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Electric Locomotives for the C., M. & St. P. Railway

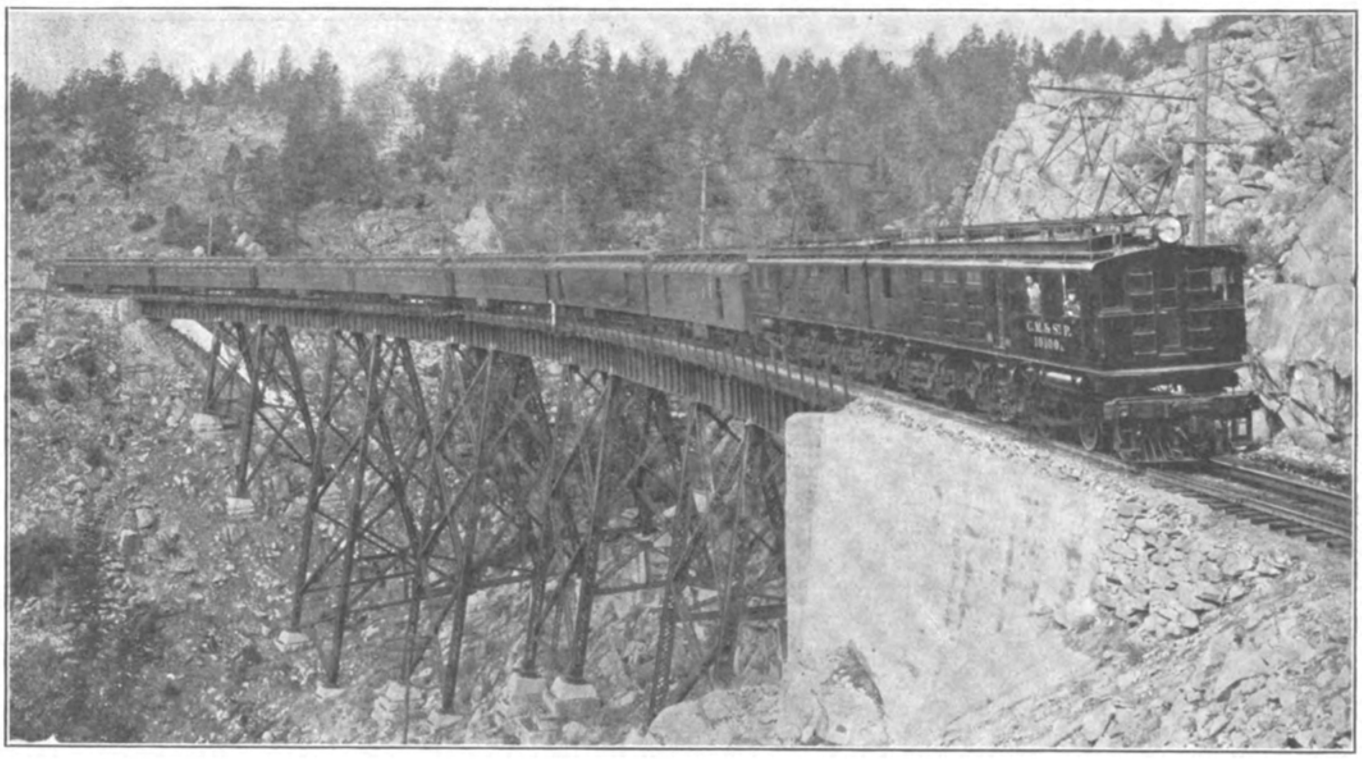
The 3,000-volt direct-current electrification of the Chicago, Milwaukee & St. Paul Ry. is the most extensive railway electrification that has, thus far, been developed and, as such, has attracted worldwide attention. It covers a distance of about 850 miles from Harlowton, Montana, to Seattle and Tacoma, crossing the Big Belt, Rocky, Bitter Root and Cascade ranges. In crossing these four mountain ranges there are several grades of one per cent. or more, the most difficult being the 21 miles of two per cent. between Piedmont and Donald and the longest the 49 miles of one per cent. grade on the west slope of the Belt mountains. The curvature is necessarily heavy, the maximum being ten degrees.

About 440 miles of this line from Harlowton, Montana, to Avery, Idaho, have been under electric operation for about four years, and now the balance is to be put into service.

The current for the operation of the line is furnished by the Montana Power Co., which has now completed the development of fourteen hydro-electric plants with an aggregate capacity of 171,530 kilowatts, of which the largest is the plant at the Great Falls of the Missouri River of 60,000 kilowatts. To this must be added a 40,000 kilowatt plant at Holter on the Missouri River, which is in course of construction, and four steam plants having a total capacity of 5,920 kilowatts.

The transmission lines from these plants form a network covering a large part of Montana, and which tap into the railway system at seven different points, where the power is most needed. So that, with this completely interconnected transmission system, each sub-station may be fed from either direction, and also at the tie-in points from a third source of power, by which the reliability of the source of power is insured.

The portion of the line first electrified was operated by 300-ton locomotives with geared motors having a ratio of reduction of 4.56 to one. The General Electric Co. are just completing an order for a number of gearless locomotives, which will be used in both passenger and freight service. These engines are of the following general dimensions, weights and capacity.



CHICAGO, MILWAUKEE AND ST. PAUL 3,000 V. D. C. ELECTRIFICATION TRAIN NO. 16 DESCENDING 2 PER CENT GRADE.

Length inside knuckles	76 ft.
Length over cab	68 ft.
Total wheel base	67 ft.
Rigid wheel base	13 ft. 11 in.
Diameter driving wheels	44 in.
Diameter guiding wheels	36 in.

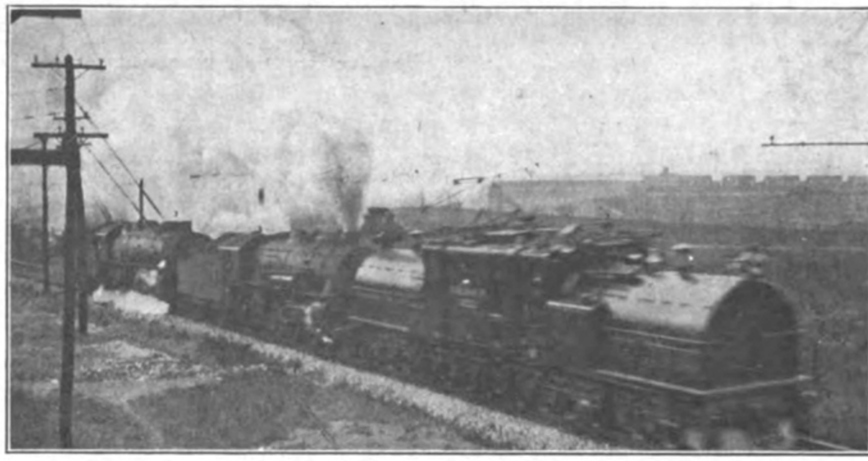
Weight of electrical equipment, 235,000 lbs.
Weight of mechanical equipment, 295,000 lbs.
Weight of complete locomotive, 530,000 lbs.
Weight on drivers............458,000 lbs.
Weight on guiding axle.......36,000 lbs.
Weight on each driving axle..38,166 lbs.
Number of motors..................12
One hour rating ....3,240 H.P.
Continuous rating ....2,760 H.P.
Tractive effort, one hour rating, 46,000 lbs.
Tractive effort on 2 per cent. ruling grade with 960-ton train.....56,500 lbs.
Coefficient of adhesion on ruling grade ....12.3 per cent.
Starting tractive effort, 25 per cent. coefficient of adhesion......115,000 lbs.
Rate of acceleration starting on 2 per cent. grade, 0.48 miles per hour per second

It will be seen from this that the engines rank well to the fore in a comparison with any steam locomotives. The starting tractive effort of 115,000 lbs. with a continuous rating of from 42,000 to 56,500 lbs. reaches the highest of steam locomotive practice.

The locomotive is designed to haul a 12-car passenger train, weighing 960 tons, up a 2 per cent. grade at a speed of 25 miles per hour. This requires the tractive effort of 56,500 lbs. given in the tabulation above. But even this involves so low a coefficient of adhesion (12.3 per cent.) that there is no liability of slipping the wheels.

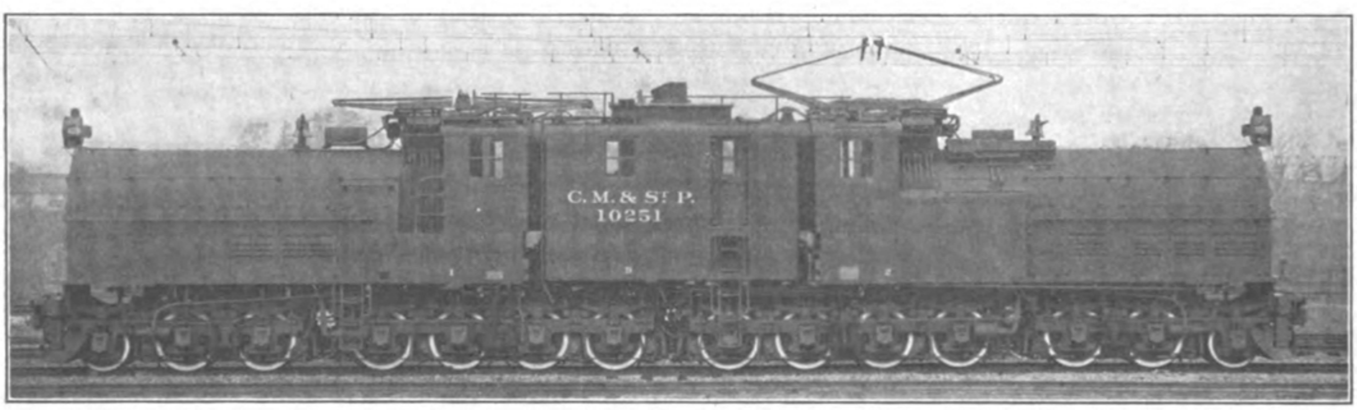
The change from the geared to the gearless type has resulted in an increase of efficiency. A diagram of efficiency rating running from 25 to 65 miles per hour, shows that up to about 32 miles per hour the geared locomotive is the more efficient machine of the two. At higher speeds it is the gearless that is the more efficient. At a speed of 25 miles per hour the efficiency of the geared engine is about 88.5 per cent. This rises to 90 per cent. at 30 miles per hour, remains constant to about 32 miles per hour and then falls off on a nearly straight line to 70 per cent. at 65 miles per hour. On the other hand, the curve of the gearless motor starts at about 86 per cent. efficiency at 25 miles per hour, rises on an easy curve to nearly 92 per cent. efficiency at about 38 miles per hour and then runs straight and without change out to 65 miles an hour. So that at this high speed there is a marked difference between the two.

The control equipment for these locomotives is similar in most respects to that used on the geared locomotives. Modifications were, of course, necessary to comply with the different arrangements of motors. Advantage is taken of a new method 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. Thus an appreciable reduction in the weight of control equipment is obtained, at the same time providing for effective regenerative electric braking 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 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.



TESTS OF GEARLESS LOCOMOTIVE. STEAM AND ELECTRIC LOCOMOTIVES DURING REGENERATIVE BRAKING TEST.

The motor is bipolar, the two fields being supported upon the truck springs with full freedom for the vertical play of the armature between the pole faces. The illustration of the end elevation of the gearless locomotive shows its outline 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 1,000 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 losses in when a single large blower is used.



3000 VOLT GEARLESS PASSENGER LOCOMOTIVE, CHICAGO, MILWAUKEE AND ST. PAUL RAILWAY.

In designing the new locomotives a distinct change was made in the running gear. The original engines consisted of two units, each comprising three trucks. There was a four-wheeled guiding truck which was located at the end of the machine, followed by two other four-wheeled motor trucks, to which was added another unit arranged in the reverse order. The arrangement of the new engine also consists of three trucks at each end. The guiding truck is two-wheeled, and is followed by a four-wheeled and then by an eight-wheeled truck. Then comes the same arrangement in reverse order. These trucks are so coupled together that any lateral oscillation that may be caused by inequalities of the track are broken up and the machine given a very easy motion, so that the riding qualities at high speed are remarkably good, as demonstrated on the test track at Erie, Penna., which has also demonstrated that an equally satisfactory performance can be obtained at higher speeds.

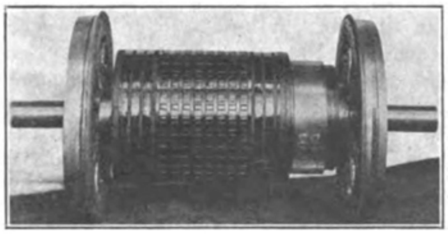
The cab is in three sections. The weight of the end section is so supported on the front and rear trucks that any lateral thrust or kick of the leading or trailing wheel against the track is cushioned by the movement of the cab, which increases the weight bearing down on the wheels at the point where the thrust occurs, and automatically reacts to prevent any distortion of the track. This assists in securing the fine riding qualities already referred to.

In the center cab there is an oil-fired boiler, with its accessories, for heating passenger trains. The accessories consist of tanks for oil and water, circulating pumps and a motor-driven blower for furnishing forced draft. This center cab is so arranged that it can be lifted off from the trucks in case it becomes necessary to make repairs upon the boiler.

The current is collected from the overhead wires by means of a slider pantograph, one of which is placed on the cab at each end of the engine. There are two sliding contacts on the pantograph, so that there are four on the slider with a double trolley. This, with the flexible twin trolley construction, enables the locomotive to collect ample current at any speed, running as high as 2,000 amperes at 60 miles an hour, and that without any appreciable arcing at the contact points.

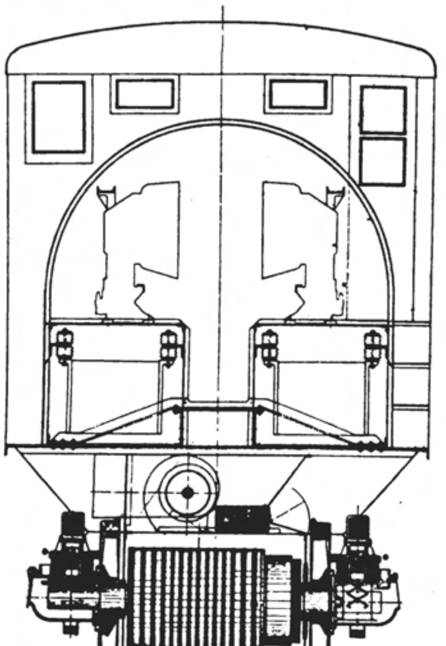
Only one pantograph is used at a time, the second being lowered and held in reserve.

The movement and adjustment of the pantograph is controlled by means of an air valve. To raise the pantograph, air from the main reservoir is admitted to a pair of cylinders. The pistons of these cylinders energize powerful springs, which, in turn, raise the collector and, at the same time, regulate the pressure against the trolley wire. The raising springs are energized at all times while the collector is in use, by maintaining air pressure in the cylinders. To lower the pantograph, air is exhausted from the cylinders, thus de-energizing the springs. The pantograph will then drop to its minimum collapsed height. The range of action of the trolley is between 17 ft. and 25 ft. above the rail.



DRIVING WHEELS AND G E-100 ARMATURE

One of the prominent features of the system is the use of regenerative braking for the control of trains on a descending grade. This feature adds very materially to the safety of operation by supplying a second braking system in addition to the air brakes. It provides increased economy of operation by reducing wheel, track and brakeshoe wear. It permits faster speeds down grades, due to the better ability of definitely controlling the locomotive, which is difficult at best with the air brakes. It also adds materially to the comfort of the passengers, because of the smoother operation down grades. And this is attained by means of very simple and reliable additions to the equipment required for motor running.



END ELEVATION OF GEARLESS LOCOMOTIVE.

With the simple direct current motor adopted for these locomotives, their operation as motors or generators depends upon whether the voltage of the trolley system at the locomotive is above or below the voltage at the motor terminals. When the locomotive is motoring, the voltage at the motor terminals is lower than the trolley potential, and power flows into the locomotive. When the locomotive descends a grade, and is braking, the engineer effects an increase in the voltage across the motor terminals so that power flows from the locomotive into the transmission system. The generation of this returned energy reacts on the locomotive so as to cause retardation or braking, besides effecting an economy by returning power to the line. So these locomotives which are descending grades, by revolving their motors as generators, deliver power to any other ascending locomotive. In this way a conservation of energy is effected in that a portion of the power required for raising the locomotives to the top of the divide is later returned in the descent.

In train braking there is no external evidence of this internal resistance of the locomotive other than the reduced or controlled speed on a descending grade. A rather spectacular demonstration of the possibilities was recently given to a gathering of railway officials on the experimental track at Erie, Penna.

Two heavy steam freight locomotives were attached to a single electric locomotive, and the engineers of the steam locomotives were instructed to push the electric locomotive, which was placed in regenerating position, at a speed of from 25 to 28 miles per hour. This was done, and their exhausts told the story of long cutoffs and heavy work Meanwhile the generated current was poured back into the line to such an extent that, for a time, the major portion of the General Electric shop at Erie was run by this current. Probably the first time on record that the draw-bar pull of a passing locomotive was used to drive the machinery of a shop alongside the track. It is roughly estimated that about 40 per cent. of the drawbar horsepower of these two steam locomotives was converted into useful work in driving the shop tools.

Another demonstration of the power of the electric locomotive was made at the same time in a tug-of-war contest. The two steam engines were coupled to the electric and allowed to acquire a speed of from three to four miles an hour, when the current was thrown on to the electric. The two were stopped and slowly pushed backward. This merely showed that in this case the electric locomotive was more powerful and had a greater adhesive weight than the combined weight on drivers of the other two. But as the two were large and heavy engines, the mere fact of ability to stop them and push them against themselves made an impressive sight.