Electric Operation on the St. Paul

In a Collection of Notes on This Electrification the Author Points Out the Simplicity of Construction of the Locomotives, the High Current Collecting Capacity of the Twin Trolley Wires and the Economy of Having Engine Divisions 220 Miles Long

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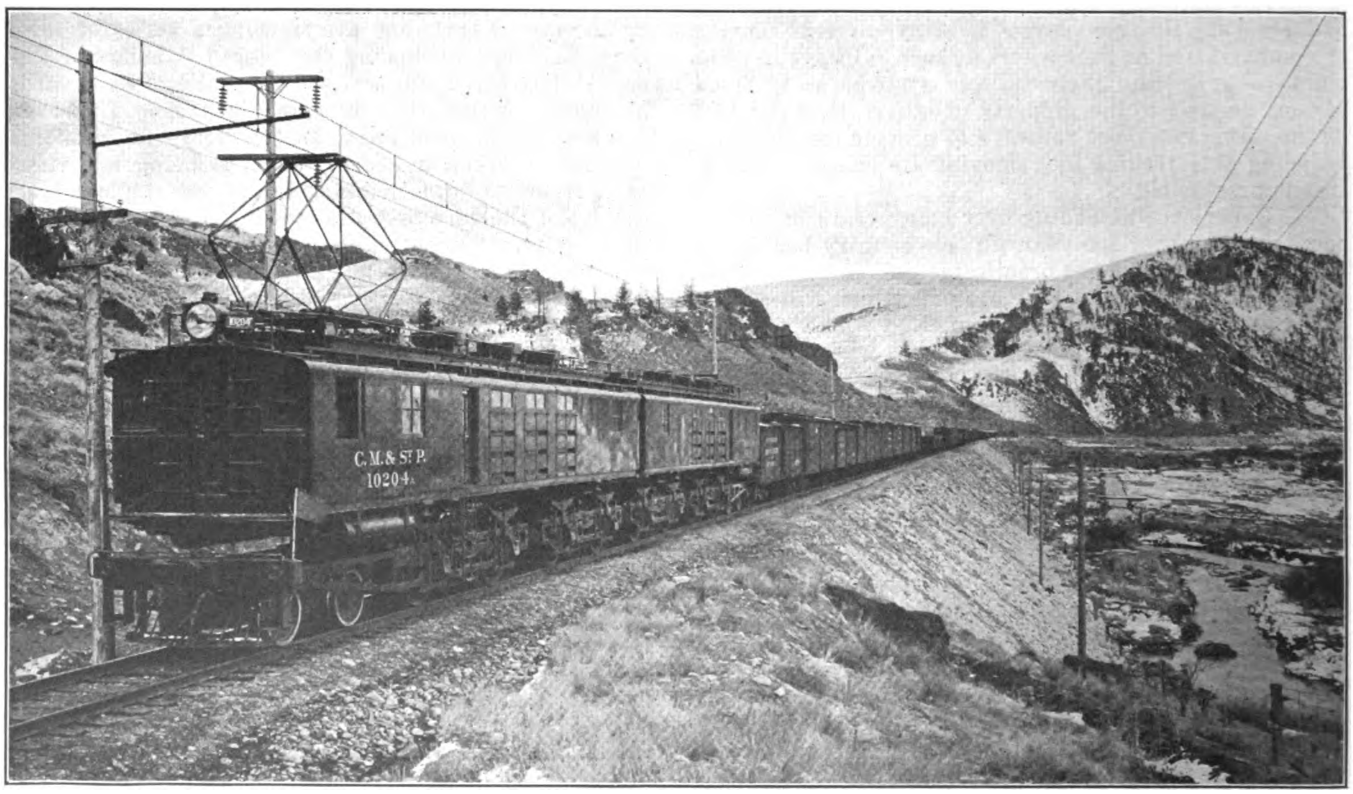
DURING the past six months electricity has replaced steam on 220 miles of track on the Chicago, Milwaukee & St. Paul Railway. This mileage comprises two steam-engine divisions, and, in war terms, the new facilities thus introduced have been "consolidated" since the territory was occupied.

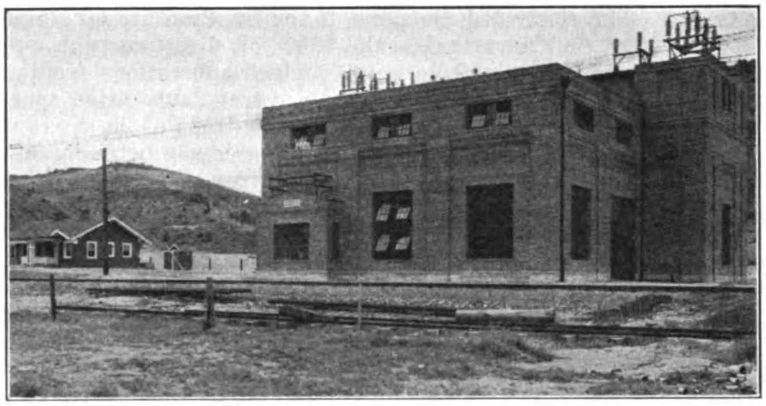
Naturally, any such radical change as the substitution of electricity for steam gives rise to equally great operating changes just as soon as the capabilities of the new type of motive power become understood and fully appreciated. Not until a complete change in motive power is made can it be realized how many of the previous rules and regulations are, in effect, only the traditions handed down from generations of steam-engine practice. Very many such rules reflect dearly-bought operating experience and apply equally to the operation of any type of motive power, but with the electric locomotive, the greater tractive power at higher speeds, the independence from the individual efficiency of the operating crew, the freedom from any restrictions of coal and water supply, the higher speeds on down grades made possible by the use of electric brakes, and the many other operating advantages must result in radical changes from previous steam operating methods. An often-used phrase best describes the original method of operation as "steam railroading subject to all the limitations of the steam engine," and in the future, railroad transportation will undoubtedly be conducted on a broader basis with the greater facilities and flexibility provided by electric locomotives.

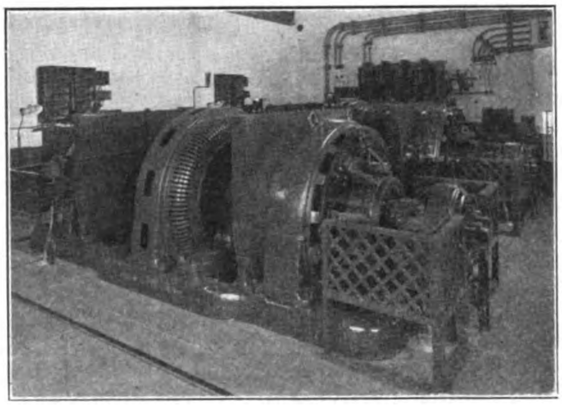
A story is told of an engineer making his first trip on a St. Paul electric locomotive run between Deer Lodge and Three Forks. He had full charge of the running of the locomotive, under the direction of an instructor, and he handled his train over the Rocky Mountain Divide without giving any outward expression to his thoughts until reaching the tunnel at the summit, when he exclaimed: "This is the first time I ever saw the inside of this tunnel." Having ridden through tunnels in the cab of a steam engine, the writer can fully appreciate how it affected an old steam engineer to ride on an electric locomotive for the first time and to be free from the gases, steam and smoke that make tunnel operation with the steam engine hazardous, as well as most uncomfortable for the crew.

On the Chicago, Milwaukee & St. Paul the operation of the electric locomotives has been taken over by the regular steam engine crews after proper instructions, and it is interesting to note how smoothly the change from steam to electricity has been accomplished. Of course, the handling of the air brakes is identical with steam-engine practice, although in this matter of braking the use of the air brakes is restricted to the stopping of trains, as the electric brakes are used exclusively to hold the trains at constant speed on the down grades.



ST. PAUL ELECTRIFICATION—EIGHTY-TWO-CAR FREIGHT TRAIN HAULED BY SINGLE ELECTRIC LOCOMOTIVE

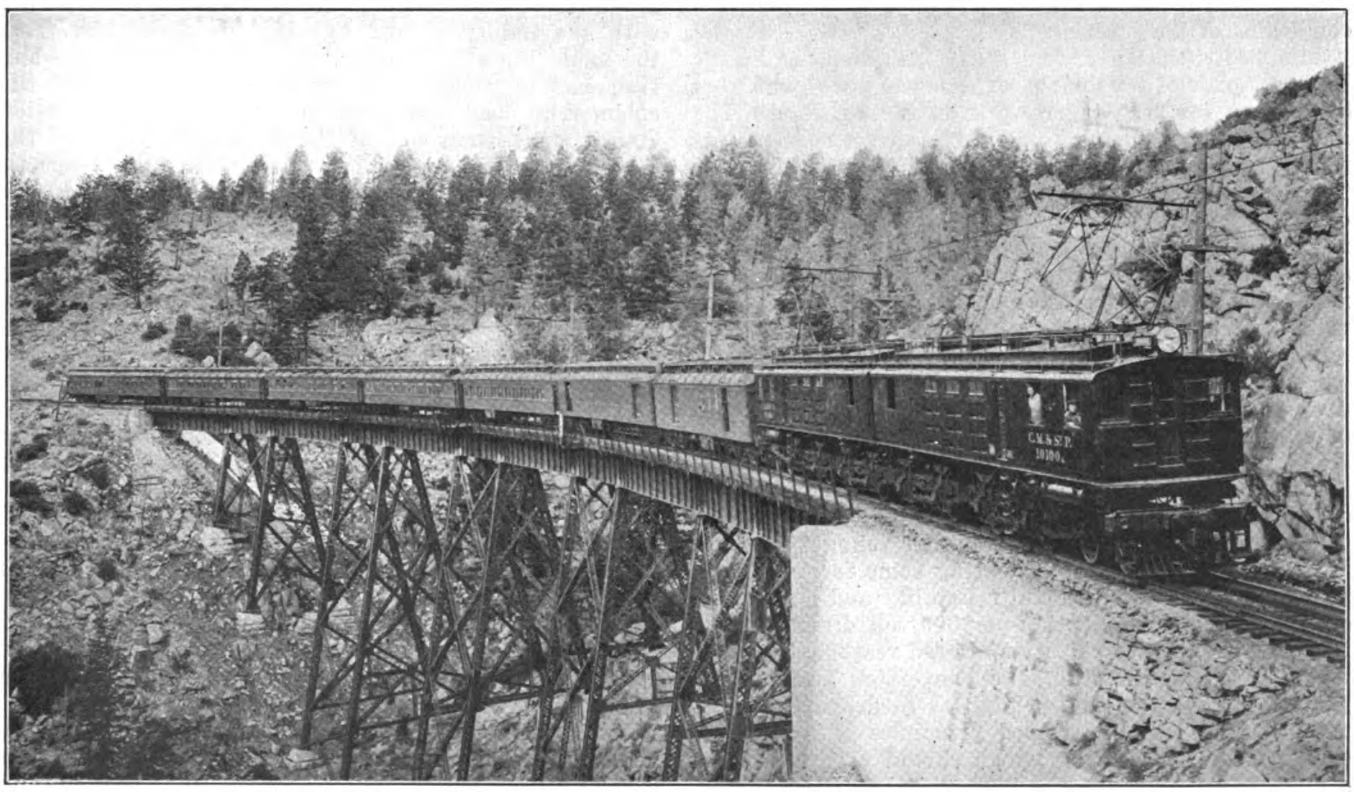




ST. PAUL ELECTRIFICATION—EXTERIOR AND INTERIOR OF EUSTIS SUBSTATION ON EASTERN ENGINE DIVISION

Perhaps there is no feature of the St. Paul electrification that is more impressive than the operation of this regenerative electric braking. In the early consideration of plans for the electrification, electric brakes were considered, and they were finally insisted upon by the railway officials when their full advantages became apparent. The perfection of regenerative electric braking with series direct-current motors called for considerable development work, as nothing of the kind had ever been done on a scale approaching the magnitude of 282-ton locomotives equipped with motors aggregating 3400 hp. The direct-current locomotive, however, offered so many advantages for main line service in this instance that it was considered of the greatest importance to adhere to this type, especially if electric braking could be made operative with the series-wound direct-current motors operating from a fluctuating trolley voltage. Fulfilling the promise of early experiments made at Schenectady, direct-current motor regenerative braking was successfully developed and put into service without losing the ruggedness in operation of the series-motor characteristics. The result has been a locomotive of remarkable flexibility, with speed and tractive power admirably suited to train haulage over a broken profile and, withal, of an extremely simple mechanical and electrical construction that has been patterned closely after well-known designs of proven superiority and reliability.

On these locomotives, the motors are of practically standard design and they present no features of special interest except the large continuous capacity of 375 hp. and the fact that each has a potential of 1500 volts across its brushes, operating two in series on 3000 volts. The motors are geared to the axles through twin gears, an arrangement that has proved so successful on the Butte, Anaconda & Pacific, Detroit Tunnel, Baltimore & Ohio, Cascade Tunnel, and other electrifications having operating records of several years with this method of drive. In the St. Paul locomotive construction, the motors are spring suspended on the bolster and also drive through springs in the twin gears, thus providing great flexibility, cushioning all shocks and eliminating all noise of grinding gears. The high efficiency, simple construction and low cost of twin-gear drive were fundamental facts of importance influencing its adoption on the St. Paul locomotive, and the results of six



ST. PAUL ELECTRIFICATION—PASSENGER TRAIN DESCENDING A 2 PER CENT GRADE months' operation fully justify the preference for this design.

The efficiency from trolley to the rim of driving wheels approximates 89 per cent, including all motor and gear losses when delivering full rated tractive effort. The construction is simple, rugged and well able to withstand the strains incident to heavy train haulage over mountain grades of 2 per cent, one such grade on the St. Paul extending unbroken for 21 miles over the main divide of the Rocky Mountains. During six months of operation no failure or delay of any kind has been due to the twin gear drive, and all indications are that in this item cost of upkeep will be small.

The St. Paul freight locomotives are rated at 2500 tons trailing load on a 1 per cent grade, and this calls for a tractive effort of 72,500 lb. and a current input to the motors of 860 amp. at 3000 volts, the speed being 15.75 m.p.h. Such a large current could readily be collected from a third-rail, but the problem of current collection presented some difficulties with existing forms of overhead construction and pantograph collector. Elaborate experiments were made at Schenectady with different methods of trolley suspension and roller and pan collectors and these formed the basis for the adoption of the current-collecting facilities on the St. Paul. In this case the trolley consists of two No. 0000 wires side by side and alternately suspended from the same catenary by the usual loop hangers. The construction offers great flexibility in the overhead conductor, provides for contact with at least one wire at all times with consequent elimination of flashing, and permits the collection of heavy currents at high speeds. Pan collectors with copper contact surfaces are used and lubrication is successfully depended upon to reduce wear. This construction has already been described in previous publications, but it is worthy of additional comment as it has solved the question of collection of large currents at high speed. Tests made at Schenectady and Erie have demonstrated that it is perfectly feasible to collect 2000 amp. at speeds as high as 60 m.ph. with this construction, and subsequent operation on the St. Paul has resulted in no flashing or even sparking under the conditions of daily service.

The electrification of the Butte, Anaconda & Pacific Railway provided valuable experience upon which to base plans for the larger work on the St. Paul. The increase from 2400-volt to 3000-volt direct current was found to be possible without sacrificing anything in the simplicity and ruggedness of the twin-gear drive on the locomotive and it offered certain advantages in reducing feeder copper and providing for greater substation spacing. Taken in connection with the improvements in overhead construction and pan collection, 3000 volts was sufficiently high to insure the satisfactory collection of current under all possible conditions of service operation. At the same time this voltage did not involve anything beyond conservative design in the case of single-conductor, 1500-volt motors operating two in series on 3000-volt supply, thus permitting the use of the simple twin-gear drive. Experiments with direct-current apparatus with potentials as high as 6000 volts demonstrated the possibility of higher voltages, but also indicated the necessity of adopting some form of freak mechanical drive of doubtful reliability and poorer efficiency. Hence the adoption of 3000-volt direct current for the St. Paul electrification offered reasonable advantages in the distribution and conversion system, and yet the voltage was not so high as to demand any departure from the understood principles of sound and conservative engineering which should govern in such a huge undertaking as the immediate electrification of 440 miles of trunk line railway.

The electrified divisions of the St. Paul are all single track, but nevertheless the 3000-volt direct-current supply is obtained from only fourteen substations feeding 440 miles of route, making an average substation spacing of 31 miles. Maximum trolley drops of 20 per cent are obtained with 2500-ton trains midway between substations, but the average voltage drop with the variable tonnage of passenger and freight trains of all classes will be less than 10 per cent. This reasonable distribution loss is obtained with trolley feeders of 500,000 circ. mil. cross-section extending over 85 per cent of the entire route mileage, or where the ruling grade is 1 per cent or less. Heavier feeders up to 1,400,000 circ. mil. section are used on higher gradients up to the 2 per cent ruling grade. The entire cost of this feeder copper, figured on a 20-cent basis, amounts to less than 8 per cent of the total cost of electrification.

It is as yet too early to expect any operating figures as to economies effected by the electrification. Full electrical operation of all freight trains, and all passenger trains except one on a local run, is now in effect on two steam engine divisions totaling 220 miles of track. These two steam engine divisions have been consolidated into one electric locomotive run, crews being changed midway at the old division point. An additional 220 miles of track will be in operation by the end of this year, and here also two steam engine runs will be combined into one electric division.

Partial operation for six months has proved the physical success of the undertaking and the general fitness of the locomotives and distribution system for this very severe mountain service. The high-voltage direct-current system offers special advantages for the conditions obtaining in the Northwest with its abundant supply of 60-cycle power and the broken profiles of the railroads. In the substations, synchronous motor generator sets, which have a combined efficiency at full load of approximately 92 per cent, and automatically providing a power factor of 100 per cent or a slightly leading current at practically all loads, permits feeding the St. Paul substations from the general transmission networks of the Montana Power Company without causing interference with the industrial and lighting loads supplied from the same lines. In fact, this ability of utilizing any frequency of power supply without interfering with the commercial load connected to the same transmission circuit, constitutes one of the chief advantages of the high-voltage direct-current system. In other respects, also, direct-current construction is well adapted to the work in view. The profile calls for crossing three mountain ranges with long stretches of level and low-grade track intervening. Freight trains mount the ruling grades at approximately 15 m.p.h. with two locomotives, and run on level track at double this speed with one locomotive, an accomplishment readily achieved with the flexible characteristics of the direct-current motor. Moreover, the locomotive speed is automatically proportioned to all intermediate gradients, thus resulting as nearly as possible in a constant-output locomotive and minimizing the load fluctuations due to the very broken profile. As a matter of fact, a variable speed characteristic for the locomotive is pre-eminently adapted to general railroad operating conditions, as questions of alignment of tracks and peak-load power supply place limits on the speeds up grades while it is desirable to operate on level track and on the lesser grades at as high a speed as the track alignment and condition of rolling stock will permit.

Much of the engineering success of the St. Paul installation is the result of the gradual development of a direct-current motor for locomotive construction and the advance in the art of generation, transmission and conversion of alternating-current power. Two novel features, however, stand out conspicuously as being introduced for the first time and completing the development of the 3000-volt direct-current system. These are, first, the twin conductor flexible overhead construction with lubricated, copper-pan collectors, and, second, the regenerative braking control of the series-wound, direct-current locomotive motors. The first has made possible the collection of current far in excess of operating requirements and has settled for all time any claims for higher trolley voltage based upon the question of current collection. Thus, it is perfectly feasible with the St. Paul construction to collect 2000 amp. at practically any speed and this makes it possible to receive 6000 kw. at 3000 volts through one pan collector, more than enough to slip the wheels of the 282-ton locomotive at 30 per cent coefficient of adhesion. Then, too, the introduction of regenerative braking control with direct-current, series motors greatly broadens the field of the locomotive and permits placing a proper value upon this one feature of electric operation, because it is not secured at the expense of sound and conservative engineering in other respects. Regenerative electric braking undoubtedly has an important value in electric railroading by adding to the safety and economy of operation, and it is a welcome addition to the other advantages of the direct-current-motor locomotive.

In general, the St. Paul electrification extends over such a length of track, 440 miles, that no restrictions need be placed upon the free operation of the electric locomotives. The Mallet locomotives previously used over the mountains are being transferred to the adjoining non-electrified division as fast as they are released, with a view to handling the heavier tonnage trains delivered to that division by the electric locomotives, thus resulting in raising the weight of trains moved over the road and effecting material economies.

Progress of Car Building Industry

A PRELIMINARY summary of the general results of the 1914 census of manufactures with reference to the construction of steam and electric railway cars was issued this week by Director S. L. Rogers, of the Bureau of the Census, Department of Commerce. It consists of a detailed statement of the quantities and values of the various products manufactured, prepared under the direction of William M. Steuart, chief statistician for manufactures.

Returns for 1914 were received from 242 establishments which manufactured 138,178 steam and electric cars, valued at $165,071,427. These totals include figures for 118 railroad repair shops which reported the construction of 11,049 new cars, valued at $12,811,087, and seven establishments engaged primarily in other lines of manufacture but which produced 4481 railway cars, valued at $3,178,677, as subsidiary products. For 1909 there were reported 280 establishments which manufactured 101,243 cars, valued at $102,147,396. Of these 280 establishments, 140 were railroad repair shops which constructed 14,792 cars, valued at $13,952,-923, and sixteen were establishments engaged primarily in other industries but which built 8981 cars, valued at $5,934,871, as subsidiary products. The number of establishments engaged in this industry thus decreased by thirty-eight, or 13.6 per cent, during the five-year period, but the number of cars built increased by 36.5 per cent, while their value increased by 61.6 per cent.

The number of electric cars manufactured in 1914 was 2821, and their value was $10,041,888. In 1909 there were built 2772 electric cars, valued at $7,263,109. The number of cars constructed was thus only 1.8 per cent greater in the later year than in the earlier, but during the five-year period their value increased by 38.3 per cent. The output of electric cars in 1914 comprised 2583 passenger cars, 110 freight cars and 128 other cars. The statistics for 1914 and 1909 are summarized in the following table:

CONSTRUCTION OF CARS FOR USE ON STEAM AND ELECTRIC RAILROADS—COMPARATIVE SUMMARY: 1914 AND 1909

	1914	1909	Per Cent of Increase, 1909-1914
Number of establishments..	242	280	13.6*
Total cars built:			
Number	138,178	101,243	36.5
Value	$165,071,427	$102,147,396	61.6
Steam:			
Number	135,357	98,471	37.5
Value	$155,029,539	$94,884,287	63.4
Passenger:			
Number	3,558	1,819	95.6
Value	$45,027,083	$15,120,961	197.8
Freight and others:			
Number	131,799	96,652	36.4
Value	$110,002,456	$79,763,326	37.9
Electric:			
Number	2,821	2,772	1.8
Value	$10,041,888	$7,263,109	38.3

*Decrease.

Boston Elevated Exhibit at Technology Dedication

IN connection with the dedication of the new $7,000,000 plant of the Massachusetts Institute of Technology at Cambridge on June 14, the Boston Elevated Railway had an interesting exhibit of transportation progress in the past half century. With electrical and water-power displays, the exhibit was housed in one of the wings of the immense new establishment on the border of the Charles River Basin, and was visited by a vast crowd of appreciative guests. A working model of a rapid transit car was shown, equipped with third-rail shoes and operating automatically on a track provided with complete miniature signals of the automatic illuminated type, governed by a standard installation of track relays. Colored photographs illustrated the evolution of street conveyances from the omnibus of 1856 to the latest type of semi-convertible, prepayment car in use on the system to-day, and other views illustrated the company's methods of track maintenance, subway shelter designs in America and Europe, cross-sections of rapid transit subways, the South Boston generating station of 125,000-kw. ultimate capacity, and the high-tension distribution system of the road. Elevation drawings of the latest subway rolling stock were shown for Boston and other cities, and graphic charts of the company's financial development and of its traffic and transfer growth were exhibited.

BOSTON ELEVATED RAILWAY EXHIBIT