that the carrying capacity of existing tracks and other facilities over this section of main line could be practically doubled if electric motive power were substituted for steam motive power. Operating data which are now available and also reliable, since the electric locomotive has been in exclusive use since early in 1917, will show that under average conditions the year around this is actually being done. Confining ourselves now to a comparison of past to present conditions over the electrified section it must be remembered that 10 per cent of the gross daily tonnage consists of company coal movement necessary to steam operation. With the introduction of electrification this is entirely eliminated, or, in other words, results in a direct increase of 10 per cent in revenue ton miles. Train schedules have been increased by 25 per cent due to the increased capacity of electric locomotives and the absence of stops for coal and water. Other items such as the total elimination of tie-ups and costly delays as mentioned above, the track relief that results on mountain grades in both directions, and the release of rolling stock due to reduction in running time, all add to double the carrying capacity of previous trackage. It must also be borne in mind that one of the most valuable assets to the electric locomotive in carrying out this performance is that during the severe winter weather conditions when the steam engine is virtually struggling for existence with its trailing load, the electric locomotive operates at its maximum efficiency, due allowance being made for rail conditions.

The type of electric locomotive adopted for use on this electrification is shown in Fig. 1. A brief description of this locomotive is given in the November, 1919 issue of the Journal. The type of steam freight locomotive which has been released for service elsewhere on steam divisions is the Mallet type shown in Fig. 2.

A comparison of the Mallet locomotive used on these mountain grades and of the electric locomotive which supplanted it is given in the following table.

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EXPLANATORY NOTES FOR ILLUSTRATIONS ON PAGE 21.

Fig. 1. Chicago, Milwaukee & St. Paul Electric Locomotive.

Fig. 2. Mallet Type of Freight Locomotive.

Fig. 3. Gold Creek Substation and Operators Bungalows.

Fig. 4. Synchronous Motor Starting Panels and Part View of Motor-Generator Room. Eustis Substation.

Fig. 5. 2,000 k.w., 3,000 volt D. C., 2,300 volt A. C. Synchronous Motor-Generator Set. Tarkio Substation.

Fig. 6. 100,000 Volt Power Line Entrance. Drexel Substation.


Fig. 1

Fig. 2

Fig. 3

Fig. 4

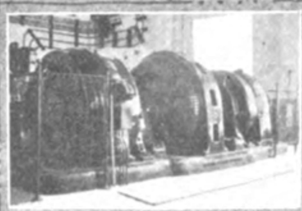

Fig. 5

Fig. 6

Comparison of Mallet and Electric Locomotives

| | Mallet | Electric |
|---|---|---|
| Total weight | 555,700 lbs. | 520,000 lbs. |
| Weight on drivers | 324,500 lbs. | 400,000 lbs. |
| Weight per driving axle | 54,000 lbs. | 50,000 lbs. |
| Rated tractive effort | 76,200 lbs. | 85,000 lbs. |
| Percent weight on drivers | 23.5% | 21.2% |
| Rated tonnage 1 percent grade | 1800 tons | 2500 tons |
| Tractive effort for above | 54,000 lbs. | 71,700 lbs. |
| Coefficient of adhesion | 16.7% | 17.7% |

The Mikado type steam passenger locomotive was used and it required a Mikado and a Mallet engine to haul transcontinental passenger trains over the mountain ranges. The use of these two steam engines has been replaced with one electric passenger locomotive at the same time doubling the average running speed.

The first electric locomotives built had a continuous rating of 3000 h. p. This required large current collection and if pantograph and trolley were used, it meant a high current density at the point of contact. The problem was very successfully solved by using the flexible twin catenary type of overhead construction, and by using two sliding contact shoes on each pantograph, thus giving a four-point or really a four-line contact. With this arrangement a current of 2000 amperes can be collected without arcing at a speed of 60 miles per hour. Fig. 1 shows the forward pantograph raised in running position. The type of span construction used with the flexible twin catenary over main line, and single catenary over passing and commercial tracks, and in yards may also be seen.

Electric power for railway service is purchased from the Montana Power Company whose transmission system is operated at 100,000 volts, 3 phase, 60 cycles. It is delivered to the railway company at seven points along the 440 miles. The railway company owns and maintains its own high tension transmission line which parallels the railroad right-of-way, and which is also operated at 100,000 volts a. c. Fourteen substations at an average distance of 32 miles apart receive this power and by means of transformers and motor-generator sets change it from 100,000 volts a. c. to 3000 volts d. c.

From east to west these substations are located at Two Dot, Summit, Josephine, Eustis, Piedmont, Janney, Morel, Gold Creek, Ravenna, Primrose, Tarkio, Drexel, East Portal, and Avery. With the exception of the last three named, the substation buildings are of the same general design, having the flat roof construction with parapet walls. Drexel, East Portal, and Avery are located in the Bitter Root Mountains where snowfall is heavy and the gable roof construction is used. At each substation there are two modern bungalows provided for station operators and their families. Fig. 3 shows the Gold Creek substation and operators' bungalows. It will be noted that the substation building is divided into two distinct parts. The lower section or main generating room which is next to the track in all cases, houses the motor-generator sets, all the low tension switching equipment, and auxiliary apparatus. The higher and somewhat longer section of the building or transformer room houses the large 100,000/2300 volt transformers, the 100,000 volt oil-switches, the lightning arrester tanks, and all high tension switching equipment. The buildings are constructed of a good grade of brick, and are without basements except for pits under the motor-generator sets and switchboard, and a small pit under the power transformers in the transformer room. The two rooms are provided with a number of large steel sash windows which admit good general illumination, also with pivoted ventilating windows near the ceiling. In the pits under the machines are ventilating blowers which force outside air up through the machines and discharge it in an upward direction toward the ventilating windows. The direct current conductors are carried in this pit from the machines to the switchboard which is located in one end of the room, where the power is distributed through circuit breakers and switches to feeders running east and west. The pit in the transformer room contains oil tanks for draining the transformers if necessary in case of repair. The control panels for the large synchronous motors of the motor-generator sets are located along the wall which separates the two rooms. The starting and running oil switches for the motors are in brick cells built into this dividing wall, as may be seen in Fig. 4.

The main generating room is equipped with a 10-ton hand operated traveling crane for handling machines and apparatus, while the transformer room has a 5-ton chain hoist for lifting the cores from the transformers. A standard gauge track is built into the concrete floor and runs the length of the high tension room to a turntable and then out to the motor-generator room. A specially constructed low frame steel truck enables apparatus to be brought from the high tension room out under the traveling crane where it can be hoisted for loading into cars. A spur track enters the motor generator room to the nearest machine.

The motor-generator sets consist of a synchronous motor, direct connected to two 1500 volt direct-current generators. The two generators are permanently connected in series giving a potential of 3000 volts d. c. for the trolley. In Fig. 5 may be seen the type of motor-generator set installed throughout the electrification. They are built in two capacities—1500 k. w. and 2000 k. w. The substations serving the heavier grades contain three units, while the others contain only two units. They are equipped as follows: Two Dot, Summit, Josephine, Eustis, Morel, Gold Creek, Ravenna, Primrose, Tarkio and Drexel, each have two 2000 k. w. units; Piedmont, Janney and Avery each have three 1500 k. w units; and East Portal has three 2000 k. w. units, being the largest capacity substation.

The power lines are carried into the buildings through a specially designed compound filled roof-bushing. These are located in ceiling of the transformer room of the stations having the flat roof construction. In the three stations having the gable roof construction, the power lines enter through the same type of bushing built into the side wall at an angle of 30 degrees from the vertical, as may be seen by reference to Fig. 6. In the former type of stations the horn-gaps for lightning arresters are mounted on the roof, while in the latter they are inside the building directly over the arrester tanks. The high tension conductors in the station are ¾-inch copper tubing carried on post insulators. A copper ground bus extends around the walls of the two rooms for grounding the lightning arresters and frames of apparatus.

All concerns interested in railroad work, and in fact the whole engineering world has been watching this wonderful achievement with the keenest interest. It has presented many new problems both to the designing and operating engineer which have been solved in a remarkable manner. Operating characteristics and data are being closely studied, and it seems conservative to venture the statement that in the immediate few years we will see some even more far reaching strides in main line electrification.