A 3000-volt Direct-current Passenger Locomotive for the Chicago, Milwaukee & St. Paul Railway

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The original electric locomotives of the C., M. & St. P. Ry. were of the geared type, and differed for freight and passenger service only in the gear ratio. As is well known the performance of these locomotives has been entirely satisfactory; but the advantages of the gearless type of construction for passenger service as demonstrated by the gearless locomotives of the New York Central Railroad have led to the development of a similar type for the C., M. & St. P. Ry. These locomotives are now being placed in operation and will eventually replace the geared type of passenger locomotives, which will be assigned to freight service with a change of gear ratio. The mechanical and electrical features of these new locomotives are described in this article.—Editor.

The original electrification of the Chicago, Milwaukee & St. Paul Railway has now been operating for a number of years under the extremely bad weather conditions of the Rocky and Bitter Root Mountains and, as a result of the unqualified success of this Montana electrification, the same system will now be used to meet the severe grades and snow conditions of the Cascade Range. The motive power equipment of the original electrification consisted of 42 locomotives for freight and passenger service, and four switchers. Of this equipment, the freight and passenger locomotives differed from each other only in the gear ratio between the motors and driving axles.

The new 3000-volt direct-current locomotives, which are now being placed in operation for passenger service on the Othello-Seattle-Tacoma electric zone of the railway, are of an entirely different design. They are built distinctively for passenger service and possess some very interesting mechanical and electrical features. (The geared passenger locomotives will be employed for freight service with a change of gear ratio.) The new locomotives are of the bi-polar gearless type, with the motor armatures mounted directly on the driving axles. In this fundamental feature, they follow the design of the gearless locomotives which have given remarkable operating results during the past ten years on the New York Terminal of the New York Central Railroad. The chief advantage of this method of construction is the great simplicity of mechanical design which eliminates all gears, armature and suspension bearings, jack-shafts, side-rods or other transmitting devices. The remarkably low cost of maintenance of the New York Central locomotives over the entire period is attributed largely to the gearless type of construction.

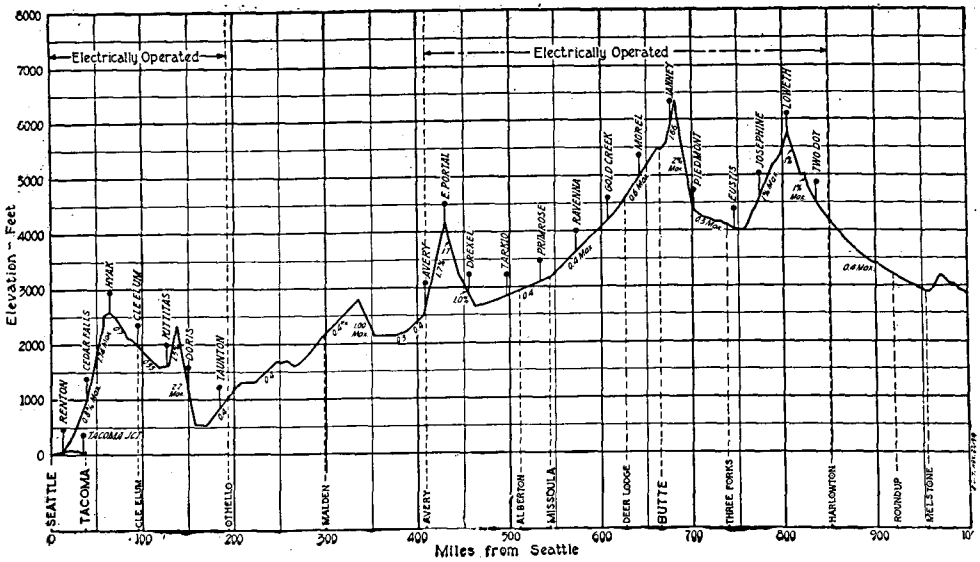

Fig. 1. Profile showing the Electrified Divisions of the C., M. & St. P. Ry. on the Rocky Mt. and Cascade Mt. Ranges. These electrifications now constitute nearly one third the length of this Railway from Chicago to the Pacific Coast

The new Chicago, Milwaukee & St. Paul locomotives weigh 265 tons each, with 229 tons on the drivers. They have fourteen axles, twelve of which are driving, and two guiding axles. The weight of the armatures and wheels is the only dead weight on the track, and this is approximately 9500 pounds per axle. The total weight on the drivers (458,000 pounds) is 86 per cent of the weight of the locomotive, but, being distributed among twelve axles, results in a weight of only 38,166 pounds per axle.

One of the most interesting and important features of the locomotive is the design of the leading and trailing trucks and the method of suspending the cab weight upon them. The successive trucks are coupled together in such a way as to dead-beat or break up any lateral oscillations which may be caused by inequalities of the track. The weight of the main cab is so supported on the front and rear trucks that any lateral thrust or kick of the leading or trailing wheel against the track is cushioned by the movement of the main cab which automatically increases the weight bearing down on the wheels at the point where the thrust occurs and automatically reacts to prevent any distortion of the track. The result of this design is such as to give riding qualities at high speeds which have probably never been attained before in a double-ended locomotive. Exhaustive tests on the General Electric Company's test tracks at Erie, Pa., have demonstrated the remarkable riding qualities of the new locomotive at speeds as high as 65 miles per hour, which is the limit of speed on the length of test track available. These tests also indicate that the locomotive will operate at much higher speeds with equal success.

The locomotive is designed for handling in normal service a 12-car train weighing 960 tons trailing against a grade of 2 per cent at 25 miles per hour. This performance requires 56,500 pounds tractive effort which is equivalent to a coefficient of adhesion of 12.3 per cent of the weight upon the driving axles. The wide margin thus provided between the operating tractive coefficient and the slipping point of the wheels, as well as the ample capacity of the motors, will allow this locomotive to haul trains of as many as fourteen cars in emergencies. For continuous operation, the locomotive is designed to operate at 42,000 pounds tractive effort at a speed of 25 miles per hour.

The total weight supported on the driving axles is practically the same as that on the

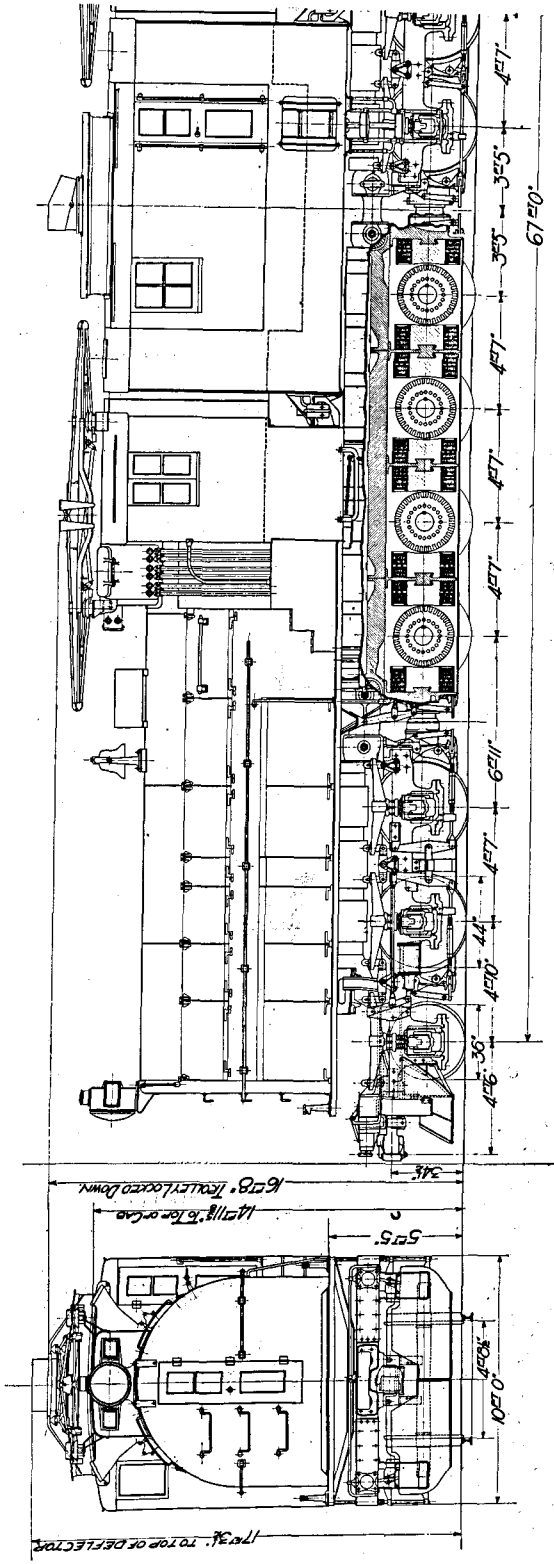

Fig. 2. End Elevation and Side Elevation of a Portion of the New 3000-volt, Direct-current Gearless Passenger Locomotive. One of the eight-wheel trucks with four motors is shown in section

present geared passenger locomotives, a total of 300 tons. Table I gives the principal dimensions, weights, and capacity of this new locomotive.

TABLE I

Length inside knuckles	76 ft. 0 in.
Length over cab	68 ft. 0 in.
Total wheel base	67 ft. 0 in.
Rigid wheel base	13 ft. 11 in.
Diameter driving wheels	44 in.
Diameter guiding wheels	36 in.
Weight electrical equipment	235,000 lb.
Weight mechanical equipment	295,000 lb.
Weight complete locomotive	530,000 lb.
Weight on drivers	458,000 lb.
Weight on each guiding axle	36,000 lb.
Weight on each driving axle	38,166 lb.
Number of motors	12
One hour rating	3240 h.p.
Continuous rating	2760 h.p.
Tractive effort; one-hour rating	46,000 lb.
Tractive effort; continuous rating	42,000 lb.
Tractive effort; two per cent ruling grade with 960-ton train	56,500 lb.
Coefficient of adhesion ruling grade	12.3 per cent
Starting tractive effort; 25 per cent coefficient of adhesion	115,000 lb.
Rate of acceleration starting two per cent ruling grade	0.48 m.p.h.p.s.

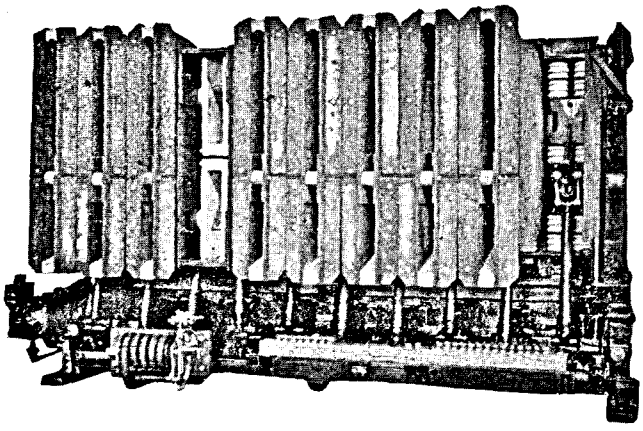

Fig. 3. Electro-pneumatic Series-parallel Switch for Changing the Connection of the Motors from Six in Series to Three in Series

The control equipment for the new locomotive is similar in most respects to that now used on the original locomotives which have now been operating nearly four years. Modifications were, of course, necessary to comply with the different arrangement of motors. Advantage is taken of a new scheme of connections by means of which four of the main locomotive motors are utilized to furnish exciting current during regeneration, thus reducing the size of the motor-generator set used for control, accessories, and train lighting. An appreciable reduction in the weight of control equipment is obtained yet, at the same time, effective regenerative electric braking is provided on the down grades. The motor-generator set furnishes control current for operating the contactors and for charging an 80-volt storage battery which supplies lights and power for the accessory apparatus. The battery is, in general, similar to those used on the passenger coaches. The master controller is constructed in three sections arranged for both motoring and regenerating, all of the cylinders being suitably interlocked to prevent incorrect manipulation.

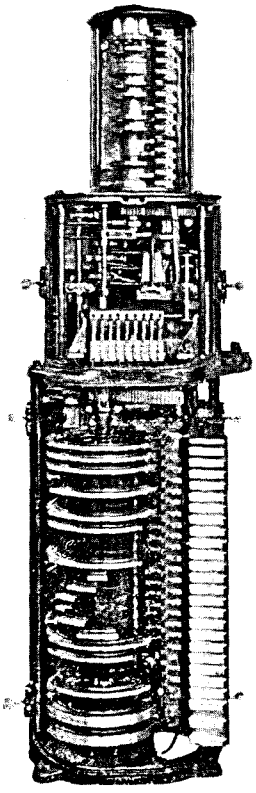

Fig. 4. Master Controller That, Through Low-voltage Auxiliary Circuits Actuates the 3000-voltDir ect-current Switches

The motors are bi-polar, the two fields being supported upon the truck springs with full freedom for vertical play of the armature between the pole faces. Fig. 2 shows the outline of the locomotive with a sectional view of four of the motors indicating the location of the armatures and the magnetic section. For full-speed operation, the twelve motors are connected three in series with 1000 volts per commutator. Control connections are also provided for operating four, six, or twelve motors in series. Additional speed variation is obtained by tapping the motor fields in all combinations. Cooling

air for each pair of motors is supplied by a small motor-driven blower. This arrangement avoids the heavy duct losses encountered with a single large blower.

As may be seen from the curves in Fig. 6, the gearless locomotive shows a much better efficiency at high speeds than the geared type, owing to the elimination of the gear drive. In passenger service, where there are long stretches of level track and stopping points are comparatively few, a much higher efficiency is obtained in all-day service. These curves show an efficiency at 50 miles per hour approximately 10 per cent higher than the geared type of locomotive.

The 3000-volt contactors and grid resistors are mounted in the curved end cab at each end of the locomotive. In one of these cabs there is also located the 3000-volt direct-current air compressor and storage battery. In the other is located a small motor-generator set and the high-speed circuit breaker. The operating cabs contain the master controller, indicating instruments, and a small air compressor operated from the battery circuit and having sufficient capacity for raising the pantograph when first putting the locomotive in operation. Near the controller are the usual air brake handles for the standard braking equipment.

The center cab is occupied by the oil-fired steam boiler for heating the passenger train and by accessories including tanks for oil and water, circulating pumps, and a motor-driven blower for furnishing forced draft. A

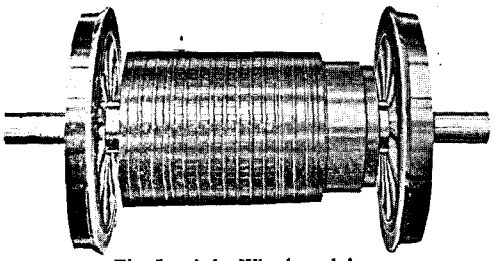

Fig. 5. Axle, Wheels and Arms

slider pantograph, similar in construction to those now in use, is mounted on each of the operating cabs. This pantograph has two sliding contacts, giving a total of four points per slider with the double trolley. The pantograph and flexible twin trolley construction enable the locomotives to collect currents as high as 2000 amperes at speeds up to 60 miles per hour without noticeable arcing at the contact points. The second pantograph is held in reserve as a spare. Sand boxes, with pipes leading to each pair of driving wheels, are located directly beneath the pantograph outside the operating cab.

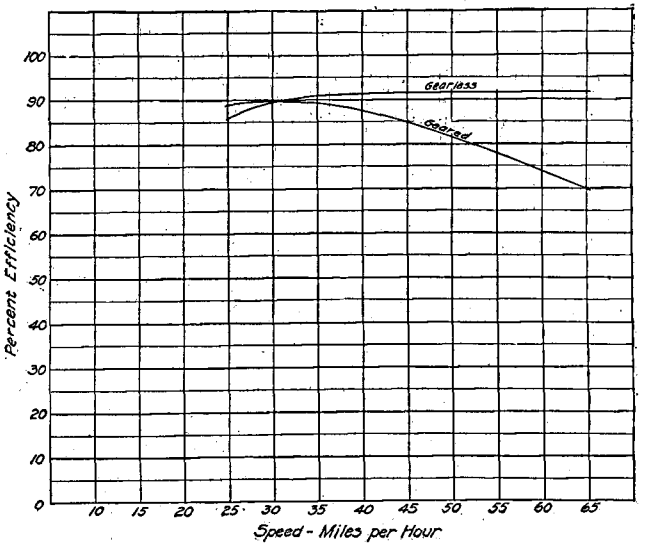

Fig. 6. Speed-efficiency Curves of Geared and Gearless Locomotives, showing the superior efficiency of the gearless type at passenger speeds

Fig. 1 is a continuous profile from Seattle to a point about 1000 miles east, including the Cascade electrification, the Harlowton Avery electrification and the intervening 220 miles. The new locomotives will operate over the section between Othello, Seattle, and Tacoma, including 17 miles of 2.2 per cent grade from the Columbia River west, and 19 miles of 1.7 per cent grade between Cedar Falls and the summit of the Cascades. The traffic over this division consists of the heavy main line transcontinental passenger trains "Olympian" and "Columbian," carrying from 8 to 12 steel passenger coaches which will be handled over the maximum grades without helpers. Freight pushers are already in operation on the 2.2 per cent grade, using two of the locomotives from the original electrification. It is expected that electrical operation during the coming winter will assist in overcoming many of the delays which are commonly met during winter operation in this district.