C. M. & St. P. Electric Locomotives Tested at Erie

Five Units of This Type Will be Used in Passenger Service Over the Cascade Electrified Section

TESTS were made on one of the five electric locomotives built by the General Electric Company for the Chicago, Milwaukee & St. Paul at Erie, Pa., on Friday, November 7. The large number of nationally prominent engineers and railroad men present at the demonstration was evidence of the interest taken in the subject of electrification. The representation included 11 American railroads, two Canadian railroads, the Chilean Railway Commission, manufacturers from the United States, France and Japan, several consulting engineers and representatives of the General Electric Company from various parts of the world. All of those present were guests of the General Electric Company.

During the morning a number of speed runs were made along the three-mile test track. Two passenger cars were hauled on some of these runs and some were made with the locomotive running light. The runs were continued until everyone had had an opportunity to ride on the locomotive. It was particularly interesting to note that practically all of the railroad men who rode in the cab of the locomotive, underestimated the speed. A speed of 60 miles an hour was estimated usually at about 45. A buffet luncheon was served in one of the shop buildings at noon.

In the afternoon tests were made to show what could be done with regenerative braking. Two New York Central steam locomotives were brought onto the test track. One of these was a (4-6-2) Pacific type and the other a (4-8-2) Mohawk type. These were coupled in tandem to the electric locomotive and used to push it while the electric locomotive was made to regenerate electric power to the trolley and thereby resist the power of the steam locomotives. The steam engineers were instructed to use all the power they could, but it was possible with both steam locomotives working to full capacity to hold the speed down to any desired value by regenerating with the electric. The noise of the exhausts was good evidence of the fact that reverse levers were left in the extreme forward position and that throttles were wide open. A measurement of just what the steam locomotives were doing was obtainable in the substation where the meters showed that the electric locomotive was returning 1,200 amperes at 3,000 volts, or almost 5,000 hp. of electrical energy to the power system. This was done at a speed of about 25 miles an hour. When pushed by another electric locomotive, one of these engines has returned as much as 1,600 amperes to the line.

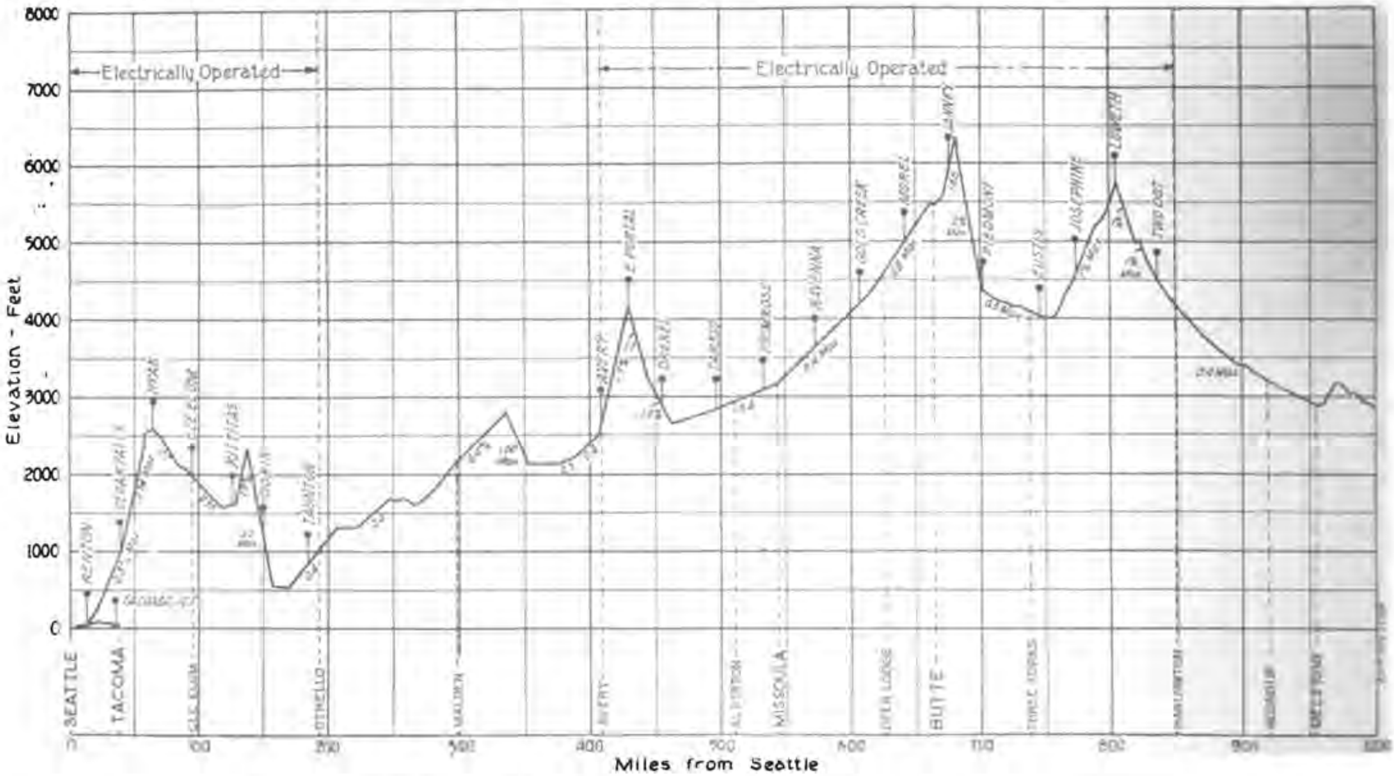
After a number of regeneration tests had been run all of the observers were taken in a train hauled by an oil-electric locomotive to a point near one end of the test track where a tug-of-war test was made. This part of the track was used because of the possibility of damaging rails by slipping drivers. The three units were coupled as before and at a given signal the steam locomotive engineers started to push the electric locomotive and the driver of the electric started to push against them. The steam men showed some very expert handling in this test and neither one slipped the drivers of his engine. At first the steam locomotives were allowed to push the electric a short distance. Then additional power was applied to the electric until the steam locomotives were pushed slowly backward. This was repeated several times. Comparative data for the two locomotives is given in the table. The local weights given for the steam locomotives do not include the tender.

	Pacific	Mohawk	Electric
Total weight, lb.	273,000	343,000	530,000
Weight on drivers, lb.	173,000	234,000	458,000
Weight on each driving axle, lb.	57,667	58,500	38,167
Diameter of driving wheels, in.	72	62	44
Size of cylinders, in.	22 x 28	28 x 28	
Number of drivers	3	4	12

From the data in the table it may be seen that the total weight on drivers of the electric locomotive is 51,000 lb. greater than that of both steam locomotives.

therefore, of the success of the original installations, that the same system will now be used to meet the severe grades and snow conditions of the Cascade range.

The motive power now in service on the eastern electrified section consists of 42 locomotives for freight and passenger service and four switchers. Of this original equipment, the freight and passenger locomotives were practically the same and differed from each other only in the gear ratio between motors and driving axles.



Profile Showing the Two Electrified Divisions of the Chicago, Milwaukee & St. Paul

For this reason the test did not illustrate the fact that greater adhesion is possible with the electric locomotive because of uniform torque. On the other hand, as the total weight of the steam locomotives is 86,000 greater than that of the electric it afforded unmistakable evidence of the greater amount of power which can be delivered to the rails by an electric locomotive as compared with steam locomotives of the same weight. The test also showed the ease with which an electric locomotive can be controlled, and illustrated the possibilities of regenerative braking in a manner to convince the most skeptical.

Five of these electric locomotives will soon be completed and placed in operation for passenger service on the Othello-Seattle-Tacoma electric zone of the Chicago, Milwaukee & St. Paul. They are of the 3,000-volt direct current, gearless type.

The original electrification from Harlowton to Avery, 440 miles, has now been operating for a number of years under the bad weather conditions common to the Rockies and Bitter Root mountains. It is significant,

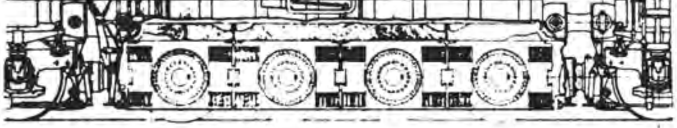
The new locomotives are of an entirely different design, built distinctively for passenger service and possess some very interesting mechanical and electrical features. They will be used on the new Cascade electrification strictly for passenger service, and the passenger engines will be adapted for freight service by changing the gear ratio. The locomotives are of the bi-polar gearless type, with motor armatures mounted directly on the driving axles. In this fundamental feature they follow the design of the gearless locomotives in use on the New York Central. The principal advantage of this method of construction is the simplicity of mechanical design, which eliminates gears, armature and suspension bearings, jack-shafts, side-rods, or other transmitting devices.

The new locomotives weigh 265 tons with 229 tons on drivers. They have 14 axles, 12 of which are driving and two guiding axles. The weight of the armature and wheels is the only dead weight on the track, and this is approximately 9,500 lb. per axle. The total weight on drivers, 458,000 lb., is 86 per cent of the weight of the locomotive, which, being distributed among 12 axles, results in a weight of only 38,166 lb. per axle.

One of the most interesting and important features of the locomotives is the design of the leading and trailing trucks and the method of suspension of the cab weight upon them. The successive trucks are coupled together in such a way as to dead lead or break up any lateral oscillation which may be caused

Two Steam Locomotives Used to Supply Power which was Regenerated to the Trolley by the Electric Locomotive

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 increases the weight bearing down on the wheel at the point where the thrust occurred, and automatically reacts to prevent any distortion of the track. The result of this design is such as to give particularly good riding qualities at high speed. Exhaustive tests have demonstrated the remarkable riding qualities of the new locomotives at speeds as high as 65 miles an hour, which was the maximum speed permissible on the length of test track available. These tests also indicated that the

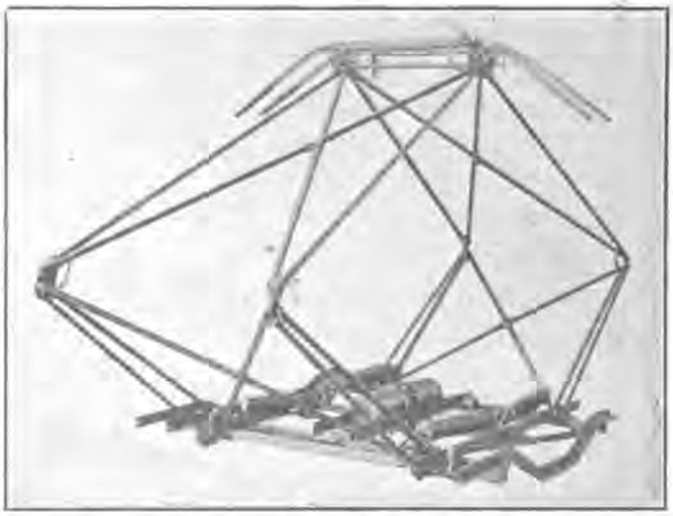


Side Elevation of Portion of Locomotive with Vertical Section Showing Arrangement of Armatures, Axles and Motor Fields

locomotives will operate at 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 an hour. This performance requires 56,500 lb. tractive effort which is equivalent to a co-efficient of adhesion of 12.3 per cent of the weight upon driving axles. The wide margin thus provided between the operating tractive co-efficient and the slipping point of the wheels, as well as the ample capacity of the motors, will allow this locomotive to haul trains with as many as 14 cars in emergency. For continuous operation the locomotive is designed to operate at 42,000 lb. tractive effort at a speed of 27 miles an hour.

The total weight supported on driving axles is practically the same as that on the present geared passenger locomotives, weighing a total of 300 tons. The



Type of Two Contact, Slider-Pantagraph Used on New Locomotives

table gives the principal dimensions, weights and capacity of the gearless locomotives.

Weight electrical equipment	235,000 lb.
Weight mechanical equipment	295,00 lb.
Weight complete locomotive	530,000 lb.
Weight on drivers	458,000 lb.
Weight on guiding axle	36,000 lb.
Weight on each driving axle	38,166 lb.
Number of motors	12
One hour rating	3,240 hp.
Continuous rating	2,760 hp.
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.
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.

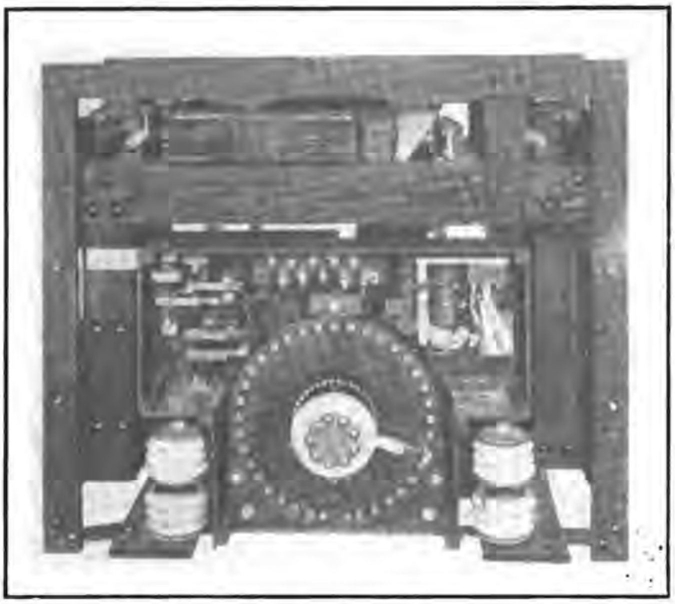
Motors

The motors are bi-polar, the two fields of each being supported upon the truck springs with full freedom for vertical play of the armature between the pole faces. The armatures are mounted directly on the driving axles. For full speed operation, the 12 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.

Regenerative electric braking on down grades is obtained by using four of the motors as generators to supply exciting current for the other eight, which then return power to the trolley. This reduces the size of the motor-generator set required for control, accessories and train lighting, and thereby effects an appreciable reduction in the weight of control equipment.

Secondary Apparatus

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



Side View of High Speed Circuit Breaker with Covers and Arc Chute Removed

blower. The six blower motors may be operated six in series, or in two groups of three in series, thus allowing for two rates of cooling for the main driving motors.

The center cab is occupied by an oil-fired steam boiler for heating passenger trains and with accessories, including tanks for oil and water, circulating pumps and a motor-driven blower for furnishing forced draft. This center portion of the cab can be lifted out in case the steam boiler is in need of heavy repairs.

In the curved end of one of the cabs is located a small motor-generator set operating in conjunction with an 80-volt storage battery in the other cab, which supply power for operating switches, contactors, lights and accessory apparatus. The battery is, in general, similar to those used on the passenger coaches. In the cab with the storage battery are also the 3,000-volt contactors and grid resisters and an air compressor driven by a 3,000-volt direct current motor. The high speed circuit breaker is placed in the cab which contains the motor-generator set.

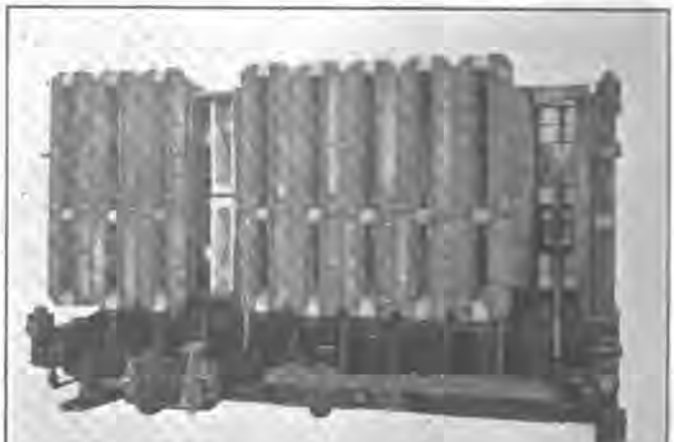
Power for train lighting is obtained from the motor-generator set. A switchboard located in the operator's section of one of the cabs is equipped with switches, resisters and meters for controlling the train lighting set. The head end system of lighting is in use on the St. Paul trains over this division. In the other operating cab there is a small motor-driven air compressor, operated from the battery circuit, with sufficient capacity for raising the pantograph when first putting the locomotive in operation.

A 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 on the slider with a double trolley. The pantograph and flexible twin trolley construction enable the locomotive to collect current as high as 2,000 amperes at speeds up to 60 miles an 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 pantographs outside of the operating cab.

Control

The driving motors are controlled by a reverser handle and two control handles. Within reach of the driver are also the straight air and automatic air brake valves, the sander, the bell ringer, several meters to show what the locomotive is doing, and a number of switches for the headlight, the cab lights, the cab heater, etc. The control handles are mechanically interlocked to prevent incorrect manipulation.

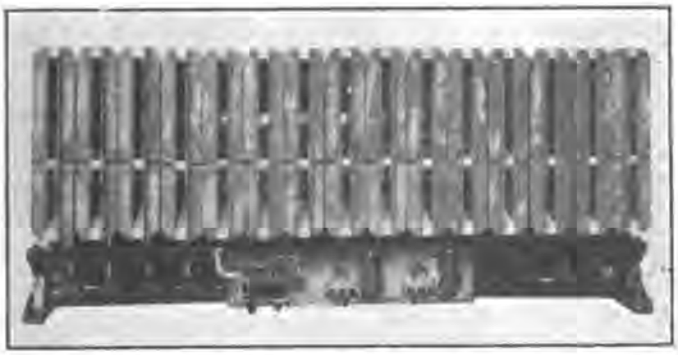
The meters indicate line voltage, speed, line current and field current. The needle of the ammeter which registers line current will swing in either direction and show how much current the motors are using or how much they are regenerating to the trolley. The ammeter which registers field current resisters from zero to 400. The meter scale is black from zero to 200 and red from 200 to 400, to indicate to the operator that he



Series-Parallel Switch Group. These Switches are Air Operated

must not run continuously with values of field current in excess of 200 amperes.

The diagram shows a profile of the road from Seattle to a point about 1,000 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 eight to twelve steel passenger coaches, which will be handled over the maximum grade without helpers. Freight



Resistance Control Contactor Group. These Contactors are Solenoid Operated

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 with during winter operation in this district.

MASSACHUSETTS INSTITUTE OF TECHNOLOGY CONDUCTS CAMPAIGN FOR ENDOWMENT FUND

What would the engineering profession do without technically trained men? The Massachusetts Institute of Technology recently launched a $10,000,000 Endowment Fund campaign. Back of all its appeals the fundamental argument of the M. I. T. is that she is producing the competent technical experts that the country needs year after year.

The research division of the electrical engineering department is an important factor in the department and has done some admirable work. For example, an exhaustive report of "Experimental Researches on the Skin Effect in Steel Rails" was brought out in 1916 by A. E. Kennelly, Sc.D., professor of electrical engineering at the institute, and F. H. Achard and A. S. Dana, research assistants. The research originated from a Technology student's thesis, and was conducted under an appropriation from the American Telephone & Telegraph Company. Its objects were to determine, by direct measurement, the impedance offered to alternating currents of the strengths likely to be employed in the electric-railway work by standard steel rails of various shapes and sizes; also to ascertain how this impedance varied with frequency and with current-strength, and whether the impedance could be reduced to a sample engineering theory, so as to admit of being predicted within reasonable limits from physical data concerning the steel used in the rails.

Tests were extended to 11 sample track rails and 2 sample contact rails, 10.07 metres in length, ranging in linear mass from 30 to 50 kilograms per metre, with corresponding cross-sections from 38.5 to 64.5 square centimetres. Three frequencies were used in the tests, namely 25, 45 and 60 cycles per second, the bulk of the work being carried on at or near 25 and 60 cycles. The current-strengths employed in the test rails varied from 10 to 800 amperes. The test circuit was constructed to make the measurements as nearly as possible under practical railway conditions. The results were very interesting and represented a marked advancement along this line. The report was published by the Journal of the Franklin Institute and in separate pamphlet form. This is typical of the work being done by the research division.

During the war the electrical engineering department of the institute furnished 25 men from its staff either to military service or associated government work.

Technology has hundreds of graduates in active service with railroad and street railway companies. John S. Blecker, '98, is general manager of the New Orleans Railway & Light Co.; William Rawson Collier, '00, is sales manager of the Georgia Railway & Power Co. and manager of its electrical department. William Babcock Poland, '90, was vice president and chief engineer of the Philippine Railway Co. and later chief engineer and general manager of the Alaska Central Railway Co. Matthew Brush, '01, was president of the Boston Elevated Railways and successful in his striking policy of putting the road under public control. Samuel Morse Felton, '73, the president of the Chicago Great Western, at the head of 12,000 railroad engineers reorganized the shattered railroad systems of France. These are only a few of the many Tech men with whose achievements the readers of the *Railway Engineer* are familiar.

This is a time for expansion in American industrial projects. Technology wants to keep her place among the leaders in technical training. The industries want Tech men. Tech can produce the men only if she has the money. Tuition fees cover just one-third of the annual budget in spite of the fact that the tuition fee is now the largest in the country. The logical solution lies in an Endowment Fund. A mysterious friend of the Institute, realizing this, has promised $4,000,000 provided another $4,000,000 is pledged by alumni and friends. This individual prefers to remain unknown, and is generally referred to as "Mr. Smith". He is reported to be an industrial leader of large wealth who is not a Technology graduate, but who has a vital interest in technical education.