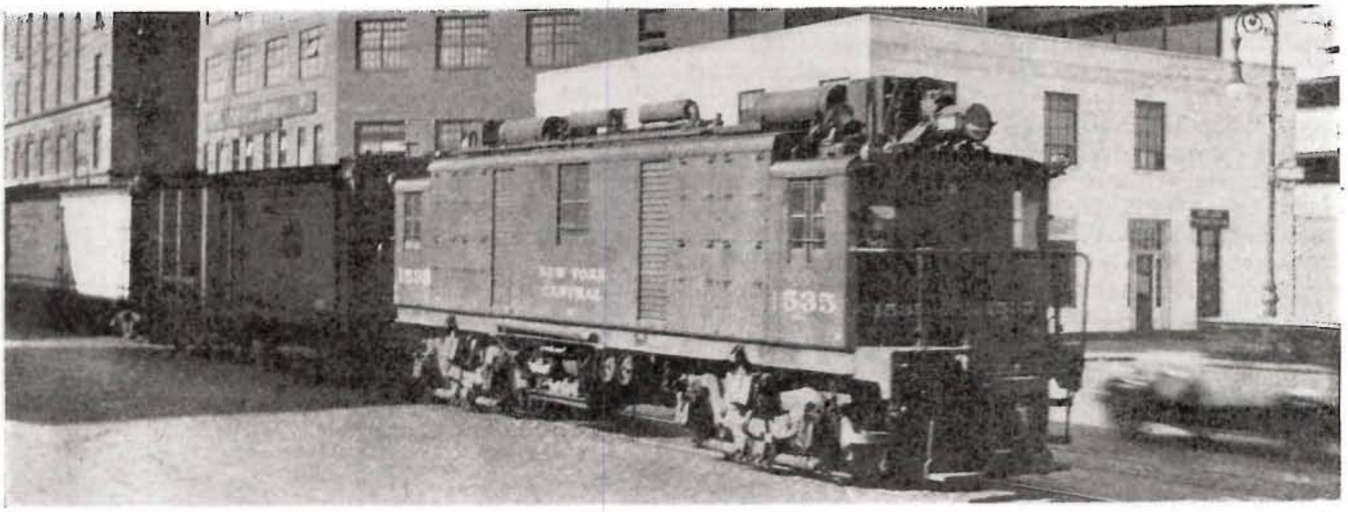

Locomotive in Service on Eleventh Avenue at Forty-First Street, New York City

Performance of Three-Power Locomotives*

Operating results on West Side lines of New York Central prove this type of motive power to be highly satisfactory in switching and transfer service and show an availability factor of 85 per cent

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THE New York Central Lines have in service a total of 42 three-power locomotives, 36 of which are on the Electric Division around New York City. Each of these 36 locomotives is capable of operating from three sources of power; third rail, battery, or engine and battery together.

The main line of the New York Central runs into Grand Central Station, but the freight is handled on a line known as the "West Side", which leaves the main line at Spuyten Duyvil at the extreme northern end of Manhattan Island. In addition to a number of sidings there are two main yards besides the downtown terminal at St. John's Park, 12½ miles south of Spuyten Duyvil and about a mile from the southern end of the island. The largest yard is the "60th street Yard" which extends from 60th street to 72nd street on the river front, while the other one is known as the "30th St. Yard" and extends between 30th and 33rd streets and from 10th avenue to the river front, with a number of sidings and industrial spurs outside this area.

Operation from Spuyten Duyvil to 60th street is over New York Central-right-of-way, but from 60th street to 30th street operation is on 11th avenue in the middle of the city street amid a continual stream of taxicabs, trucks and all the other vehicles constituting a busy city's traffic.

The traffic is of the type that must be moved promptly as required, and because of the other railroads serving the territory, around 30th street, is on a highly competitive basis.

Locomotive Requirements

In considering the elimination of steam locomotives from the West Side, it was considered desirable to electrify the main line tracks down to 72nd street and because of the mail and express trains this electrification will be extended to 30th street when the proposed new right-of-way is completed.

It was out of the question to electrify the present tracks in the city streets, nor was it considered economical to attempt completely to electrify either the 60th street or 30th street yards, because of the congestion, as well as the high cost involved. Attention was turned to the possibility of using Diesel engine propelled locomotives for switching in these yards and also for operating the line from 30th street south.

A number of designs of straight oil-electric locomotives were considered and one 750-hp. and one 880-hp. oil-electric locomotive were purchased. A 60-ton, 300-hp. oil-electric locomotive was also tried out in service, but was not considered large enough.

It was felt that for this service a locomotive should have the following characteristics:

1. Weight on drivers should be at least 125 tons.
2. Be capable of operating either from third rail or internal power.

* Abstract of a paper presented before the Central Railway Club, Buffalo, New York, February 11, 1932.

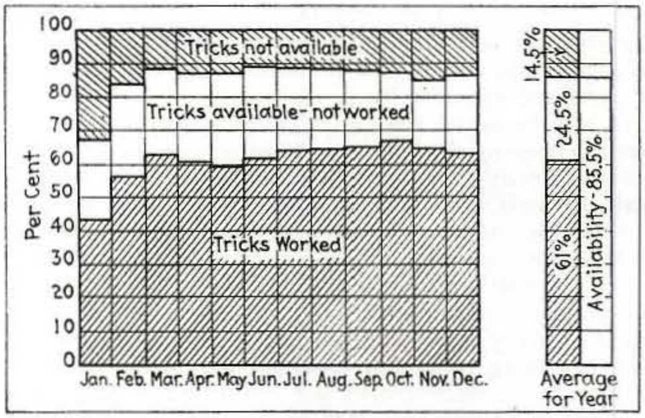

Fig. 1—Time in Service and Time Available For Service of the Three-Power Locomotives During 1931

3. Have approximately 900 engine hp. for internal power work.

4. Engine power should be divided into two or more units to prevent tying up a locomotive in case one should fail.

5. Consideration should be given to future operation under covered areas large in extent.

Characteristics of the Three-Power Locomotives

In order to meet these requirements the three-power type of locomotive was finally selected. For internal power operation a 300-hp. oil-engine-generator set and a storage battery are used, the battery to provide the peaks of power demand which occur in heavy switching service, and the engine generator set to assist the battery at times of heavy power demand and to charge the battery during times of light power demand, thus permitting continuous operation on internal power.

A sample locomotive was built and placed in service in February, 1928, and the 35 class DES-3 locomotives later placed in service were developed from experience gained from operation of the sample locomotive. These locomotives weigh 257,000 lb. in working order. All weight is on drivers, making a weight per axle of 64,200 lb., so that they are the heaviest four-axle swivel truck locomotives in service. They also had to be designed to go around a 100 ft. radius curve. A general description of the locomotives was published in the August 16, 1930, issue of the *Railway Age*.

The oil engine is of the four-cycle solid-injection type. It has six cylinders, 10 in. bore by 12 in. stroke, and develops 300 hp. at 550 r.p.m. It is direct connected to a 200-kw. generator. The governor is of the constant speed type, the speed being approximately 575 r.p.m. at no load and 550 r.p.m. at full load.

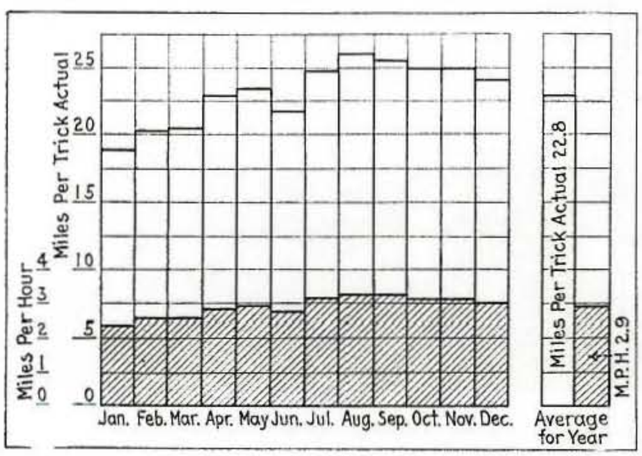

Fig. 2—Average Miles Per Hour and Average Miles Per Trick, 1931

The engine is substantially the same as furnished for a large number of locomotives by the Ingersoll-Rand Company, except that when used on locomotives without batteries a variable speed governor is used.

The storage battery consists of 240 cells of TLA-27 Exide Ironclad, made by the Electric Storage Battery Company, having an ampere-hour capacity of 650 and a Kw.h. capacity of 301. The battery is connected with all cells in series and with one side grounded. A main battery switch is provided which opens both sides of the circuit and also disconnects the two halves from each other so that only 120 cells are in series during inspection and these are not grounded.

No trouble has been experienced with insulation or leakage to ground, although these batteries have double the number of cells from the high side to ground than had been previously used. Special high-voltage porcelain insulators were designed to support the trays. Batteries are cleaned once a month by sprinkling with water in which soda has been dissolved and then washing off with hose. An air hose is then used to blow off any water that has collected.

The battery is charged by the generator only, there being no connection provided for charging from third rail. When the battery is fully charged the current from the generator is reduced to a small amount. As load is applied to the traction motors, the generator loads up, until it reaches approximately full load, the voltage falling off with increase of load. Further loading drops the voltage enough so that the battery starts to discharge and it picks up the load quickly as the voltage is reduced below this value. The total output to the motors at any given instant is the sum of the generator and battery currents at that particular voltage.

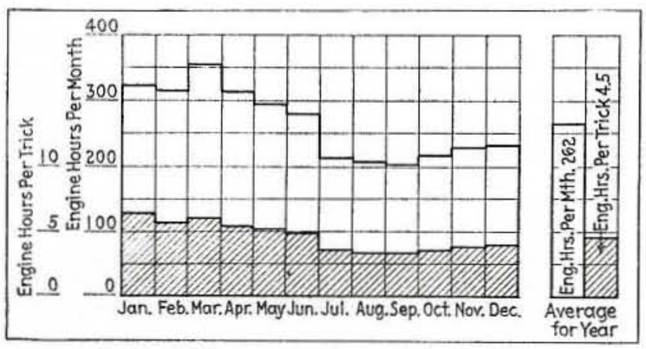

Fig. 3—Average Engine Hours Per Trick and Average Engine Hours Per Month, 1931

As the load is reduced, the generator voltage increases and when high enough the battery starts to charge. This continues until the battery is fully charged or load again occurs. The battery thus floats on the generator and automatically charges or divides the load properly during discharge periods.

Locomotive Performance

The locomotives are assigned to service as follows: 11 to the 30th street yard, 11 to the 60th street yard, 8 to the Hudson Side-Electric Division, 3 to the Harlem Side-Electric Division and 3 in the shop. Total 36.

The locomotives assigned to 30th street and 60th street yards are used for switching service, those in 30th street operating entirely on internal power. The locomotives assigned to the Hudson and Harlem sides of the Electric Division are used to handle express and mail trains down to 30th street and for way-freight and traveling switcher service between 72nd street and Harmon or White Plains, North Station. They operate on and off the third rail.

The curves and charts covering locomotive performance were prepared from selected operating statistics for the year 1931. It will be noted from Fig. 1, that the total availability is 85.5 per cent for the entire year—a very good showing—while the time in service of 61 per cent shows that they are popular locomotives with the operating department.

The actual mileage run per trick of 8 hours, month by month, averages 2.9 m.p.h., which is the usual figure obtained for switching service and is about one-half of the I. C. C. allowance of 6 m.p.h. The actual mileage, Fig. 2, is obtained from readings of odometers on one axle of each locomotive.

Engine hours per month per locomotive and also engine hours per trick give a measure of the operation on internal power. The considerable drop in engine hours per month in July, shown in Fig. 3, is due to the opening of the West Side electrification to 72nd street on June 1, it taking about three weeks to extend electrical operation to all classes of trains. Previous to that time the

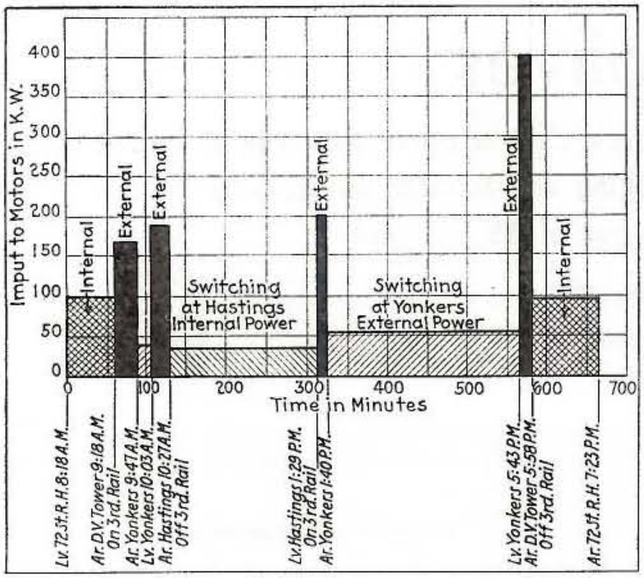

Fig. 4—Observed Performance of Locomotive No. 1525 on a Way Freight Train Over a Distance of 16 Miles

locomotives had been handling some of the trains (maximum 2000 tons) on internal power between 72nd street and Spuyten Duyvil, a distance of about 8 miles.

There has been, at times, considerable discussion as to what work this type of locomotive will actually do and for what classes of service it is best suited. The first locomotive No. 1525 was furnished with a number of instruments and meters and much data were secured, on which to base the following statements:

This type of locomotive is best suited for switching service, where the power is not on continuously and especially when used in conjunction with power supply from third rail or trolley. It has the characteristic on internal power of being able to supply large amounts of power instantly for short periods of time, as is required when kicking cars, etc.

It is not well suited for long runs with rated load on internal power only, as these discharge the battery considerably and high battery temperatures are caused

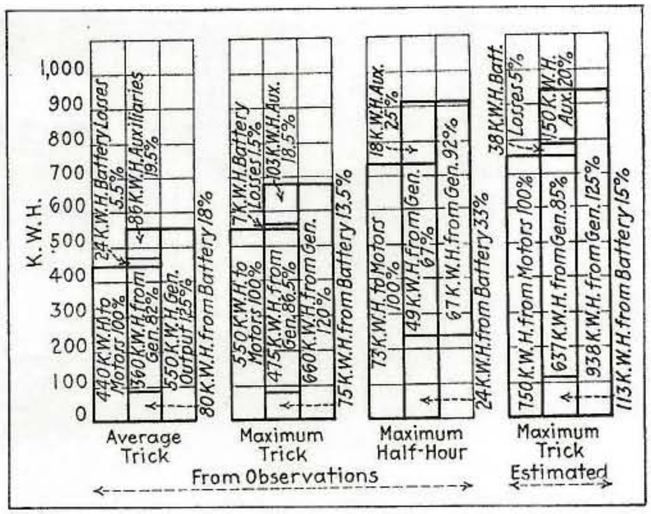

Fig. 5—Performance of Locomotive No. 1525 in Float Service Showing How Power Developed in Generator is Used

It may be seen in the case shown in Group 1 that of all the energy supplied to the motors, 18 per cent is taken from the battery and replaced by the generator—82 per cent goes directly from the generator to the motors and remainder of the power developed by the generator supplies battery losses and operates auxiliaries.

by the heavy recharging necessary. This type of locomotive has been used on continuous runs of 8 to 13 miles on internal power, but it does not work to best advantage when used on continuous runs of more than 2 or 3 miles.

For long runs the external power should be available. For way freight and traveling switcher service, where operation is partly from external and partly from internal power, the locomotives are in their element and permit this service to be very economically handled, since the cost of electrification of sidings and industry tracks can be saved. In the case of industrial plants along the right-of-way this is an important item, not only because of the cost involved, but also the physical difficulties in connection with electrifying many of these tracks.

The observed performance of locomotive 1525 on a way freight train for a distance of about 16 miles and return is shown in Fig. 4. The train handled was about 1100 tons, approximately half the tonnage rating of the locomotive. First comes a road run on internal power for about eight miles, then a road run on external power for eight miles, with a short period of switching on external power, then switching on internal power, then a short run on external power, switching on ex-

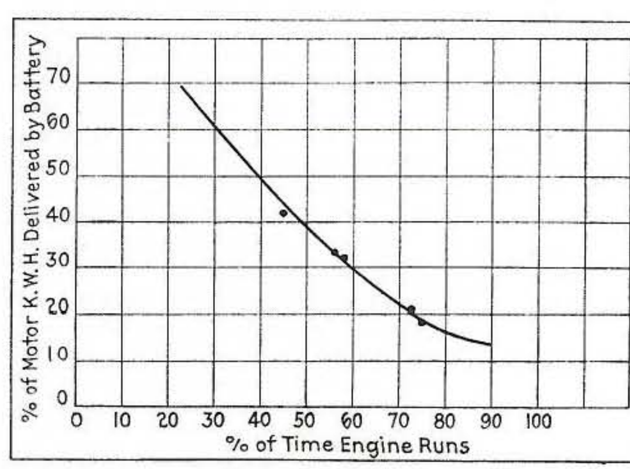

Fig. 6—The Amount of Power Delivered by the Battery Varies with the Time the Oil Engine is in Operation

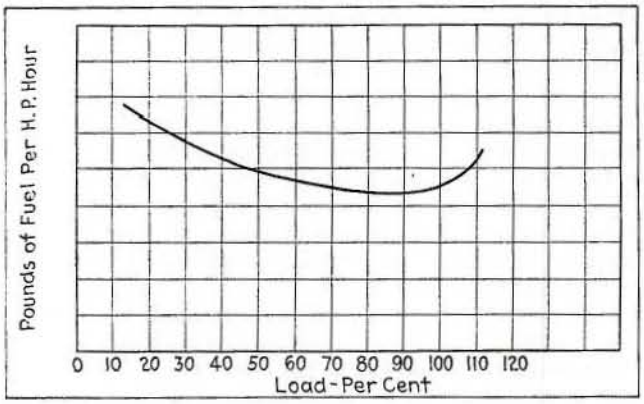

Fig. 7—Relation of Fuel Consumption to Engine Load

ternal power, a short road run on external power and finally a road run on internal power back to the starting terminal. Incidentally it was then the practice to work the locomotive a shift in float service at night and send it out on the way freight the next day.

From the time the class DES-3 locomotives went into service in August, 1930, until June, 1931, they handled 2000-ton trains in regular service from 72nd street to Spuyten Duyvil on internal power and from thence on external power. With a train of this weight the power required is about double that shown in Fig. 4.

It should be noted that only about 50 kw.h. per hour input to the motors is required for switching service even on external power. Fifty to 60 kw.h. per hour input to motors has been found to cover the average requirements of switching service, but it has also been found that peaks of 600 to 800 kw. are used momentarily especially when rapid acceleration is required, as when kicking cars, etc.

The high horsepower obtainable on external power is the reason for the excellent record of straight electric locomotives in switching service for many years and the fact that this is available when on electrified tracks, where the traffic density is usually heavy, makes this three-power type of locomotive so highly adaptable.

Battery Equals Two Engines for Short Periods

When operating entirely on internal power the capacity of the battery and the size of the oil engine limit the work that can be done by the locomotive. There has been a great deal of misunderstanding concerning the duty on the battery for a given amount of work done by the locomotive. Fig. 5 shows in graphical form some results obtained from locomotive 1525 in float service.

The first group shows the distribution of kilowatt-hours for an average trick. It will be noted that the input to the traction motors was 440 kw.h., or an average of 55 kw.h. per hour. The battery furnished, by discharging, 80 kw.h. or 18 per cent. The battery losses in recharging were 24 kw.h., or 5.5 per cent. It will be noted that the total generator output was 550 kw.h. making the electrical efficiency of the locomotive 80 per cent.

The second group shows the conditions on the maximum observed trick (based on motor kw.h. input). The third group shows conditions for the maximum half hour observed, and the fourth group shows the estimated maximum trick that this locomotive can perform. The latter is based on the locomotive being in three-trick service and with a total battery discharge for 24 hours of 125 per cent of the rated 6-hour capacity, which is the limit due to permissible temperature rise. Locomotive 1525 actually worked one trick in another service with this input to the traction motors but only 890 kw.h. output was required from the generator, as compared with 938 kw.h. estimated.

It will be noted that a relatively small amount of work is done by the battery. Most of the energy is delivered directly from the generator to the motors. The peak demands in switching service while high are only of short duration, and while very important in securing prompt and rapid movement of cars do not represent many kilowatt-hours in a trick of eight hours. There is a popular misconception of these locomotives which has the battery furnishing practically all the motor kw.h. and then being recharged from the generator. As may be seen this condition does not occur in practice. The curve, Fig. 6, has been prepared further to illustrate the same point and is based on data taken on locomotive 1525.

It will also be noted that as the engine is operated a greater percentage of the time, the percentage of the motor kw.h. delivered by the battery is reduced until a minimum of about 15 per cent is reached. These tests indicated the desirability of operating the engine practically all the time the locomotive is in use, with the exception of periods when standing idle or when certain moves have to be made on battery alone, and this is the practice followed on these locomotives. Light engine moves are usually made on battery, with engine shut down.

The average load on the generator, based on the time it is running, is usually about 40 per cent of its rated load on average tricks, and about 70 per cent on maximum tricks. The instananeous load varies from about 10 per cent to 100 per cent and the fuel is limited beyond this point to prevent overloading the engine.

The fuel economy of the engine is good, since these average loads bring the load into the part of the fuel consumption curve where the engine operates near its best economy, as shown in Fig. 7. This feature makes the over-all fuel economy as good or better than a locomotive with larger engine horsepower and no battery doing the same work, which would necessarily operate at a considerably lower load factor. The DES-3 locomotives averaged 43 gallons per trick, or 9.5 gallons per engine hour for the year 1931. When operating on internal power all the time they use from 65 to 75 gallons per trick.

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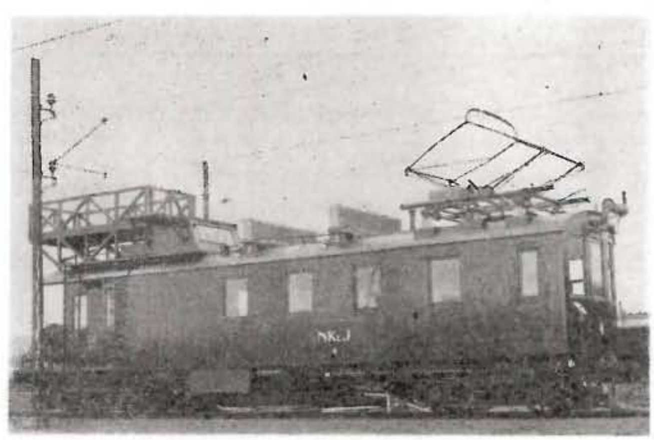

Combination Electric and Gas-Electric Work Car for Inspection and Maintenance of Overhead Lines Used on the Nordmark-Klaralven Railway in Sweden—An Observation Window Is Placed in the Front End of the Cupola—The Driving Axles Are Equipped with Differentials