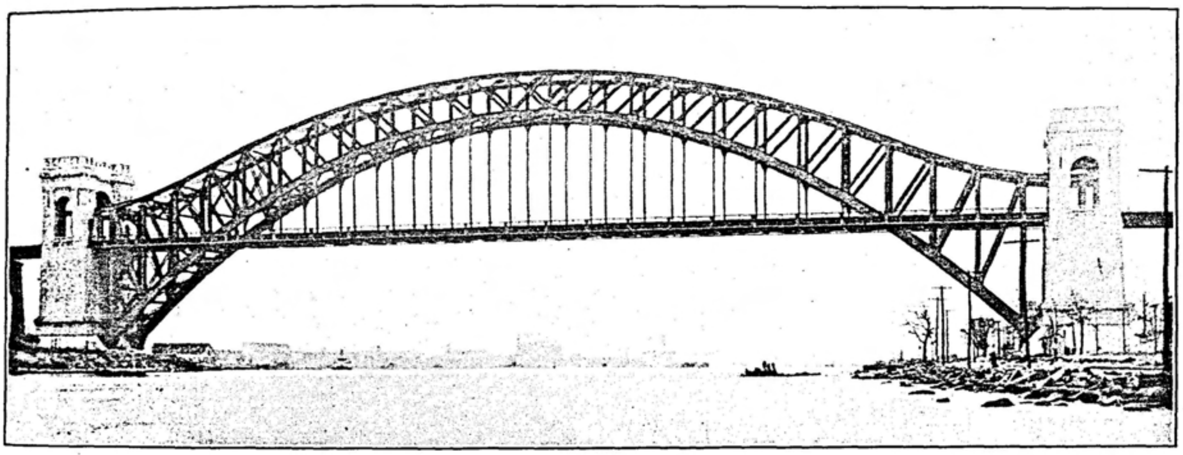


Four Improved Types of Electric Locomotives

Recent Developments Which Have Been Brought About By Demands of Traffic and Profile

RECENT ELECTRIC LOCOMOTIVES were described and illustrated at the fourteenth annual electrical meeting of the New York Railroad Club, March 14, 1918. The New York, New Haven & Hartford's new 180-ton passenger locomotive was described by E. R. Hill, of Gibbs & Hill, consulting engineers. The Chicago, Milwaukee & St. Paul's new quill geared locomotives under construction by the Westinghouse Electric & Manufacturing Company were described by F. H. Shepard of the latter company. The new Chicago, Milwaukee & St. Paul bi-polar passenger locomotives under construction by the General Electric Company were described by A. H. Armstrong of the latter company. E. B. Katte, chief engineer of electric traction, New York Central, described the new electric passenger locomotives for that road. The meeting was of particular interest because the papers read showed how the manufacturers were meeting the conditions imposed upon them by the demands of traffic, profile and limits of load on bridges in different parts of the country.

Fig. 1—Map of New York Connecting Railroad

180-Ton Locomotive for the New Haven

The following information is taken from Mr. Hill's paper. The new electric locomotives for the New York, New Haven & Hartford are of the Baldwin-Westinghouse type designed to operate on the New York Connecting Railroad (Fig. 1). The profile of this is shown in Fig. 2. The Hell Gate bridge, erected at a cost of $4,000,000, is shown in the illustration at the top of the page. The total cost of line, including the Bay Ridge improvement of the Long Island Railroad, was $40,000,000.

Express trains operated between the Grand Central station and New Haven average 11 steel cars and weigh about 770 tons. Maximum trains of this character are of 12 steel Pullman cars and weigh from 850 to 900 tons. To handle these over the New York Connecting it was found necessary to provide heavier locomotives than are now in use on the New Haven, or double head the present locomotives, as is frequently done on the heavier trains.

Another condition limiting the New Haven operation is the restriction imposed by the New York Central as to total weight and axle loading of locomotives using the drawbridges and viaducts on their lines into the Grand Central station. The New York Central's conditions limit loads on four driving axle locomotives to 47,500 lb. per axle and of locomotives with six driving axles to 41,000 lb. per axle. There are limitations also as to total weight of locomotives and the extent to which double heading is permitted.

The new 180-ton locomotives now on order represent the maximum in weight and capacity of the A. C.-D. C. type that will not exceed the New York Central's structural limitations. This, however, does not quite meet the maximum desired performance for through express trains on the New York Connecting Railroad grades. The new locomotives will handle 12-car trains on the Pennsylvania direct current terminal grade and eastbound on the New York Connecting Railroad 0.2 per cent grade, but will only handle 11-car trains on the westbound 1.2 per cent New York Connecting Railroad grade. This latter grade is two miles long and it is proposed to employ electric pushers for assisting westbound trains of over 11 cars up the grade; an alternative to this is to double head the engine with one of the old gearless types of locomotives.

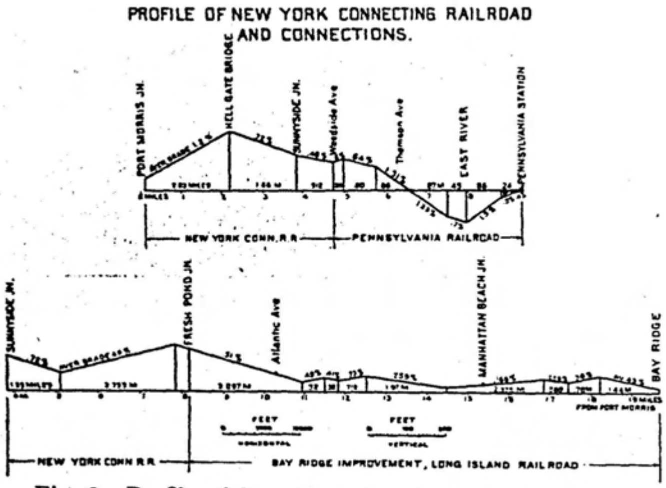


Fig. 2. Profile of New York Connecting Railroad and Connections

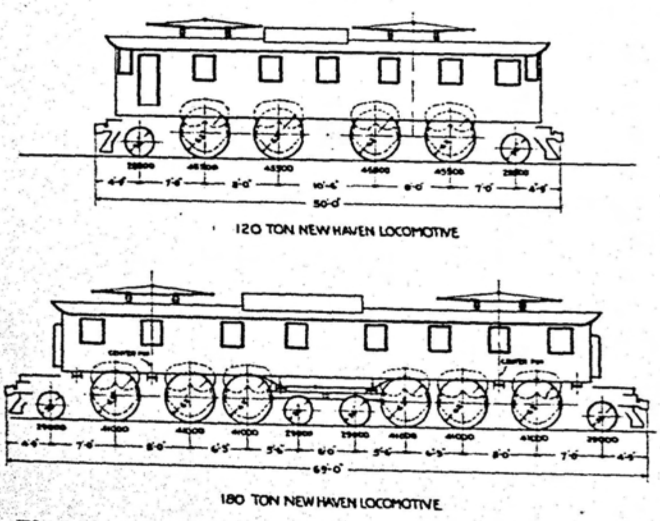


Fig. 3. Old and New Types of New Haven Locomotives

Prior to this the latest and largest type of locomotives on the New Haven road was the 2-4-4-2 locomotives of the 073-075 series shown at the top of Fig. 3, having four driving axles and two pony axles in two trucks, each driving axle being equipped with a pair of single reduction geared motors with quill drive. The new locomotive shown on the lower part of Fig. 3 is a duplicate of the present type of locomotive in all essential respects, the main differences being that there are three pairs of drivers on each truck instead of two, and pony axles are used at both ends of each truck instead of at the outer ends only. In all principal respects the details of the locomotives are identical with the 34 freight and heavy passenger straight single phase locomotives built in 1911 for use in freight service. The principal data regarding the three types of passenger locomotives of the road are given in Tables 1 and 2.

The motors are connected in groups of three permanently in series and the speed characteristics are substantially the same as those of the original gearless locomotives; the control is to be arranged for multiple unit doubleheading of these two types. They are geared for a higher speed than the present geared type locomotives and cannot be operated in multiple unit with them.

The motors are grouped in pairs and connected by means of bearings and single reduction gearing to a quill which surrounds the axle with ample radial and end clearance to prevent it coming in contact with the axle when in normal running condition. The motors, gearing and quill, are supported from the truck frame independent of the axle and wheels, the motors being directly above the center line of the axle. With this arrangement the weight of the motors, gearing and quill, is carried on springs and the only dead weight coming directly on the track is that of the driving wheels and axle. The center of gravity is high and good riding qualities and tracking conditions are secured.

The only connection between the motors and the driving wheels is through a group of six helical springs in each driving wheel, center connected at one end to the spokes of the wheel and at the other end to the disk at the end of the

TABLE I

Principal Design Data—	New 180-ton	Present 120-ton	Present 109-ton
Series number	......	073-075	01-041
Classification	2-6-2 + 2-6-2	2-4 + 4-2	2-4 + 4-2
Weight:			
Mechanical parts, lb.	187,500	123,900	105.600
Electrical and air brake parts, lb.	161,700	115,000	112,000
Steam heating equipment and miscellaneous, lb.	12,800		
Total, lb.	362,000	239,000	217,600
On each driving axle, lb.	41,000	45,500	41,900
On each pony axle, lb.	29,000	28,500	25,000
Rigid wheel base	14 ft. 3 in.	8 ft. 0 in.	8 ft. 0 in.
Total wheel base	59 ft. 6 in.	40 ft. 6 in.	30 ft. 9 in.
Length over-all	69 ft. 0 in.	50 ft. 0 in.	37 ft. 7½ in.
Diameter driving wheels	63 in.	63 in.	62 in.
Diameter driving axles	8 in.	8 in.	8 in.
Size main journals	7 in. by 13 in.	7 in. by 13 in.	7¼ in. by 10 in.
Size truck wheels	36 in.	36 in.	33 in.
Size truck journals	6 in. by 12 in.	6 in. by 12 in.	5½ in. by 10 in.
Type of drive	Quill-geared	Quill-geared	Quill-gearless
Number of motors	12	8	4
Horsepower:			
One hour	2,550	1,700	1,120
Continuous	2,025	1,350	1,125
Tractive effort:			
One hour	21,000	17,700	9,700
Continuous	14,500	12,200	6,400
Momentary max.	47,500	......	......
Maximum safe speed, m.p.h.	70	55	85

TABLE II

Principal Service Data—		
Maximum safe speed		70 m. p. h.
Balanced Speed with 770-Ton Average Train:		
On level		60 m. p. h.
On .4 per cent New Haven grade		42 m. p. h.
On .72 per cent Connecting Railroad grade		35 m. p. h.
On 1.2 per cent Connecting Railroad grade		28 m. p. h.
Schedule of Express Trains New York—New Haven:		
Without stops		43.7 m. p. h.
With four intermediate stops		37.6 m. p. h.
Grand Central Station Service East and West:		
Maximum local train	420 tons—	6 cars
Maximum local train doubleheaded with gearless engine	620 tons—	9 cars
Maximum express train	900 tons—	12-13 cars
Pennsylvania Station Service:		
Maximum eastbound express train	850 tons—	12 cars
Maximum westbound express train	770 tons—	11 cars

quill. This arrangement is in use on all of the geared passenger, freight and switching locomotives of the New Haven and has given excellent satisfaction. The motors are also identical with those used on certain of the passenger, and on all of the geared freight locomotives, the total of such motors being over 400. By adopting this same type of motor, suspension and drive duplication and uniformity of parts is secured and savings in shop maintenance and operation is thereby effected.

The truck center pin is located between the first and second driving axles, thus making the truck unsymmetrical fore and aft of the center pin; this will tend to prevent oscillation or nosing of the trucks.

The drawbar pull between trucks is transmitted through a radial bar coupling and not through the cab. The weight of the cab is borne on each truck by six spring mounted pads. The truck frames are of the integral cast steel type, the entire frame and crossties being cast in one piece. The saving in weight by the use of this type of truck frame is estimated to be 3,200 lb. per locomotive. This feature is important not only because it is desirable to minimize the dead weight of the locomotives in general, but also because of the weight limitations of the bridge structures over which those engines are to operate and the guarantee which the manufacturers were required to give was that the total weight should not exceed 181 tons.

The motors and transformers are ventilated by two motor-driven blowers mounted in the cab. For train heating purposes the locomotives will be equipped with flash type, kerosene fired boilers capable of evaporating 4,200 lb. of water per hour. Tanks having a capacity for 1,440 gal. of water and 370 gal. of oil will be provided as part of the heating equipment of each locomotive.

These locomotives illustrate in a general way the adaptability of electric traction in meeting the constantly increasing requirements of railroad service. In this case, without modifying the general type or any of the mechanical or electrical details and without exceeding existing weight limitations on bridge structures, a locomotive 50 per cent larger than the present has been produced simply by the addition of a driving axle and a pair of motors to each truck with adaptation of mechanical and electrical details for the mounting and control of the additional parts.

Baldwin-Westinghouse Passenger Locomotive for St. Paul

The map, Fig. 4, shows the electrified section of the Chicago, Milwaukee & St. Paul. The profile for this section of line is shown in Fig. 5. The following information is taken from the paper read by Mr. Shepard.

This new locomotive, Fig. 6, ten of which are now under construction, was designed for passenger service. The weight of the locomotive complete is 266 tons, of which the electrical equipment weighs 121 tons, the mechanical parts 118 tons, and the heating equipment, including water, 27 tons.

The locomotive consists of two running gears, with the Pacific type wheel arrangement, coupled back to back, supporting a single cab, with the control auxiliaries and heating apparatus. The drive wheels are 68 in. in diameter, the driving wheel base is 16 ft. 9 in., the wheel base for each truck is 36 ft. 2 in., the total wheel base is 79 ft. and the total length of the locomotive between knuckles is 88 ft. 7 in. A large portion of the cab is occupied by the heating equipment, which includes boiler, water and oil tanks. The rheostats are placed near the top of the cab close to the controlling switches, the locomotive may be operated from either end and each end has its complement of meters, air brake valve, master control, sanders, etc. The controller has nine running positions corresponding to one-third, two-thirds and full speed positions, with two speed control positions on each. This gives economical operation over a wide range of speed. Regeneration from maximum speed down to a minimum of about 10 miles per hour is provided for the purpose of holding the train on down grade or for making slow-downs.

Fig. 4. Map of Electrified Sections of the Chicago, Milwaukee & St. Paul

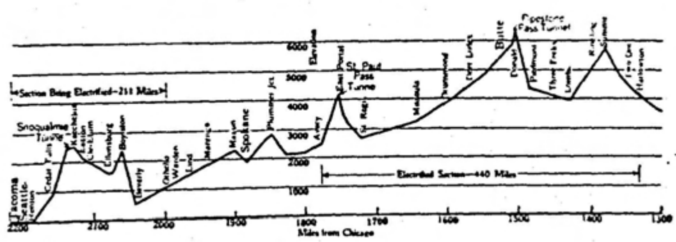


Fig. 5. Profile of Electrified Sections of the Chicago, Milwaukee & St. Paul

The continuous capacity of the locomotives is 3,200 horsepower, corresponding to a tractive effort of 4,900 lb. at 24.5 miles an hour. The maximum starting tractive effort will be 110,000 lb.

The motor equipment consists of six twin motors with quill drives, two of which are mounted above each driving axle. Each armature carries a single pinion and the twc

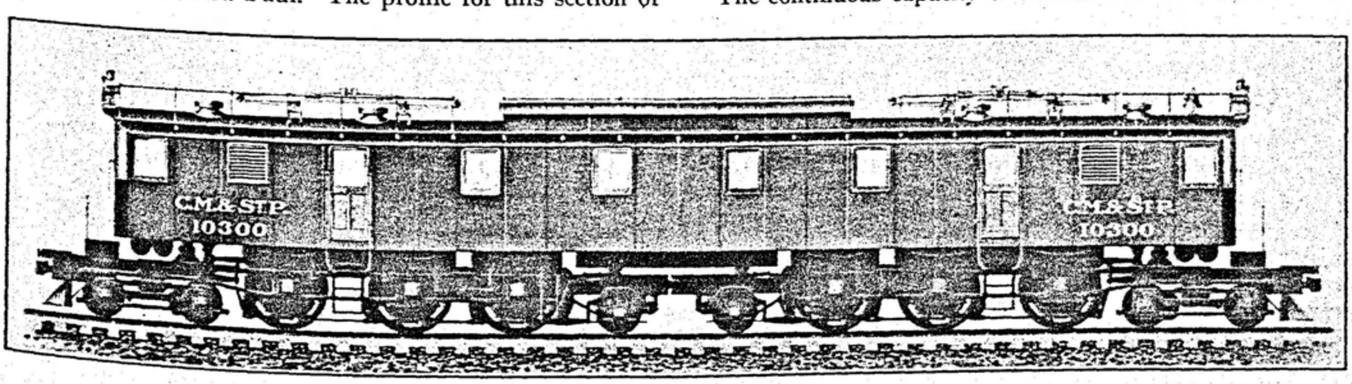


Fig. 6 Baldwin-Westinghouse Electric Locomotive for the Chicago, Milwaukee & St. Paul

drive a single solid gear mounted upon the quill shaft and held in position by quill bearings. This allows a movement of the axle within the quill shaft of 1¾ in. from normal position.

The locomotive is provided with the well-known electro-pneumatic control. Power from the line is obtained from the 3,000-volt trolley. A motor-generator set delivering current at approximately 80 volts supplies current for train lighting and for a storage battery. The blowers, air compressors, light and control are all operated at 80 volts and their operation, due to the presence of the battery, is independent of the line power. In addition to the motor-generator set and battery there is a third source of low voltage supply, which is utilized for the operation of the auxiliaries and for the excitation of the fields of the main motors for regeneration whenever the train has acquired requisite speed. This source of power is from the axle driven excitators, of which there are two on the locomotive, each being mounted on the inside axles of the 4-wheel trucks. These axle driven generators are about the size of an ordinary street car motor and furnish current at low voltage for the excitation of the main motor field when regenerating. At other times they furnish current for the operation of the blowers and air compressors, independent of the battery. A locomotive is at all times independent of line power for the supply of air to the brakes.

It is natural to question the reason for this type of locomotive, presenting as it does certain mechanical complications as compared to other types. It was understood that structure, but unfortunately, the yield of the rails due to wheel loads is not uniform, varying greatly, depending upon the track joints, special work, condition of ballast and subgrades. These general conditions are exaggerated by the extreme weather conditions experienced in this country.

Much importance has been placed upon such questions as center of gravity, wheel arrangement, size of wheels and equalization on steam locomotives, especially for passenger service. The steam locomotive, of necessity, consists of a large mass including boiler and cylinders carried on the locomotive frame, the driving wheels being loosely and flexibly connected thereto. Space limitations require a relatively high center of gravity. It is a curious coincident that these limitations in the design of steam locomotives automatically secure action which inherently is easy upon the road bed, because of the flexibility of the heavy parts of the locomotive and the fact that the individual axles are relatively free from restraint due to directly imposed weight. In the electric locomotives described these advantageous features are all retained.

St. Paul Gearless Locomotives

The gearless locomotives now under construction in the General Electric shops for the Chicago, Milwaukee & St. Paul will also operate over the line shown in Figs. 4 and 5. Following are extracts from the paper read by Mr. Armstrong:

The excellent operating results obtained during the past ten years with gearless locomotives on the New York Central's

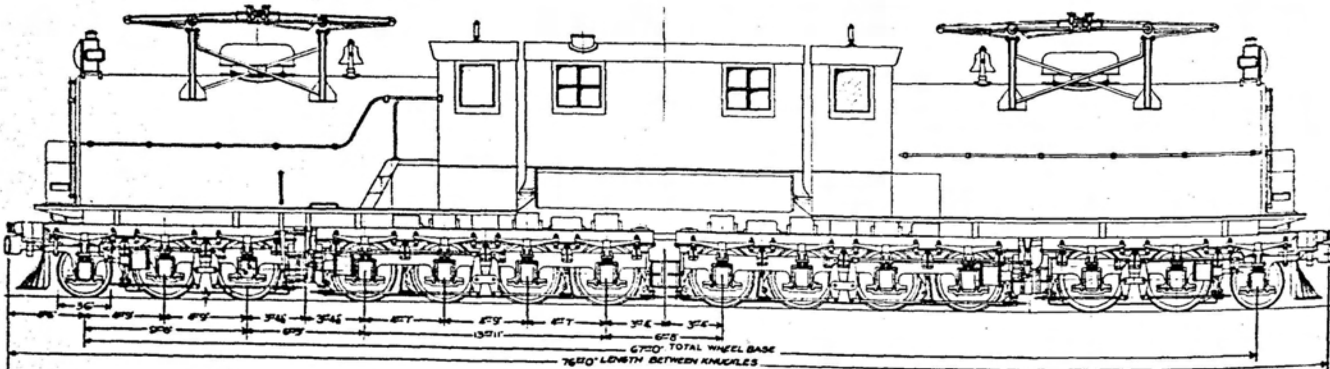


Fig. 7. Gearless Electric Locomotive Built by the General Electric Company for the Chicago, Milwaukee & St. Paul

the weight on the driving axles, both as to amount and disposition, in the present locomotive would not be accepted for additional locomotives for passenger service. This required the departure from the design of locomotives at present in passenger service. It could have been accomplished by the use of more driving wheels with smaller and lighter motors or by the use of very large motors with side rods. Service conditions require a minimum of six driving axles with a weight of 55,000 lb. on each. This can reasonably and economically be met by twin motors with quill drive, and this construction possesses advantages as follow: (1) The limitation of voltage across any commutator to 750 volts, thereby obtaining stable commutation for both motoring and regenerating. (2) The greater accessibility, the lesser restriction in design and the greater freedom from injury to motors due to their position above the axle and remote from the road bed. (3) The mounting of the motors rigidly upon the locomotive frame, thereby securing great flexibility between the road bed and the motor weight. (4) A center of gravity which is 43½ in. above the rail. (5) The use of a minimum number of gears and the removal of main gears. (6) A desirable wheel arrangement, with distribution and equalization.

The American railroad track is a cushioned, yielding tracks have attracted increasing attention to this form of construction. The locomotives for the Chicago, Milwaukee & St. Paul are equipped with 14 axles, 12 of which are drivers and two are guiding axles. The armatures are mounted directly upon the axles and, with the wheels, constitute the only dead or non-springborne weight of the locomotive. This weight is approximately 9,500 lb. as compared with 17,000 lb. dead weight on the driving axles of the present geared locomotives now operating on the St. Paul. The two fields are carried upon the truck springs and there is full freedom for vertical play of the armature between them. The construction of the motors throughout is practically identical with that employed upon the New York Central's gearless locomotives, but the capacity of the locomotive is much increased and the wheel arrangements somewhat different. The general physical characteristics of the locomotives now under construction are given in Table 3.

With twelve motors per locomotive available for different control combinations, there is a possibility of securing a wide range of speed to meet the varying conditions of passenger train operation. Motors are connected three in series, or 1,000 volts per commutator for full-speed operation, but the control also permits a connection of four, six and twelve motors in series for fractional speed operation. Provision for variable speeds is made by shunting the motor fields in all combinations of motors, but it is probable that the greatest value of the field shunt will be obtained with the full-speed connection of three motors in series. The speed possibilities of this locomotive are shown in Table 4.

It is especially desirable that a passenger locomotive have sufficient weight on the drivers and reserve motive power to haul additional train weight on occasion, and in this respect the gearless locomotives under construction present attractive possibilities. The manufacturer's guarantees cover the operation of a 12-car train weighing 960 tons against an adverse 2 per cent grade at a speed of 25 miles per hour. Under these conditions there is a demand for 55,200 lb. tractive effort at the rim of the driver, equivalent to 12 per cent co-

TABLE III

Dimensions and Weights C. M. & St. P. 3,000-Volt D. C. Locomotive.

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.
Approximate height center of gravity	57 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 guiding axle	36,000 lb.
Weight on each driving axle	38,166 lb.
Dead or non-springborne weight per axle	9,500 lb.

efficient of adhesion to the weight upon the driver. There is, therefore, ample margin both in weight upon drivers and capacity of the motors to haul not only 12 cars, but on occasion 13 or 14 cars with practically no sacrifice in schedule speed and without overloading the motors or exceeding known and conservative practice as regards loading of driving wheels. For example, the gearless locomotive now being built will permit the starting of a 12-car train on a two per

TABLE IV

Speed Characteristics C. M. & St. P. 3,000-Volt Gearless Locomotive 960 Tons Trailing Load.

	Level	½% Grade	1% Grade	2% Grade
3 motor shunt field	63.0	47.2	38.5	30.5
3 motor full field	49.5	36.0	30.0	25.0
4 motor full field	40.5	27.0	22.0	18.0
6 motor full field	29.0	17.8	14.2	11.0
12 motor full field	15.0	8.0	6.0	4.0

cent grade with a coefficient of adhesion of only 20 per cent, and accelerate the train at 0.3 miles per hour per second.

While the manufacturing guarantees are limited to 42,000 lb. tractive effort as a continuous output of this locomotive, the preliminary tests upon a sample motor indicate that this rating is conservative and that the final test upon a completed locomotive may show values materially higher than the guarantees made. This fact is of the greatest importance and holds out wide visions of radical changes in the operation of transcontinental trains, both passenger and freight. The total weight upon drivers of 458,000 lb. is practically the same as the driver weight of the present freight locomotives now in operation on the St. Paul. If, therefore, the completed locomotive meets the expectations of the builders it offers a possibility of using the same locomotives interchangeably for both passenger and freight service.

The control of the gearless locomotives will in many respects be a duplicate of that now in operation on the geared locomotives previously installed. Provision will be made for regenerative electric braking on down grades. The geared locomotives now running utilize a motor generator set for the purpose of motor field excitation while regenerating. Careful experiments made during the past two years have demonstrated that motor generator field excitation is not essential, and taking advantage of the advance of the art, the control for the new gearless locomotives will dispense with this feature. This simplification of the control and reduction in weight and cost constitutes a marked improvement.

The original installation of the St. Paul was undertaken with a single type of road locomotive for both passenger and freight service, differing only in the ratio of the gearing between the motors and drivers. The locomotives were therefore interchangeable, except as to gears, with consequent simplifications of shop repair practice. The geared locomotives operate at a high efficiency in heavy freight service where pushers are used on up grades, but accumulated gear losses result in a low all-day efficiency of the geared locomotive in passenger service, when the profile is broken and contains long stretches of practically level track. On the other hand, the gearless motor operates at high efficiency when on level tracks or on lesser grades and it is this class of service that constitutes the bulk of the all-day duty of a passenger locomotive. The average operating speed of about 50 miles an hour shows a gain of 10 per cent in efficiency of the gear-

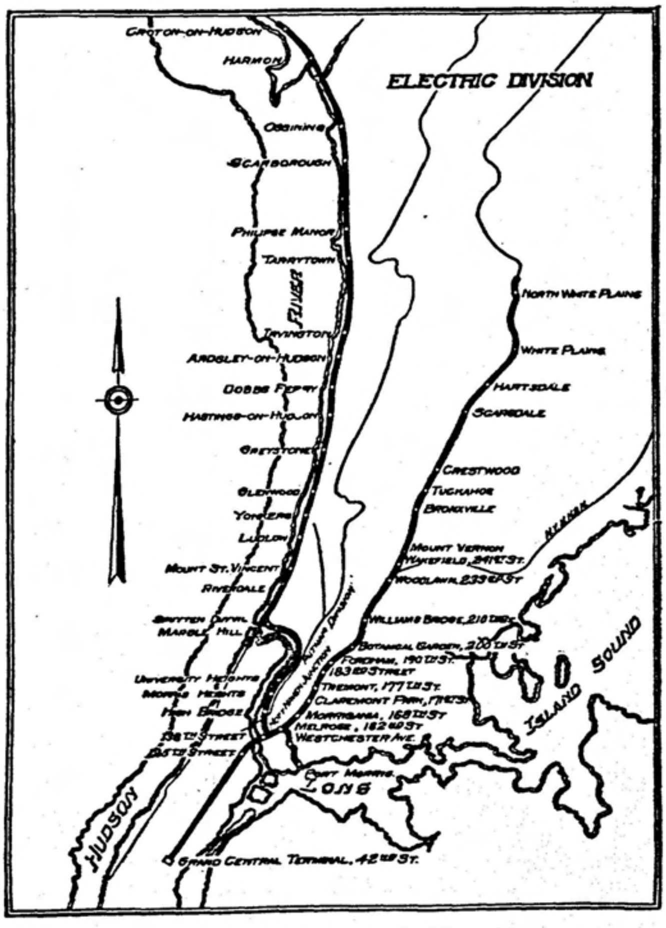


Fig. 8. Map of New York Central's Electrified Sections

less locomotive as compared with the geared type and in fact throughout the entire range of speed from 30 miles up the gearless locomotive will operate at over 90 per cent efficiency, as compared with the drooping characteristics of the geared locomotive.

The exclusion of mechanical parts, such as gears, quills, jack-shafts, side rods, etc., utilized to transmit the power from the motors to the drivers with some forms of locomotive construction, not only results in a marked improvement in the all-day efficiency of the locomotive, but is followed by an equally attractive increase in reliability and a marked reduction in maintenance expense. It is felt, therefore, that the introduction of the gearless locomotive upon the St. Paul marks a distinct advance in electric railroading and that this sort of construction, now for the first time made possible for mountain service will result in a marked improvement in the method of handling both passenger and freight trains on this most difficult class of railroad service.

Gearless Locomotive for New York Central

The section of road on which the new locomotives for the New York Central will operate is shown in Fig. 8. This section of track follows the Hudson river for the greater part of the distance from Harmon to the Grand Central Terminal and no steep grade has to be contended with. One of the new locomotives designed for service on this road is shown in Fig. 9. In describing the locomotive, Mr. Katte stated:

"During the past year we have received on the New York Central nine new passenger locomotives known as class T-2B. The tenth locomotive will be delivered next month. These locomotives are very similar to the earlier class T locomotives, in fact, when we asked the operating department if it desired to suggest any changes its representative held up his hands and exclaimed, 'For goodness sake, don't make any changes, you will spoil them.' As a matter of fact, there were 30 or 40 minor modifications and improvements made.

"These locomotives are driven by eight motors of the bipolar type, one on each axle. The total weight of the locomotive is 134 tons and the drawbar pull at 25 per cent adhesion is 66,000 lbs. The load is about equally divided on all wheels. The motors are known as G. E.-91-A and have a one hour blown rating of 325 hp., or a total of 2,600 hp. for the locomotive. The capacity of the locomotive is the hauling of a 1,200-ton train at 60 miles per hour. The maximum speed of the locomotive with lighter trains is 75 miles per hour.

"As a typical example of regular service a class T locomotive hauls train No. 71, weighing 1,035 tons, between the Grand Central Terminal and Harmon, a distance of 32 miles, making one stop, in 54 minutes running time. The average maximum speed is 57 miles per hour, and the current consumption has been shown to be equivalent to 21.9 watt hours per ton mile.

"The cost of inspecting, maintaining and repairing our electric locomotives has averaged 3½ cents per mile during the past year. The locomotives are inspected after traversing an average of 3,000 miles, which is equivalent to 33 days, between inspections. As a measure of reliability I can say that class T locomotives average 32,000 miles per locomotive detention."

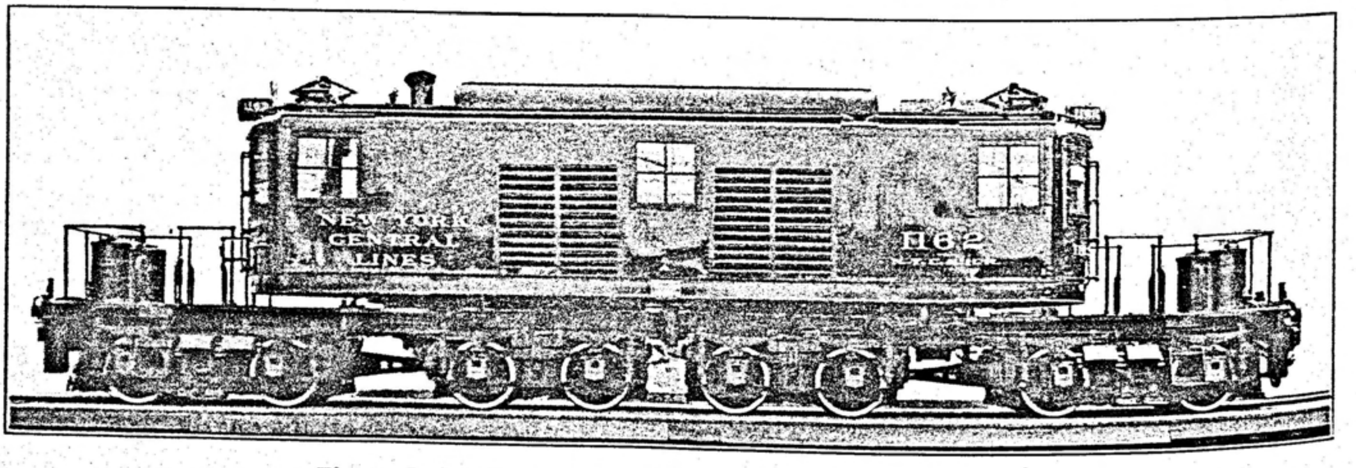
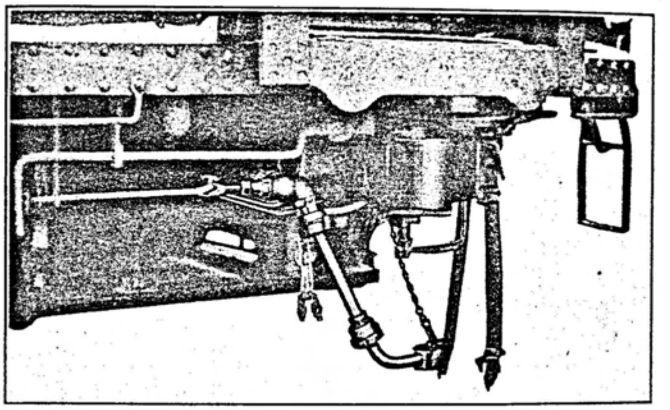


Fig. 9. Latest Type of New York Central Electric Locomotive

THE CANAL CONTROL COMMITTEE OF ENGLAND has issued a handbook on canals, giving information relating to the controlled canals, lists of the towns served by them and names and addresses of public carriers.

All-Metal Steam Heat Connection

WITH A VIEW TO PROVIDING a connection for the steam lines for passenger cars that would reduce the trouble and expense incident to the use of rubber hose, the Barco Manufacturing Company, Chicago, has developed a connection in which no rubber is used. This device has recently been placed upon the market after it had been in use for four years.



Passenger Car Equipped with Barco Steam Heat Connection

The Barco car steam heat connection is made up of two Barco joints of a special type and two sections of extra heavy steel pipe. Any standard steam-heat coupler head can be used on it. A locking clamp secures the upper flexible joint to the train line end valve, making it impossible for the connection to fall to the track. If desired lagging can be applied to the connection, but in most of the installations this has not been done. It is desirable to have a flexible bracket at the end of the train line of a type similar to that shown in the illustration.

No special tools are required to apply or remove these connectors. They will couple to cars equipped with rubber hose as well as to those having the Barco connection. The joints are more flexible than rubber hose, which makes them easier to couple. They will stand the full boiler pressure of the locomotive without leaking or bursting. The steel pipe gives a larger opening for the passage of the steam than rubber hose and eliminates the trouble due to the rubber lining becoming loose and stopping the pipe or catching in the valves. The all-metal connections remain serviceable for a long time and they also do away with frequent renewals.