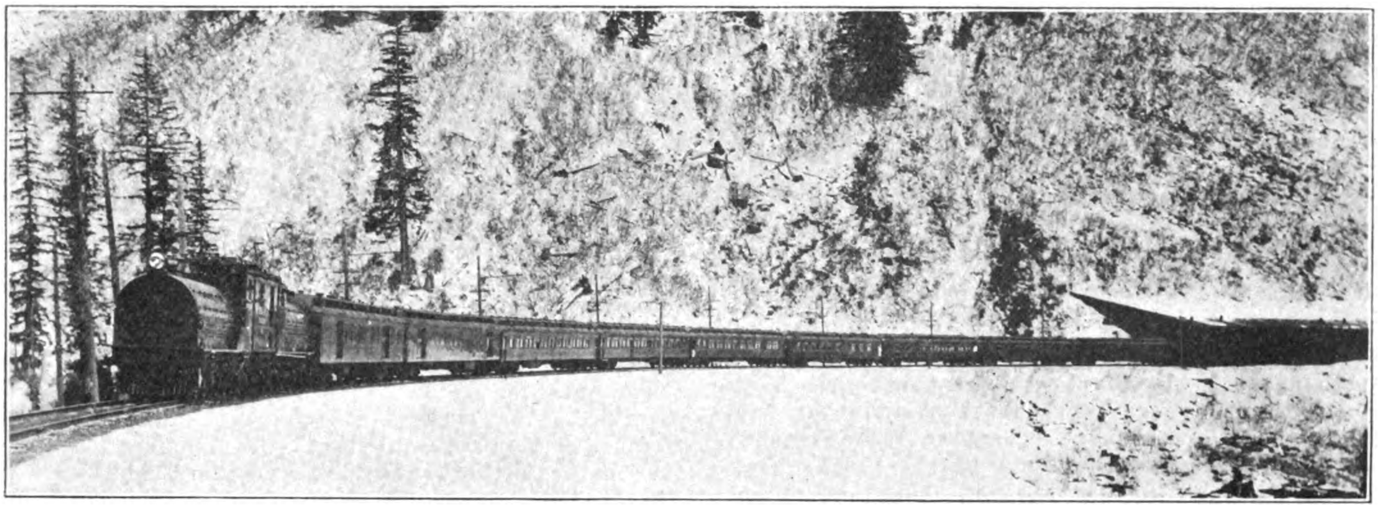


The "Olympian" Emerging from Snow Sheds on Cascade Division

The New Electrification on the St. Paul

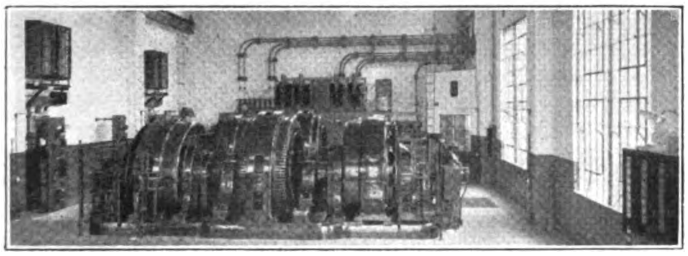
This Road Now Has the Greatest Electrified Mileage in the World. A Comparison With Steam Operation

THE Chicago, Milwaukee & St. Paul, on March 6, opened its new electrified division between Seattle, Wash, and Othello, a distance of 208 miles. This division runs over the divide of the Cascade range and includes some very heavy grades, the maximum being a 17-mile 2.2 per cent grade from the Columbia river to the west and a 19-mile 1.7 per cent grade from Cedar Falls east to the summit.

Substation Equipment and Power Supply System

The 3,000-volt power supply comes from 8 substations about 30 miles apart along the route. This power is furnished by the Inter Mountain Power Company, who in turn purchases it from the hydro-electric plants of the Washington Water Power Company and the Puget Sound Traction, Light & Power Company.

The General Electric Company supplied the equipment for five of the eight substations, namely, the Cle-Elum, Hyak, Cedar Falls, Renton and Tacoma, three of which stations have two motor generator sets, and the other two stations each have one such unit, making a total of 16,000 kw. The motor generator sets are of 2,000-kw. capacity, each consisting of two compound wound 1,000-kw., 1,500-volt d.c. generators connected in series for 3,000 volts. Each set is driven by a 2,500-kva., 2,300-volt, 3-phase 60-cycle synchronous motor and two direct connected d.c. exciters, one 12 kw. for the field of the generators, the other 30 kw., 125 volts for the synchronous motor field.



Interior of Substation Showing Two Three-Unit Sets

The overhead construction is the modified flexible catenary type, using 40-ft. wooden poles except where crossing the Columbia river and other special work, where steel construction is used. These poles carry the 3,000-volt feeders, negative ground wire, the 4,400-volt signal wires, and the power limiting and indicating control wires.

Motive Power Equipment

The motive power equipment, furnished by the General Electric Company, consists of 5 gearless passenger, 12 geared freight and 2 switching locomotives. The gearless locomotives are designed especially for high speed passenger service. The features of the design are two three-axle trucks, one at each end, and two control four-axle trucks, all articulated and equalized so as to give the same weight per driving axle and insure proper tracking at high speed. The leading wheels on the three-axle trucks are not equipped with motors, but serve as guiding wheels. The motors are of the bi-polar gearless type, having a total rating in continuous service of 3,200 hp. When regenerating, eight of the motors are used for braking, while the other four act as exciters. The locomotive is also equipped with standard air brakes. Each locomotive carries a small motor generator set to provide excitation when regenerating, to light the train, charge storage batteries and supply the various control and auxiliary circuits.

Exterior of Cle Elum Substation

By electrifying this division the C. M. & St. P. has completed the longest stretch of electrified railroad in the world, the total length being 660 miles. This vast transportation system in its completed form operates 61 electric locomotives, including passenger, freight and switching types. The introduction of these locomotives, according to the power company's estimates, has released for service elsewhere 162 steam engines, with an annual saving in fuel of approximately 300,000 tons of coal and of 40,000,000 gal. of oil, due to the fact that this railroad obtains its electrical energy supply wholly from the natural hydro-electric resources of the surrounding country.

A Comparison of Electric and Steam Motive Power*

During the year 1910 exhaustive tests were made upon th Rocky Mountain dicision of the C. M. & St. P. to determine the relation existing between horsepower hours' work done in moving trains and coal and water consumed on the steam engines in service. The summary, Table I, gives the result of these tests:

TABLE I

C. M. & ST. P.—ROCKY MOUNTAIN DIVISION

Coal and Water Used

	Water per hp.	Water per lb. coal	Coal per hp. hr.
Three Forks-Piedmont	39.6	5.08	7.75
Piedmont-Donald	35.4	4.70	7.54
Deer Lodge-Butte	39.7	4.85	8.31
Butte-Donald	40.4	4.86	8.74
Harlowton-Jenny	38.0	4.09	8.90
Jenny-Summit	44.2	4.65	9.48
Three Forks-Piedmont	41.4	6.51	6.37
Piedmont-Donald	40.2	5.63	5.78
Average of 8 tests	39.86	5.04	7.86

The above records were obtained during the portion of the runs that the engines were doing useful work in overcoming train and grade resistance—that is, all standby losses were excluded. The through run, however, included such losses in the following magnitude:

Adding standby losses, shown in Table II, to the average of 7.87 lb. per hp. obtained in the preceding eight tests, the total actual coal consumed under the engine boiler in 24 hours divided by the actual work performed by the engine was found to be 10.18 lb. per hp. at the driver rims.

TABLE II

STANDBY LOSSES

	Coal per hour
Fire banked in roundhouse	150 lb.
Cleaning fires for starting	800 lb.
Coasting down grade	950 lb.
Standing on passing track	500 lb.

As the result of this particular series of tests it was determined that standby losses raised the coal consumed while doing useful work by 30 per cent. It should be appreciated in this connection, moreover, that this value was obtained on through runs with no yard switching service or adverse climatic conditions. It may be concluded, therefore, that under all conditions of service fully one-third the coal burned on our steam engines today is absolutely wasted in standby losses of the general nature indicated above.

An electric kilowatt can be produced for so much less coal expenditure than 7 lb. that we are now in position finally to forecast the approximate extent of the coal economy that would result from electrification.

TABLE III

RELATION BETWEEN KW. HR. AND TON MILES

C. M. & St. P. Avery-Harlowton, Year 1918

	Passenger	Freight
Average weight locomotive	300 tons	284 tons
Locomotive miles 1918	651,000	1,431,500
Loco. ton miles	195,000,000	407,000,000
Trailing ton miles	434,406,000	2,903,099,000
Total ton miles	629,406,000	3,310,049,000
Kilowatt hours	24,890,000	105,287,000
Watt hrs. per ton mile	39.6	31.9
Ratio loco. to total	31%	12.3%
Watt hrs. per ton mile combined movement.	33.2	
Ratio loco. to total combined movement.	15.25%	

All power values (Table III) are given at the point of supply from the Montana Power Company at 100,000 volts, and include deductions made for the return of power due to regenerative braking of the electric locomotives on down grades and amounting to approximately 14 per cent of the total. Owing to the excessive rise and fall of the profile of the electrified zone of the C. M. & St. P., its operation is materially benefited by regenerative electric braking and the value of 33.2 watt hours per ton mile for combined and passenger movement should possibly be raised to the round figure of 40 to make it apply more nearly to conditions universally obtaining on more regular profiles.

Electrification in General

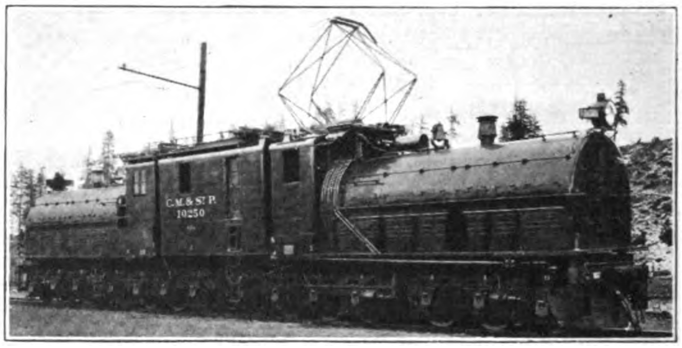
The operating results obtained on the C. M. & St. P. electrified zone check so closely with values obtained from other sources as to justify the completion of the fuel analysis of the railways, as shown in Table IV.

TABLE IV

COAL SAVING BY ELECTRIFICATION

Total ton miles steam	1,215,400,000,000
Reduction by electrification	146,000,000,000
Total ton miles electric	1,069,400,000,000
Kw. hrs. electric at 40 watts	42,776,000,000
Coal on basis 2½ lb. per kw. hr.	53,500,000 tons
Equivalent railway coal 1918	176,000,000 tons
Saving by electrification	122,500,000 tons

The startling conclusion arrived at is that approximately 122,500,000 tons of coal, or more than two-thirds the coal now burned on our 63,000 steam engines, would have been saved during the year 1918 had the railways of the United States been completely electrified along lines fully tried out and proved successful today. This vast amount of coal is 50 per cent greater than the prewar exports of England and twice the total amount consumed in France for all its railways and industries. Moreover, the estimate is probably too conservative, as now allowance has been made for the extensive utilization of water power which can be developed to produce power more cheaply than by coal in many favored localities.



Type of Electric Locomotive in Use on Cascade Division

From figures given, the following conclusion is arrived at in the matter of the power station capacity required for complete electrification of the railways in the United States:

RAILWAY POWER REQUIRED

Kw. hr. electric operation 1918	42,776,000,000 kw. hr.
Average load 100 per cent load factor	4,875,000 kw.
Power station capacity at 50 per cent load factor.	9,750,000 kw.

It appears, therefore, that approximately 10,000,000-kw. power station capacity would have been sufficient to run all the railroads for the year 1918, or one-half the station capacity which has been constructed during the past thirty years, as shown in Table V.

In order of magnitude, therefore, it is not such a formidable problem to consider the matter of power supply for our electrified railways, and it becomes evident also that the railway power demand will be sec-

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*Abstract of an address delivered before the Schenectady section of the American Institute of Electrical Engineers. By A. H. Armstrong, General Electric Company.

ondary to industrial and miscellaneous requirements.

Such being the case, the question of frequency of electric power supply becomes of great importance, if full benefit is to be obtained from extensive interconnected generating and transmission systems covering the entire country. Indeed, with the full development of interconnected power systems supplying both railway and industrial load from the same transmission wires, the above assumption of 50 per cent load factor for the railway load can be materially bettered.

Table V

Estimated Power Station Capacity United States Year 1918

Central stations	9,000,000 kw.
Electric railways	3,000,000 kw.
Isolated plants	8,000,000 kw.
Total	20,000,000 kw.

In this connection a method of limiting the troublesome peak load hitherto considered inherent to railway power supply has been in successful operation on the electrified C. M. & St. P. zone for the past year. With unrestrained peaks, the load factor was approximately 40 per cent, but this low value has been raised to nearly 60 per cent by the installation of this inexpensive and most satisfactory device, known as the power limiting and indicating apparatus.

Table VI

Load Factor Records, C. M. & St. P., 1919

	Duration of peak, per cent	Load factor, per cent
April	6.4	59.3
May	4.6	56.1
June	1.6	56.5
July	0.7	55.6
August	4.1	54.7
September	9.5	58.8

The readings shown in Table VI cover the performance on the 220 miles of the Rocky Mountain division supplied by seven substations controlled as a unit. A load factor of nearly 60 per cent brings the electric railway within the list of desirable customers and makes it possible for power companies to quote attractively low rates for power.

From the power station standpoint, the electrification of our railroads admits but one conclusion. We have some 63,000 engines now in operation and their average combined load amounts to approximately four million horsepower at the driver rims, or only an insignificant total of 65 hp. for each engine owned. It is true that owing to shopping and for one cause or another a large proportion of these engines are not in active service at all times, still the average 24-hour output of each engine is less than 10 per cent of its rating. In the case of the C. M. & St. P. electrification the average load of each individual electric locomotive is only 15 per cent of its continuous rating, but by supplying power to 45 electric locomotives from one transmission system the average combined load factor is raised to nearly 60 per cent, a figure which could even be surpassed on roads of more regular profile. Furthermore, when the railway load is merged with the lighting and industrial power of the district and the whole diversified load supplied from the same 60-cycle transmission and generating system, it is quite evident that all the conditions are most favorable for the efficient production of power. In this country such an achievement will probably be governed by the laws of economic return upon the capital required, because our vast natural fuel resources are popularly regarded as inexhaustible, but in Europe there is the compelling spur of stern necessity behind the movement to economically utilize the water powers they possess in place of coal.

Progress in utilizing the capabilities of the electric locomotive has been slow. It is hard to break away from lifelong railway traditions established by costly experience in many cases. In consequence, the electric locomotive has thus far simply replaced the steam engine in nearly similar operation. Even under such conditions of only partial fulfillment of its possibilities, the electric locomotive has scored such a signal operating success as to justify giving it the fullest consideration in future railway improvement plans.

INSPECTION OF CASALE TRAIN CONTROL INSTALLATION

Officers of the Chicago, Rock Island & Pacific and of the Casale Safety Device Company made an inspection and tests of the Casale automatic train control device which has been installed on the Rock Island between Blue Island, Ill., and Joliet on Friday, March 12, a special train being used for this purpose. In the party were J. E. Gorman, president of the Rock Island, and other officers of the system, representing the operating, mechanical, signal and engineering departments; James C. Regan, president of the Casale Safety, Device Company, and other officers of this company.

An installation of this device has been completed and placed in service on the suburban district of the Rock Island between Blue Island, Ill., and Joliet, protecting about 25 miles of double track. On the run to Joliet tests were made with signals placed in the caution and stop positions, respectively. Speed control apparatus is installed on the engines, so that when a caution indication is received the speed of the train is reduced automatically to a predetermined point, which in this case is 30 mi. an hr. When the speed control apparatus becomes effective the speed is reduced to approximately 22 mi. per hr. before a full release of the air brakes is obtained. On the first test a caution indication was received and an automatic application of the air took place, reducing the speed of the train to the predetermined rate. The engineman then attempted to increase the speed, but was checked automatically whenever it reached 30 mi. per hr. After having received the caution indication and while running at a speed of approximately 25 mi. an hr. a stop indication was received at the next ramp, the train being stopped in about 300 ft.

On the return trip from Joliet an eastbound passenger train was ahead of the special, and the special received caution indications at three signal locations just out of Joliet. Signal 336, located near New Lenox, Ill., gave a stop indication and the train control apparatus automatically stopped the train. After the stop was made the engineman released himself and proceeded under control to the next signal location, where a clear indicator was received, which permitted the engineman to proceed at speed. The speed was increased to 74 mi. an hr., the apparatus functioning properly at every ramp.

The nearest end of each ramp to a signal location is approximately 160 ft. from it, and the ramp is 120 ft. in length. Each ramp consists of two angle irons placed face to face with a copper strip placed between the angles in order to provide a better electrical contact between the ramp and the engine shoe. Every ramp opens the local engine circuit whenever the shoe is raised in passing over it. When the ramp is energized the transmission of current through the shoe maintains the local engine circuit, thus preventing an unauthorized stop being made. The circuits are so arranged that the signal repeats the indication of the ramp.

The engine apparatus may be briefly described as consisting of a shoe for making physical contact between the roadside and the moving train; a three-position relay; a storage battery set of approximately four cells of the automobile type, an automatic electro-pneumatic valve and the speed control apparatus.