THE CHICAGO, MILWAUKEE & ST. PAUL LOCOMOTIVES

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The author gives a great deal of valuable data on these most interesting locomotives. Among the points which will attract special attention are the regenerative control, the large continuous capacity of the motors, and the novel form of current collectors. The comparison given between these locomotives and the Mallet engine emphasizes the size and hauling capacity of the electric locomotives. This article appeared in the *Electric Railway Journal* of June 5, 1915.—Editor.

The flexibility in design and operation of the electric locomotive afforded by the use of electric motors renders this type of motive power especially well suited to the hauling of trains, either high speed passenger or slow speed freight. In fact the electric locomotive possesses inherent qualifications for haulage service that are becoming more fully appreciated as constituting the fundamental reasons for bringing about the change from steam to electricity, and interest in any new projected electrification therefore largely centers in the characteristics of the locomotives proposed. Work has progressed upon the Chicago, Milwaukee & St. Paul locomotives at the Schenectady and Erie Works of the General Electric Company to such an extent as to make available certain facts as to the construction and capacity that are of especial interest owing to the magnitude of the problems involved in this extensive electrification.

The general data applying to the St. Paul freight locomotives are as follows:

Type of locomotive	3000 volts direct current
Length over all	112 ft.
Total wheel base	103 ft.
Rigid wheel base	10 ft. 6 in.
Total weight	520,000 lb.
Weight on drivers	400,000 lb.
Weight on driving axle	50,000 lb.
Weight on guiding axle	30,000 lb.
Diameter of driving wheel	52 in.
Diameter of guiding wheel	36 in.
Number of driving motors	8
Total output (continuous rating)	3000 h.p.
Total output (1 hour rating)	3430 h.p.
Tractive effort (continuous rating)	71,000 lb.
Per cent of weight on drivers	17.75
Speed at this tractive effort at 3000 volts	15.75 m.p.h.
Tractive effort (1 hour rating)	85,000 lb.
Per cent of weight upon drivers	21.2
Speed at this tractive effort at 3000 volts	15.25 m.p.h.

A very exhaustive series of tests have just been completed upon the first sample motor built at Schenectady which have demonstrated that it has ample capacity to meet the heavy demands that will be placed upon it under service operating conditions. The motors are wound for 1500 volts and connected two in series for 3000 volts. The power axles are driven by twin gears, in this respect being similar to the drive on the Great Northern, Detroit Tunnel, Baltimore & Ohio and Butte, Anaconda & Pacific, except that springs are used in the axle gears. On account of the high voltage for which the motors are wound, the commutator width is small, thus allowing more space for armature iron and copper, with the result that the motor has a continuous capacity of 375 h.p. In fact special interest attaches to the large continuous capacity of the St. Paul locomotive as this is the first instance where such a liberal motor capacity has been required and provided for, and it should be noted that this large capacity is secured in an axle motor without departing from well known and thoroughly tried out forms of construction.

A study of the train dispatcher's sheet covering performance on mountain grade divisions of our steam railways discloses the fact that it is general practice to assign such a trailing tonnage to a locomotive on ruling grade as to demand a tractive effort at the driver rims equivalent to approximately 18 to 19 per cent of the weight upon the drivers. In other words, steam practice calls for a locomotive which can operate for long periods at a coefficient of adhesion of 18 to 19 per cent, leaving the difference between this value and the slipping point of the drivers as a sufficient margin with which to start on ruling gradients. Under like track conditions, the uniform torque of the electric motor should make available some 10 per cent more tractive effort than is possible with the reciprocating drive of the steam locomotive having the same weight upon the drivers. Until sufficient operating experience is available, however, to prove that an electric locomotive can be rated at 20 per cent coefficient of adhesion, it seems reasonable to

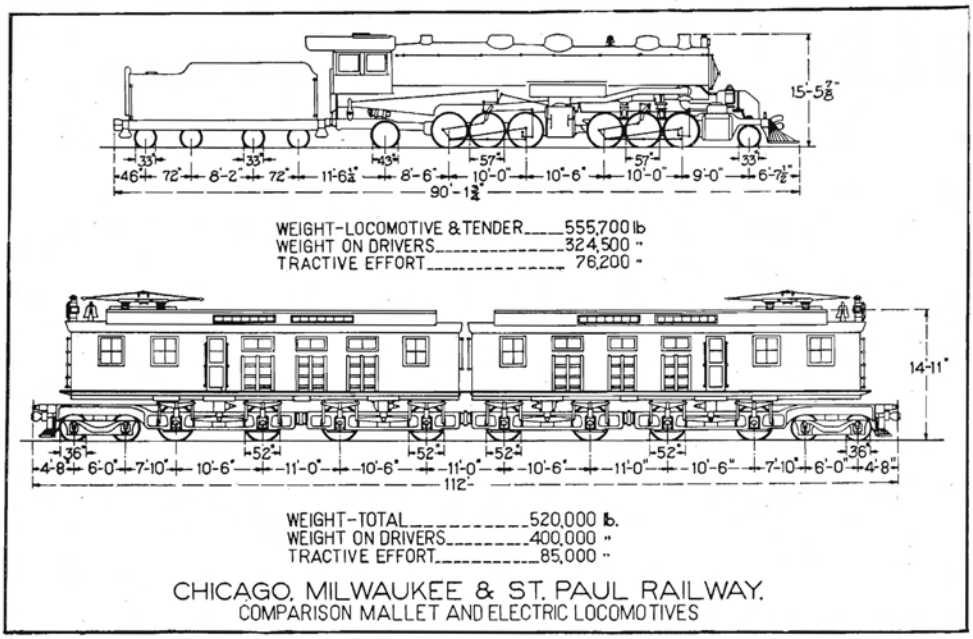

Fig. 1. Diagram of the Mallet Locomotive which has been used on the C. M. & St. P. Ry., and of the electric locomotive which is replacing the Mallet type on that road

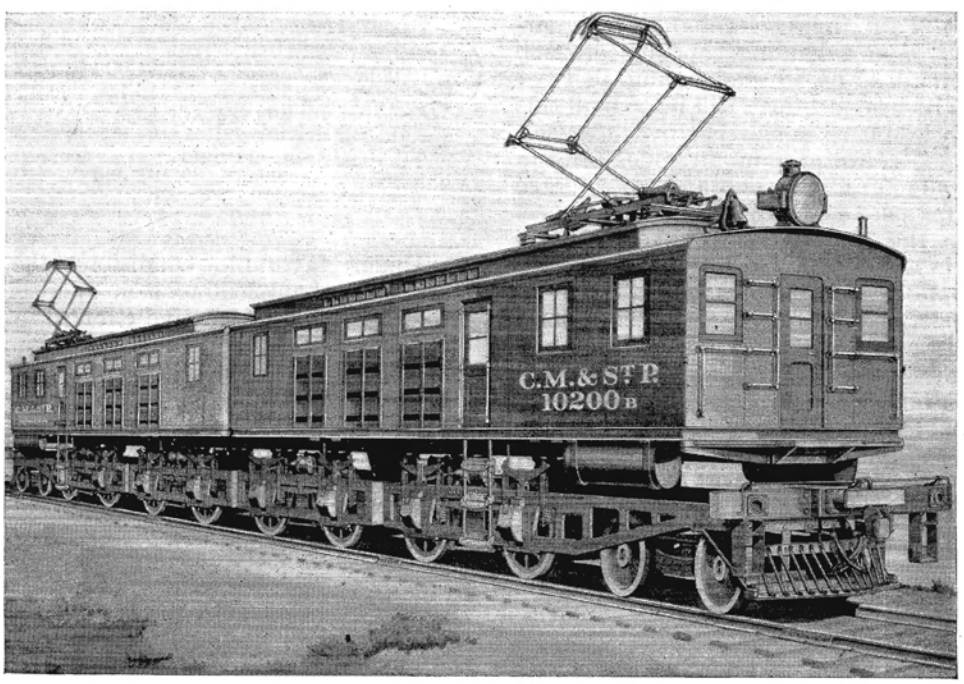

Fig. 2. C. M. & St. P. 3000-volt Direct-current Locomotive, total weight, 260 tons eight motors, total capacity 3440 H.P.

adhere to the present steam practice of a somewhat lower value. The St. Paul locomotive, therefore, with its continuous motor capacity of 17.75 per cent and a one hour rating of 21.2 per cent of weight on drivers

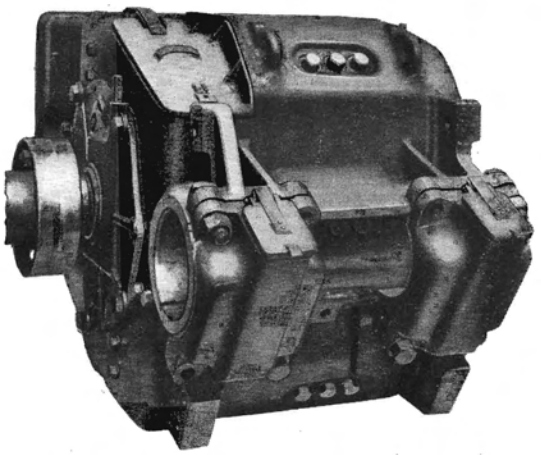

Fig. 3. One of the eight direct-current motors used on a C. M. & St. P. locomotive

gives ample assurance of ability to handle its assigned tonnage under all service conditions.

The St. Paul freight locomotive is guaranteed to have a hauling capacity of 2500 tons trailing load on all gradients up to 1 per cent, and its heaviest duty will be to haul this load from Lombard to Summit over the Belt Mountains, a distance of 49 miles with a ruling grade of 1 per cent and an average grade of 0.7 per cent over the entire distance. Including the locomotive of 260 tons, the gross train weight of 2760 tons will require a tractive effort of approximately 72,000 lb. on the 1 per cent ruling grade, based upon a train resistance of 6 lb. per ton. This practically corresponds to the continuous rating of the locomotive as tabulated herein and brings out the interesting fact that these locomotives are so proportioned as to motor capacity that they cannot be abused under normal service operation.

The necessity of rating main line electric locomotives upon a practically continuous basis is still further emphasized in the case of the St. Paul locomotives by the introduction of electric regenerative braking. The heavy demands upon the motors when operating up grade may be nearly duplicated during the following down grade running when regenerating, thus giving small chance for the time element of the motor heating to enter as a factor in proportioning its capacity for such exacting service. A 2 per cent grade requires a motor output of 46 lb. per ton up grade and gives 34 lb. per ton motor input down grade. Making due allowance for internal locomotive losses, it is evident that the motor output when operating as a generator down grade will approximate 60 per cent of its input when hauling the same train up a 2 per cent gradient, hence, the need of making provision for a practically continuous motor capacity in the St. Paul locomotives in order to meet the service requirements of the broken profile over which they are designed to operate.

It is interesting to compare the relative capacity of the new electric locomotives and the Mallet engines they will replace.

COMPARISON MALLET AND ELECTRIC LOCOMOTIVES

	Mallet	Electric
Total weight	555,700 lb.	520,000 lb.
Weight on drivers	324,500 lb.	400,000 lb.
Rated tractive effort	76,200 lb.	85,000 lb.
Per cent of weight on drivers	23.5%	21.2%
Rated tonnage 1 per cent grade	1,800 tons	2,500 tons
Tractive effort for above tonnage	54,000 lb.	71,700 lb.
Coefficient of adhesion	16.7%	17.7%
Wheels per guiding truck	2	4
Weight per driving axle	54,000 lb.	50,000 lb.
Total weight on one rigid wheel base truck	162,000 lb.	100,000 lb.

Under favorable conditions the Mallet engine can haul 2000 tons on 1 per cent grade. thus bringing its tractive effort up to 59,000 lb. and the coefficient of adhesion on its drivers up to 18.3 per cent. The electric locomotive weighs 94 per cent of the combined weight of Mallet engine and tender and has a tonnage rating 23½ per cent greater based upon using the same coefficient of adhesion in each case, that is 17.9 per cent. This comparison indicates that the electric locomotive has a hauling capacity one-third greater than the steam engine and tender of the same total weight, has less weight per axle, is provided with four-wheel guiding truck in place of two-wheel, requires no turn table, as it operates equally well in either direction, and finally, eliminates the necessity for stopping to take on coal and water.

The same type of locomotive is used for both freight and passenger service, the only difference between the two being the gear ratio, which is 4.56 for freight and 2.45 for passenger service. This interchangeability of all parts of the freight and passenger locomotive and the adoption of one uniform type for all classes of service should be reflected later in the low cost of maintenance of the locomotive as well as prove of great benefit in the economical handling of the traffic. For facility in shop repairs, the locomotive is constructed in halves, and in fact each half can be provided with draft gear in place of the articulated joint and operated singly in service up to its capacity. One passenger locomotive will haul a trailing load of 800 tons over all gradients of the road without assistance except upon the 2 per cent grade section over the main divide of the Rocky Mountains. Even on this grade a 600-ton train can be hauled without assistance. This illustrates the exacting nature of mountain railroading which demands in this instance that the passenger locomotives shall have the necessary motor capacity and smooth running qualities to successfully haul an 800-ton train at 60 miles per hour on level track and also operate over 20 miles of 2 per cent up grade. Add to this the regenerative braking feature and steam heaters for train heating. and the broad nature of the problem of designing an electric locomotive for main line mountain service becomes very apparent. The locomotive superstructure contains space for two oil fired steam heaters together with ample provision for storage of oil and water. All passenger locomotives and a certain number of freight locomotives intended as reserve passenger units will be equipped with heater boilers.

A departure from the roller current collector of the Butte locomotive has been made in the St. Paul locomotives as the result of numerous experiments made upon the test tracks at Schenectady and Erie. These tests indicate that a double pan collector bearing against twin conductor trolley wires is capable of taking off a current of 2000 amperes at speeds as high as 60 miles per hour. This is several times the demand upon one collector of the St. Paul locomotives and the double pan was adopted in place of the roller collector although the latter has been giving excellent results, reaching a life of nearly 30,000 miles in the passenger service of the Butte, Anaconda & Pacific Railway.

Provision has been made in the control to enable two locomotives to be run together in multiple unit, but the enormous starting effort of two such locomotives, 240,000 lb. tractive effort at 30 per cent coefficient of

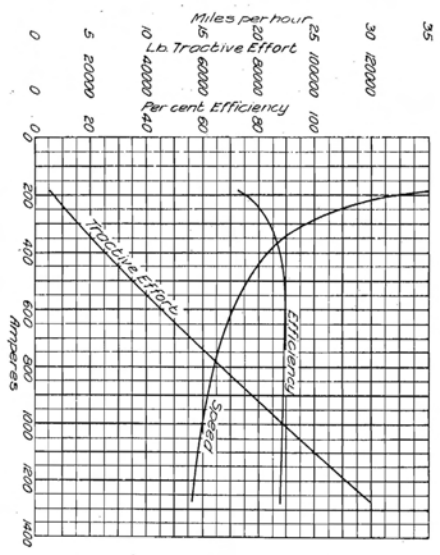

Fig. 4. Characteristic curves of a C. M. & St. P. freight locomotive. Direct current, 3000 volts; Gear ratio 4.56; Diameter drivers 52 inches

adhesion, makes such a combination of use only when it acts as a pusher on the rear of a train. The motors and starting resistances are designed to permit of a starting effort of 120,000 lb. being maintained on one locomotive for a period of five minutes without destructive heating and in this connection the thermal capacity of the heavy slow speed motors will be of great assistance.

The first completed St. Paul locomotive will probably be placed upon the test tracks at Erie during September and shipment of these locomotives commenced soon thereafter. The construction work upon trolley and substations of the first engine division between Three Forks and Deer Lodge has been so far completed as to give promise of being finished and ready for the trial runs of the locomotives as soon as they are received this fall. Ample provision has been made for power and transmission line facilities by the Montana Power Company, so that electrical operation of the Chicago, Milwaukee & St. Paul Railway should soon be an accomplished fact.