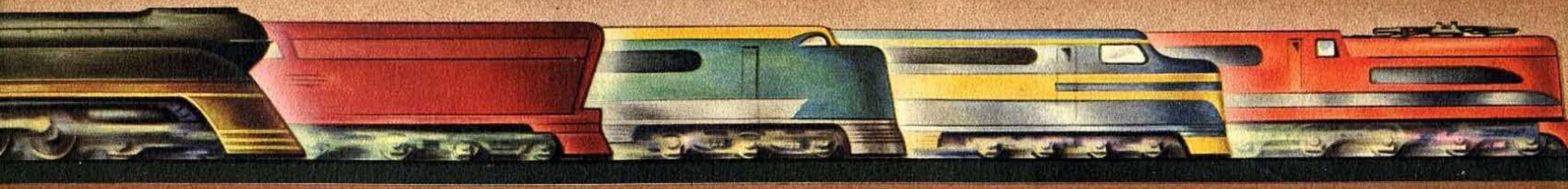
# *Westinghouse Presents*

# modern developments in railroad motive power



# WESTINGHOUSE ELECTRIC CORPORATION

# Modern Motive Power

## East Pittsburgh • Pa.

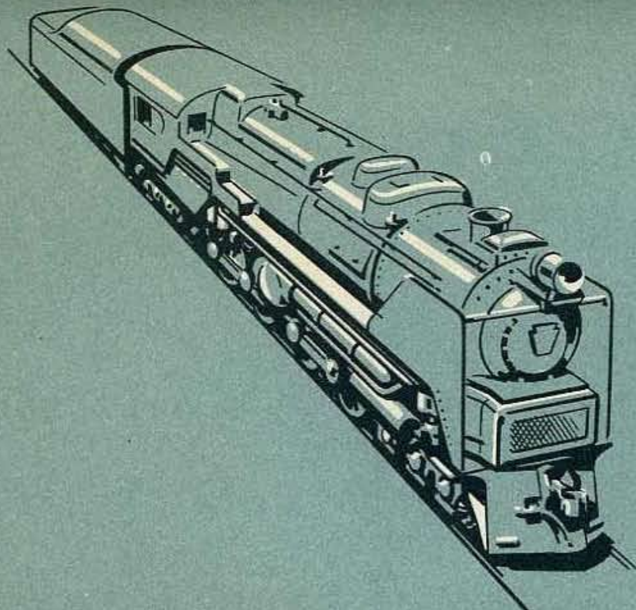
# Foreword

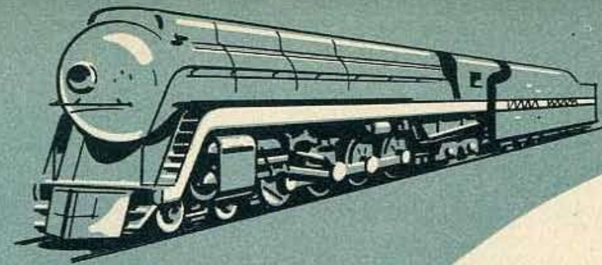
From its founding, the Westinghouse Electric Corporation has been associated with the Transportation Industry. It has always been a leader in the field of railroad electrification. It was among the first to recognize the possibilities of using a lightweight, high-speed diesel engine as a prime mover on a locomotive, and is now one of the large producers of electric transmissions for diesel electric locomotives. The development of the propulsion equipment for the first geared steam turbine locomotive in America, and for the first coal-burning steam turbine electric locomotive, was pioneered by Westinghouse. Now, utilizing its vast engineering and research facilities, it is actively engaged in the development of the gas turbine electric locomotive.

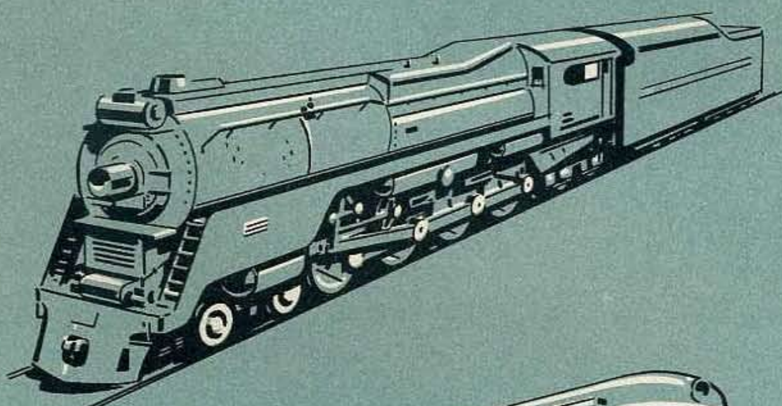
Based on present available knowledge, it appears unlikely that any one type of motive power will supplant all others in the foreseeable future. With the widely varying conditions and services to be met, and with the uncertainties in the fuel situation, it would indeed be extraordinary if any one type gave the most economical operation over the entire railway network of this country. Furthermore, no existing type of motive power has attained its ultimate perfection. Westinghouse believes that the greatest benefit will result to the railroads by continued development of all types, namely, steam, diesel, electric and gas turbine locomotives. It will direct its efforts to the limit of its facilities toward this end.

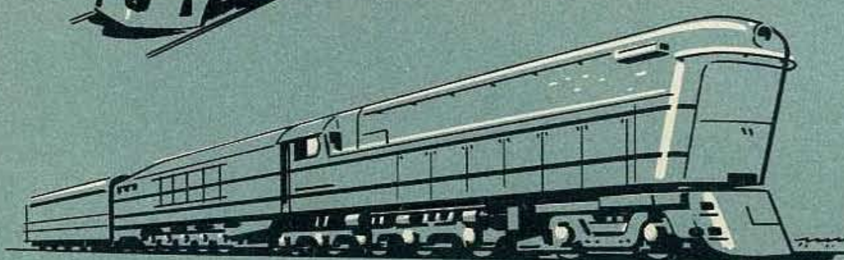
In this booklet, information and data are presented on the most modern designs of all types of motive power. Some of the most outstanding advantages of each type are briefly summarized, together with a statement of what further developments appear feasible, based on present knowledge.

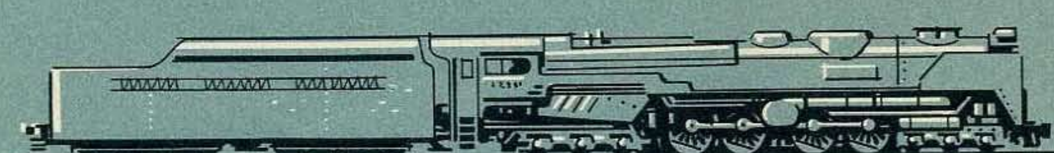
**WESTINGHOUSE ELECTRIC CORPORATION**











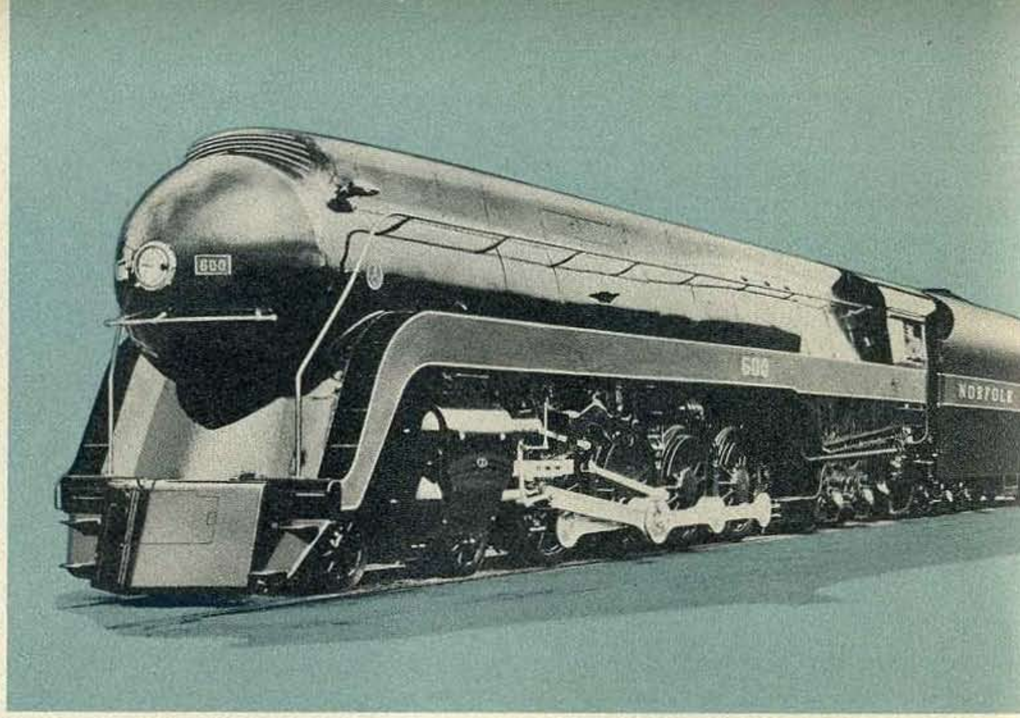
# STEAM MOTIVE POWER . . . . .

# Steam Motive Power

The steam locomotive, continually improved for more than a hundred years, has been and still remains the backbone of our far-flung land transportation system. While competitive forms of motive power are challenging its supremacy, the day is far away when the reciprocating steam locomotive will cease to be a factor in rail traffic.

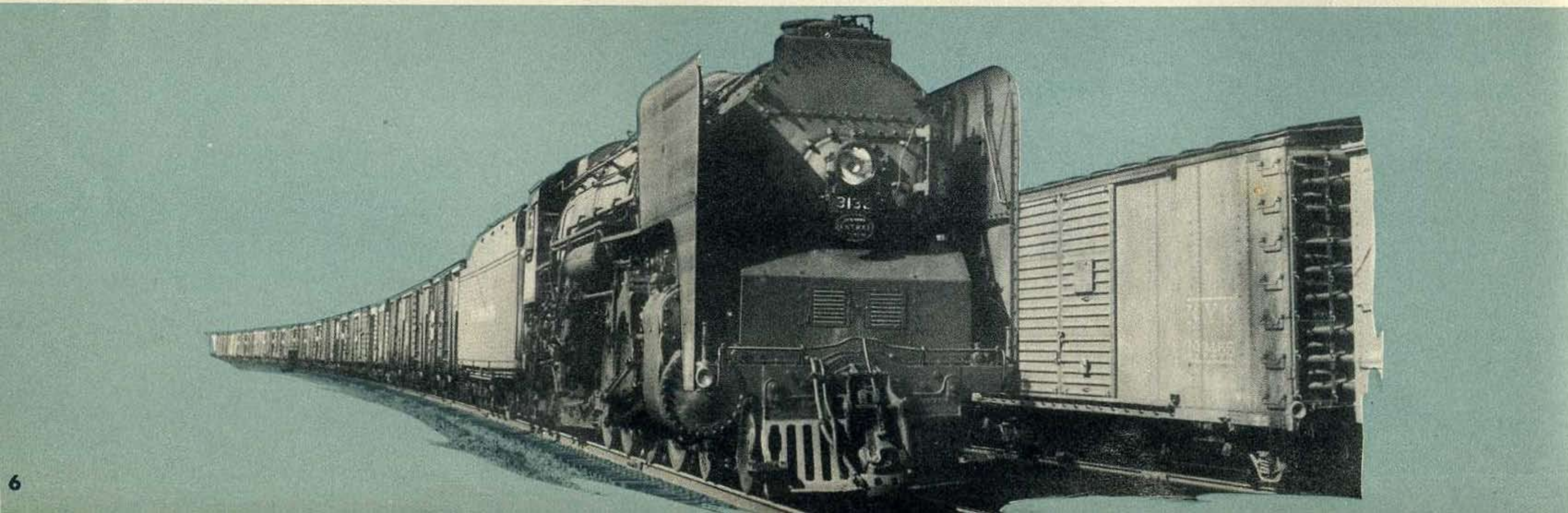
Modern reciprocating steam locomotives, when supplied with good water and good coal and given the benefit of superior servicing and maintenance, are establishing enviable operating records. As such ideal operating conditions are not universally obtainable, the factors of economics are dictating the gradual diminution of this type of motive power.

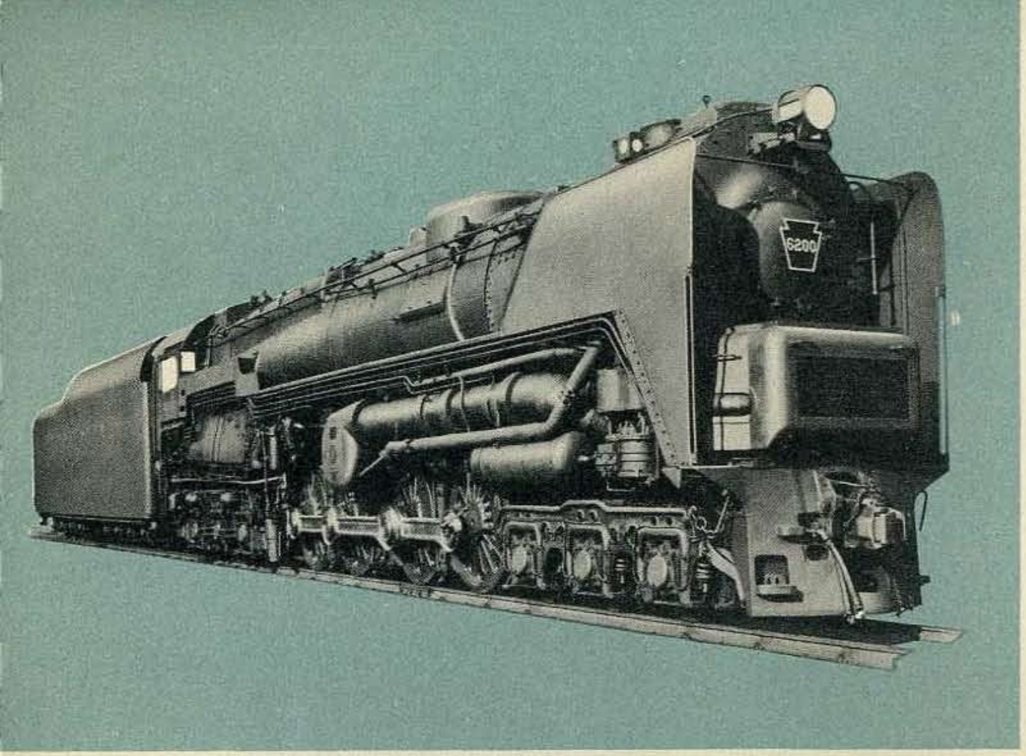
Introduction of new types of locomotives, such as the geared turbine, the turbine electric or even the reciprocating type with an advanced boiler design to provide increased efficiency of operation,



**The above illustration shows a typical, modern, reciprocating steam locomotive of the Norfolk & Western Railway.**

**Haulage with modern, reciprocating steam motive power on the New York Central System.**






America's first geared steam turbine locomotive pioneered by the Pennsylvania Railroad.

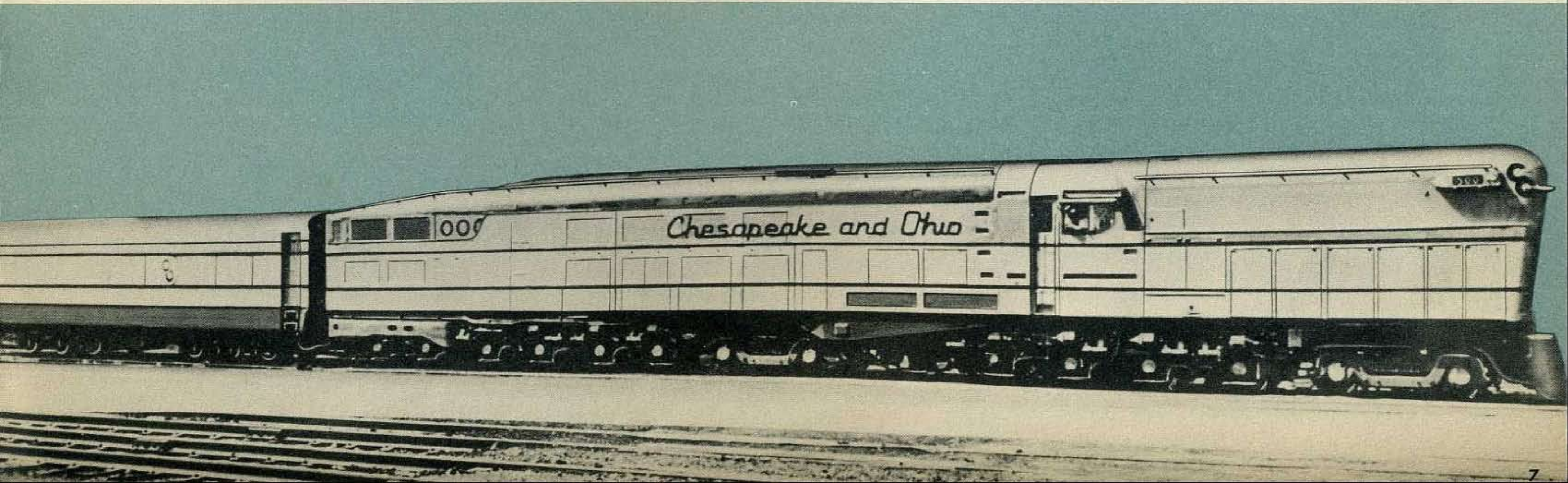
A Chesapeake & Ohio Railway Company steam turbine electric locomotive; the first of its type.

will be most effective in perpetuating the existence of steam-powered units using coal as a fuel.

The many development programs under way indicate a continued high level of interest in the coal-burning steam locomotive—a proved and accepted form of motive power that has enviable and long-held records of accomplishment.

The chief factors to be considered in evaluating the position of the steam locomotive are:

1. Lowest cost per horsepower.
2. Reliability, low repair cost and high availability when properly maintained and serviced.
3. Ability to use either coal or oil as a fuel—a significant fact when considering relative reserves of these two fuels.
4. Maximum concentration of power in a single self-propelled unit.



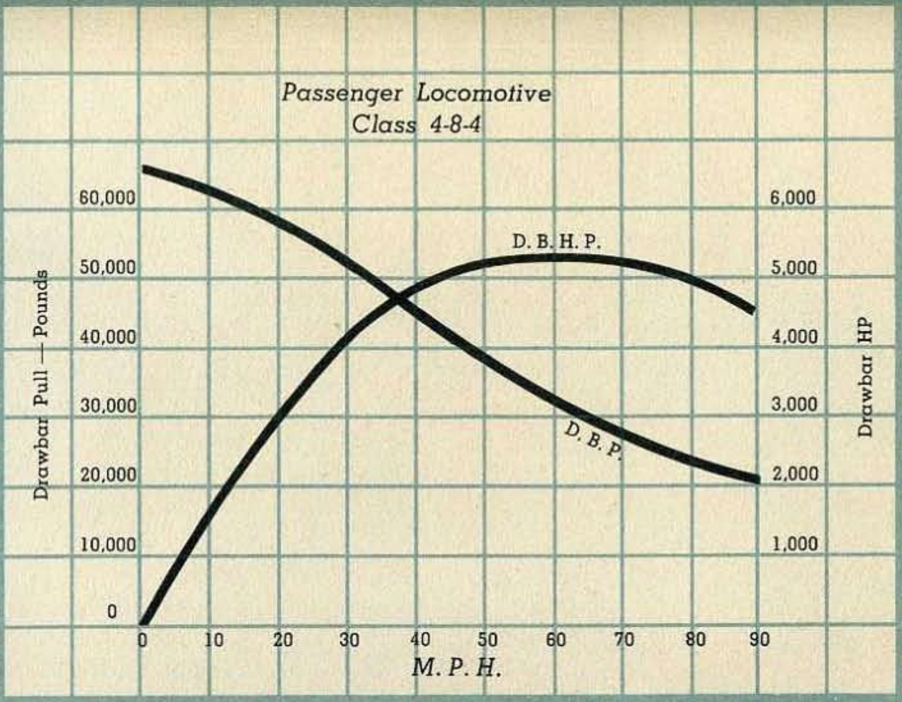
# The Reciprocating Steam Locomotive

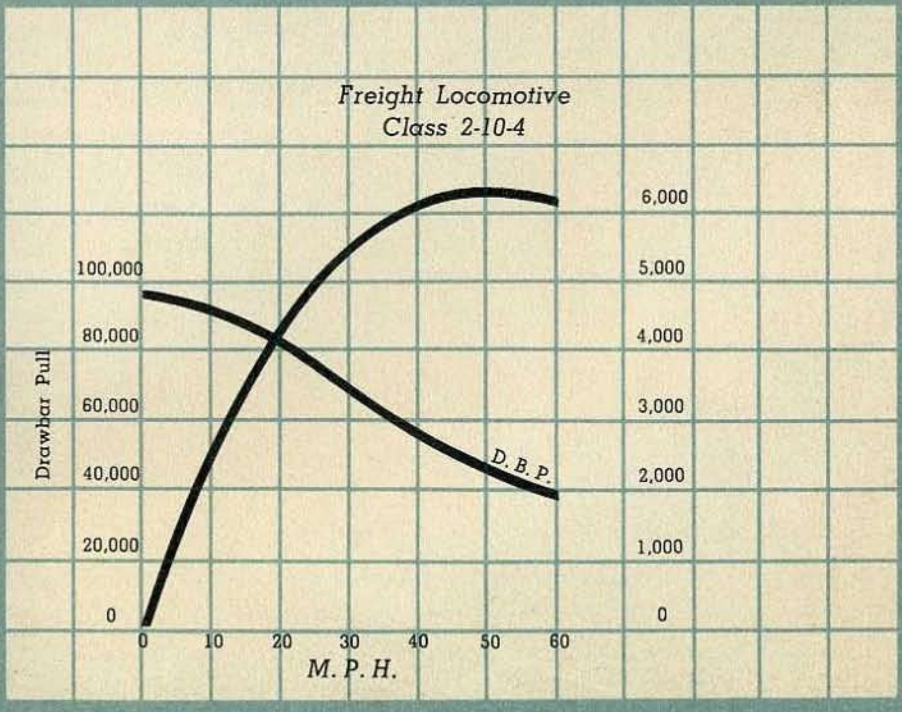
The reciprocating steam locomotive logically comes first in any consideration of railroad motive power. It was the first type used and, although introduced over a century ago, the fundamental principle of its operation has not changed. Continued and progressive improvements through the years have made it a highly reliable motive power unit for passenger, freight or switching service.

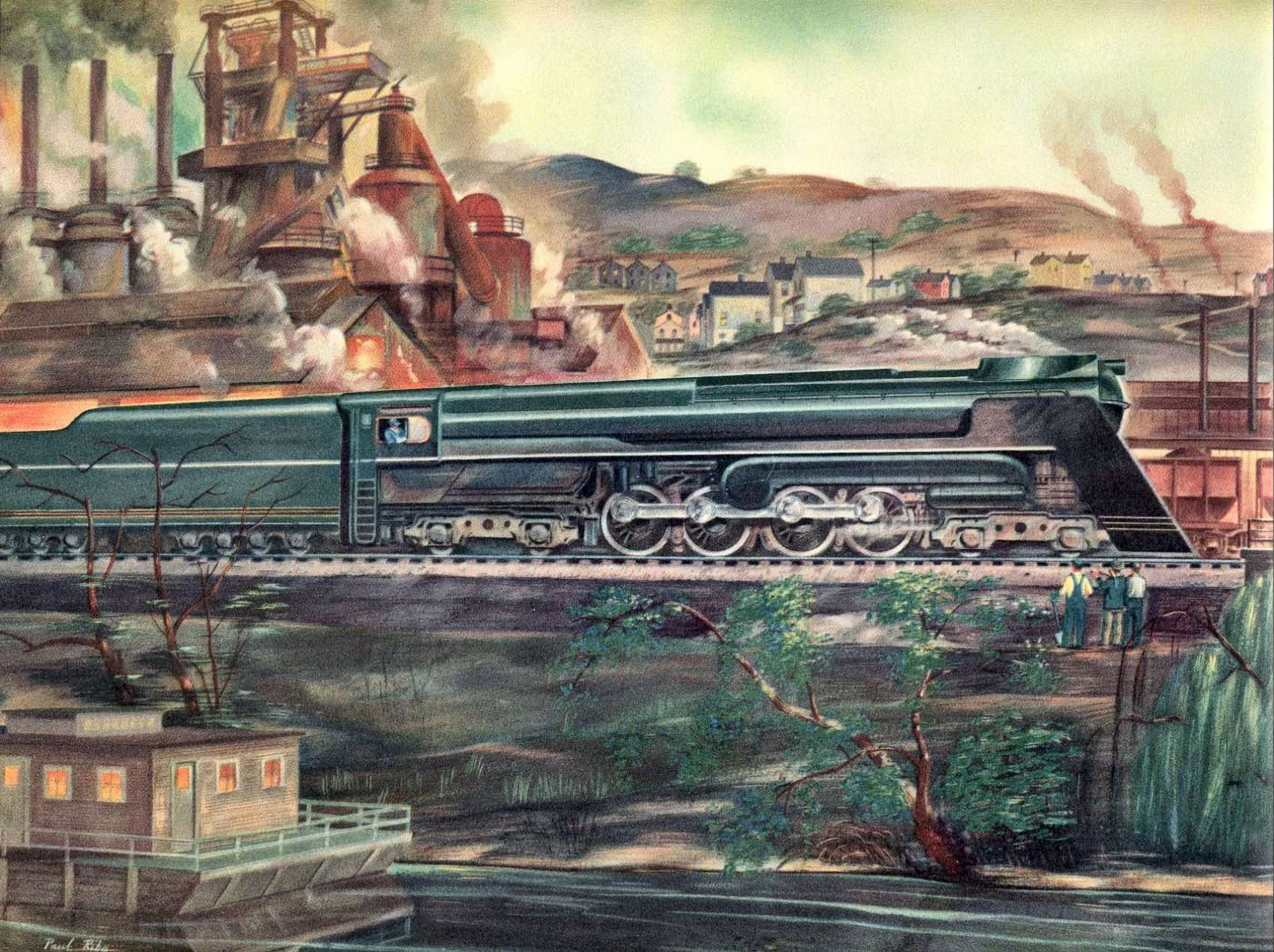
One distinct feature of the modern reciprocating locomotive is its high-capacity boiler. Modern passenger locomotives develop 6,500-7,000 cylinder horsepower each and freight locomotives approach 8,000 cylinder horsepower.

Reciprocating locomotives provide high availability with average monthly mileages ranging from 15,000 to 28,000 miles. Many are currently dispatched on long engine runs from 500 to 1,000 miles or more. With intensive utilization and excellent maintenance facilities, low repair costs continue to be reported. Coal consumption is continually being reduced per unit of tonnage hauled.

While the reciprocating steam locomotive has served the railroads long and well, it cannot compete universally, in its present stage, with newer forms of motive power. However, for years it will continue to serve the transportation industry in important assignments.



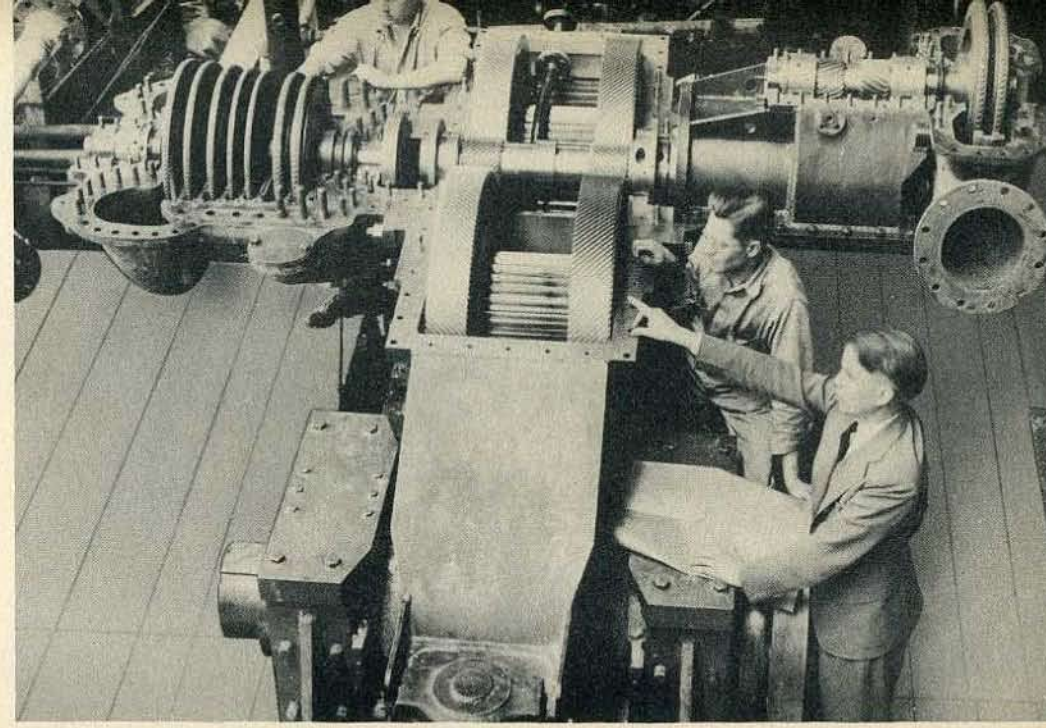


# The Geared Steam Turbine Locomotive

The pioneer locomotive of this type, designed for high-speed passenger or freight service, and known as the Pennsylvania Class S-2, made its initial appearance in 1944. This type of drive permits smaller driving wheels, provides greater space for the boiler, affords greater flexibility in the selection of wheel arrangement and operates at high mechanical efficiency. It uses only rotating apparatus, eliminating all reciprocating parts. The locomotive tracks excellently at all speeds.

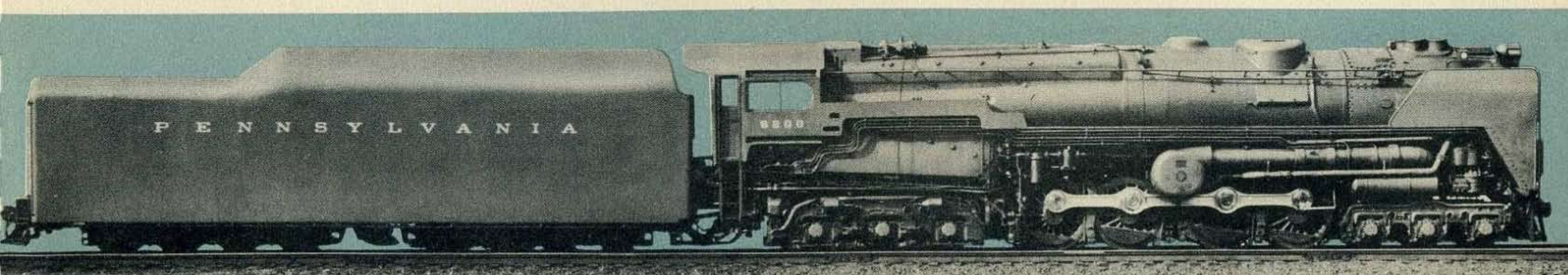
To limit the experimental portion of the locomotive to the turbine, gearing and flexible drive, a conventional type boiler (310 pounds per square inch) was selected for the first locomotive. The propulsion apparatus has operated with remarkable freedom from trouble, especially in view of the innovations which were incorporated. The locomotive has handled all assigned runs with ease. Its performance has definitely proved the practicability of the steam turbine as a prime mover, and of gearing it to the driving axles.

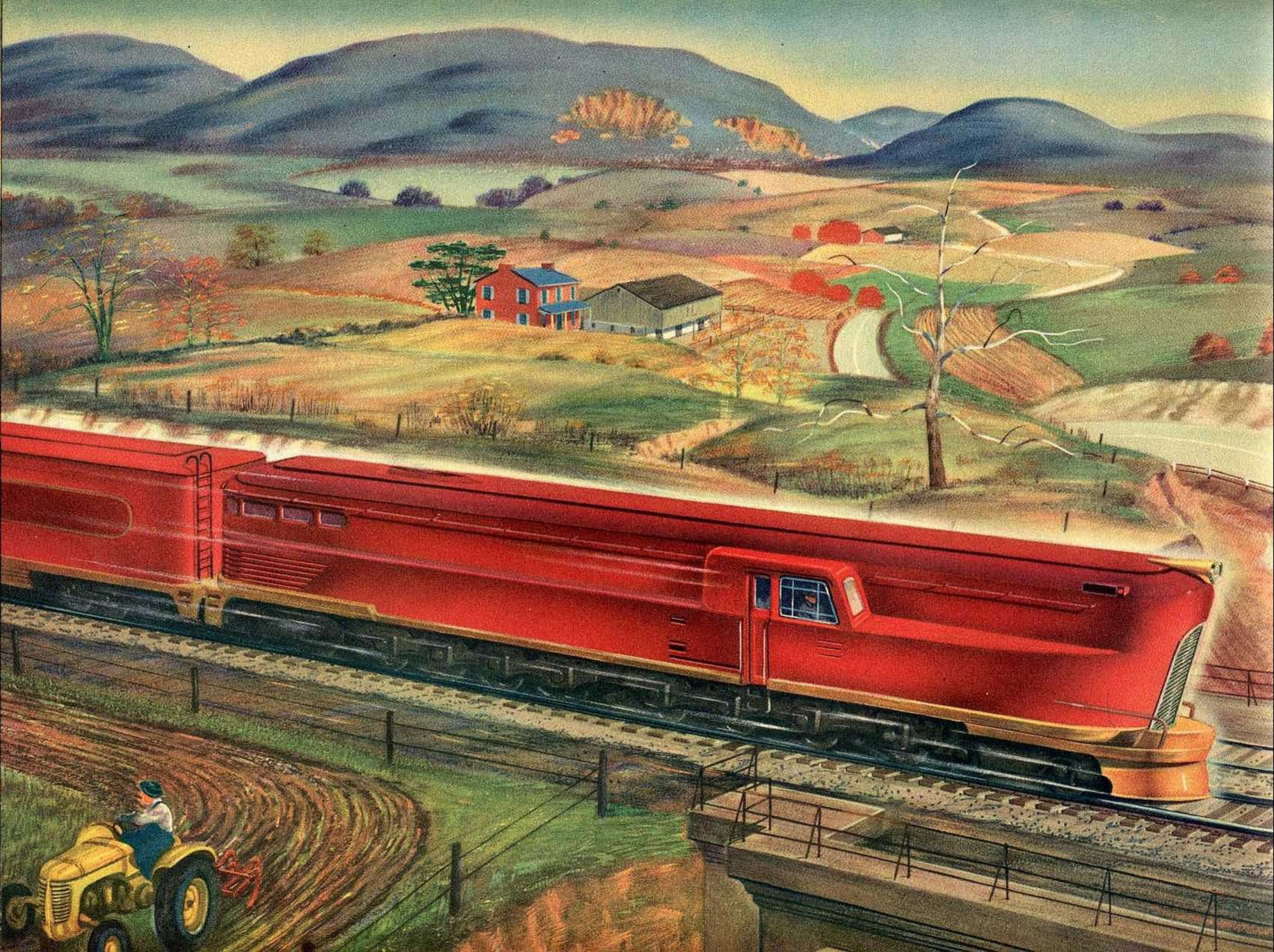
While the geared turbine locomotive is still in its infancy, it should have a field of application in services requiring high-speed and high-horsepower capacity on roads with favorable grades.



"Main propulsion equipment for geared turbine locomotive with covers removed. Main turbine operates at 9,000 rpm and develops 6,900 hp. Reverse turbine develops 1,500 hp, but is geared to produce full tractive effort in reverse. Weight of entire propulsion equipment is 39,000 lbs., or 5.65 lbs. per hp."

This illustration of the Pennsylvania Railroad geared steam turbine locomotive shows the forward turbine unit located between number 2 and number 3 driving wheels.





# The Steam Turbine Electric Locomotive

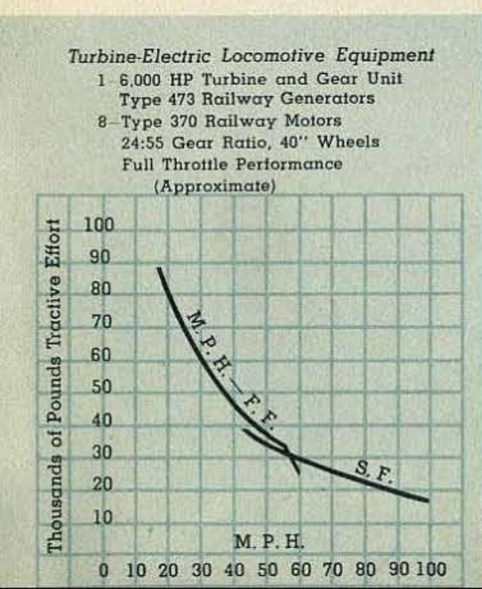
The Chesapeake and Ohio Railroad sponsored the first coal-burning, steam turbine electric locomotives for high-speed passenger service.

This type of locomotive represents a combination of elements which have extensive operating background. It has the traditional coal-fired steam boiler, a steam turbine and electric drive. The arrangement of these components, however, is quite unusual. The coal bunker is located at the head end, followed in succession by the operator's compartment, the boiler and, finally, the turbine-generator power plant. Water is carried in a separate tender behind the locomotive. Main propulsion power is provided by eight traction motors.

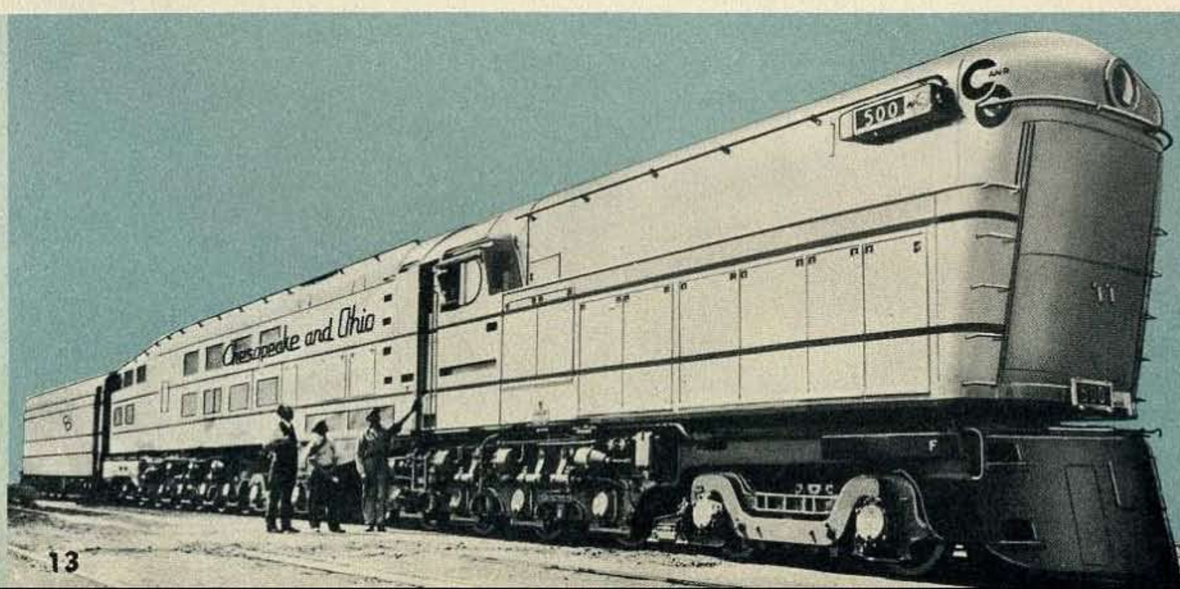
A turbine electric locomotive brings, to steam motive power practice, those advantages of electric transmission which have contributed so much to the popularity of the diesel electric. The power plant may be located in the main locomotive cab, free of restrictions encountered in direct mechanical connections to the drivers. Many axles can be drivers, the maximum in single locomotives being sixteen. With the locomotive weight distributed over many wheels, high starting tractive effort and high running drawbar pull are obtainable. Furthermore, with electric transmission, constant horsepower can be delivered at the drivers over a wide range of locomotive speed.

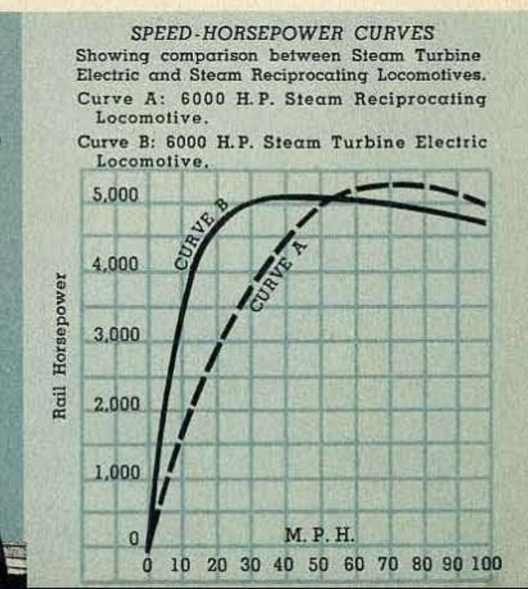
With the developments now in progress to provide better combustion and a higher efficiency boiler, this type of motive power should have most of the advantages of diesel electric motive power and will use coal as fuel.

**Speed-tractive effort curve for steam turbine electric locomotive.**




**One of the three steam turbine electric locomotives of the Chesapeake & Ohio Railway.**



# Looking Ahead with Steam Motive Power

Developments now in progress and in prospect for steam motive power should increase efficiency, enhance availability and provide a better operating performance through improved speed-tractive effort relationship.

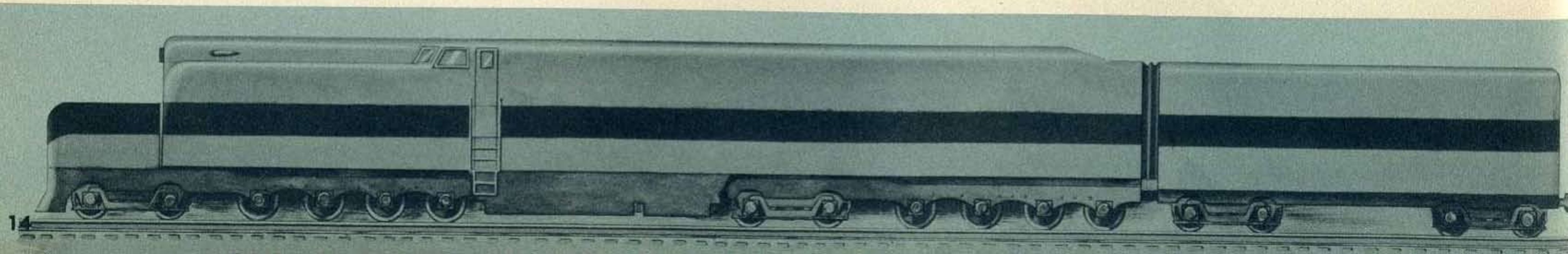
The efficiency of steam motive power must be practically doubled to match fuel costs of other types. This can be accomplished with boilers using forced or induced draft and producing high-temperature and high-pressure steam. The turbine offers the best means of fully utilizing these higher temperatures and pressures. A new type of boiler embodying these features should also improve the locomotive availability.

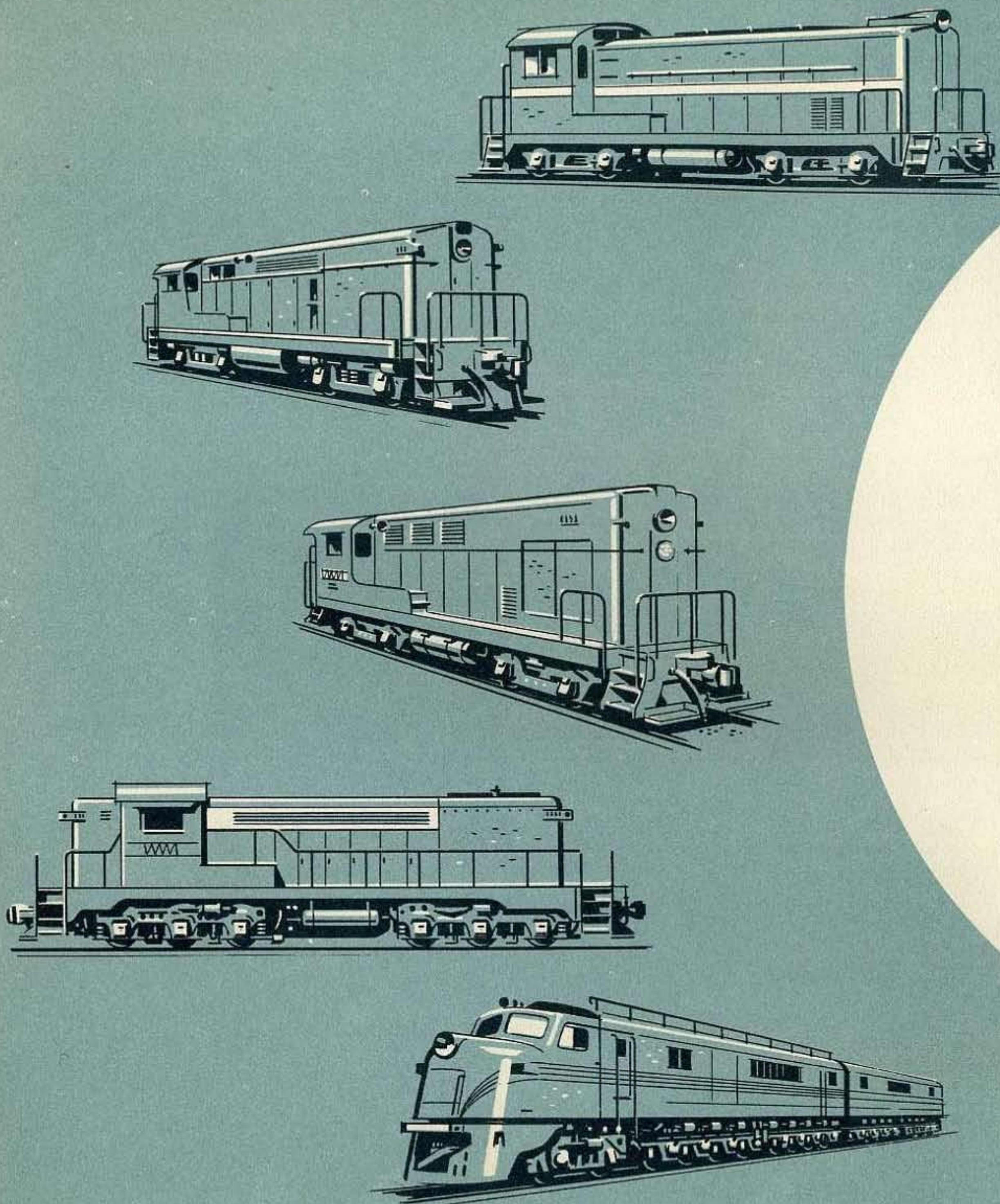
The ideal locomotive should develop high starting tractive force, should have practically all weight on a large number of driving axles and should develop constant horsepower over its entire working range. With the turbine electric drive, these features become available for the first time with steam motive power. With further developments, it may be possible to approach this ideal locomotive design utilizing mechanical drive.

If, from these developments, a practical coal-burning steam locomotive can be produced, it should be competitive in operating economy and performance with other modern types.

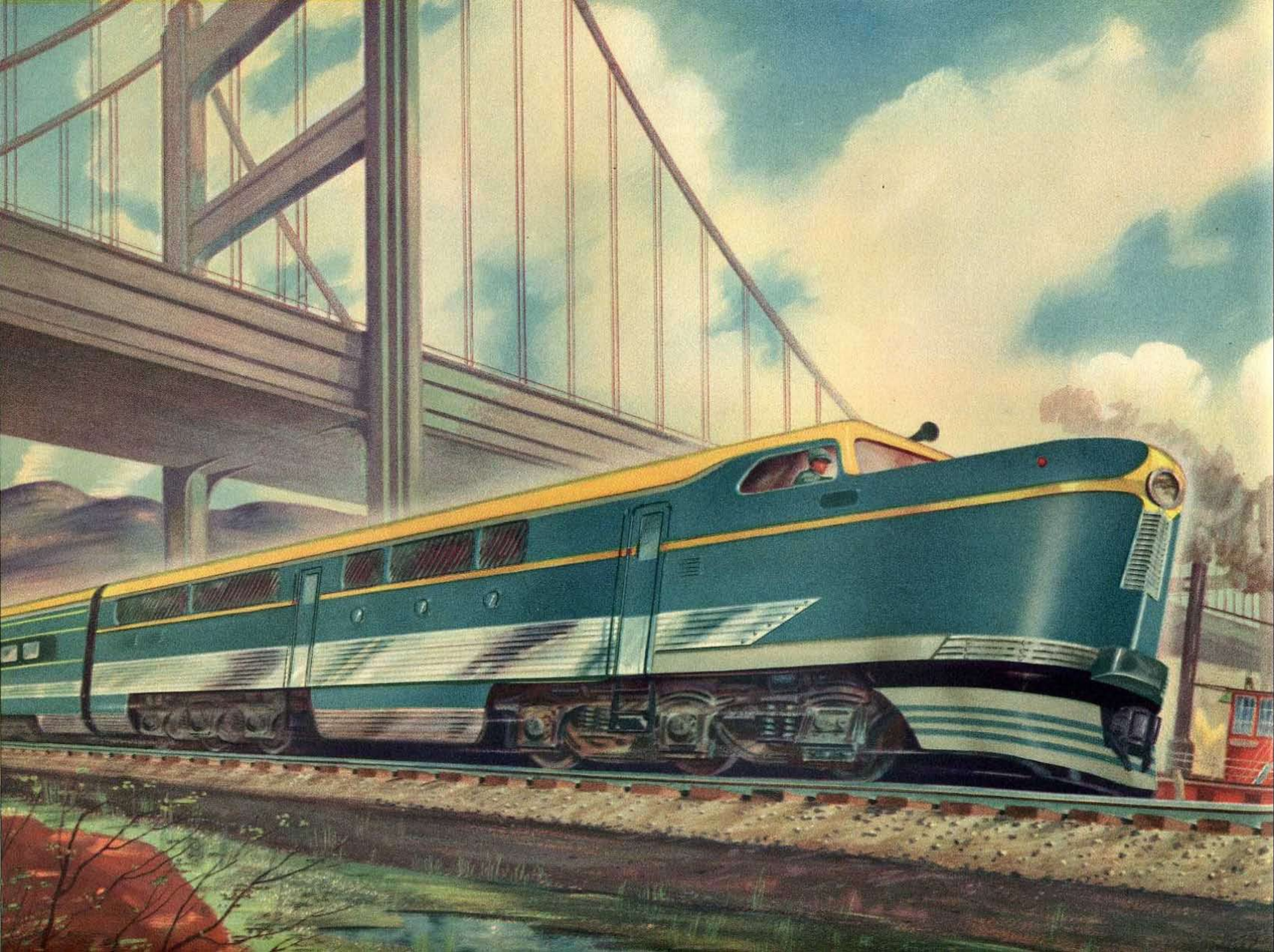
Aside from the new and radical changes in design of equipment leading to the steam locomotive of the future, there will be continued improvements on reciprocating locomotives. Among these may be improved combustion with automatic firing, induced draft, better cinder cleaning in smoke box, reduction in back pressure and more effective use of steam. Probably the greatest contribution to the future of the steam locomotive would be the adoption of practices and the provision of adequate maintenance facilities for its most economical operation.

A conception of steam power of the future.





# DIESEL ELECTRIC MOTIVE POWER . . . . .



# Diesel Electric Motive Power

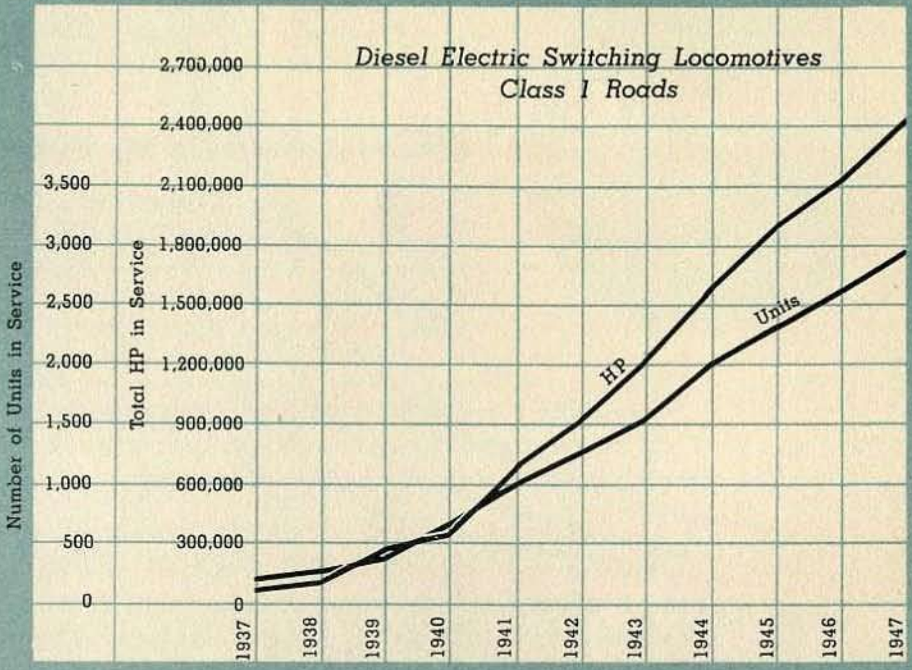
The ever-increasing popularity of the diesel electric locomotive is the result of its performance combined with operating and construction features afforded by the use of a high-efficiency prime mover and an electric transmission.

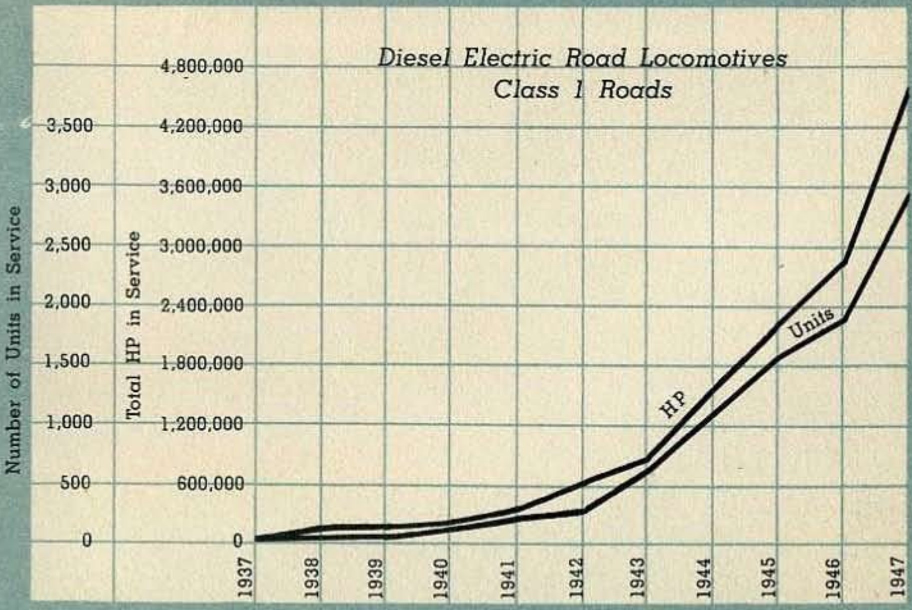
The diesel engine has the highest thermal efficiency of any existing prime mover. This characteristic contributes to economy of operation and permits carrying an adequate fuel supply for operation over long distances. Water treatment problems are eliminated as water is used only for cooling purposes. Also, stand-by losses are low.

The electric transmission between the prime mover and the wheels is really the heart of the locomotive. With its use it is possible, by very simple control means, to utilize the full horsepower of the engine over the entire speed range of the locomotive. Electric transmission provides the facility for equally distributing the locomotive weight over a large number of axles, any number of which may be powered with electric motors. This insures high tractive effort which minimizes helper service. An inherent characteristic of electric operation is the smooth, continuous and non-pulsating flow of power to the drawbar.

From the standpoint of locomotive construction, there is afforded a degree of standardization in the design and manufacture of individual parts. Motive power units can be flexibly combined to form locomotives of desired capacity to meet any condition of switching or road operation.

The growing popularity of the diesel electric locomotive is illustrated by the two charts which show installations made by Class I railroads over a ten-year period.



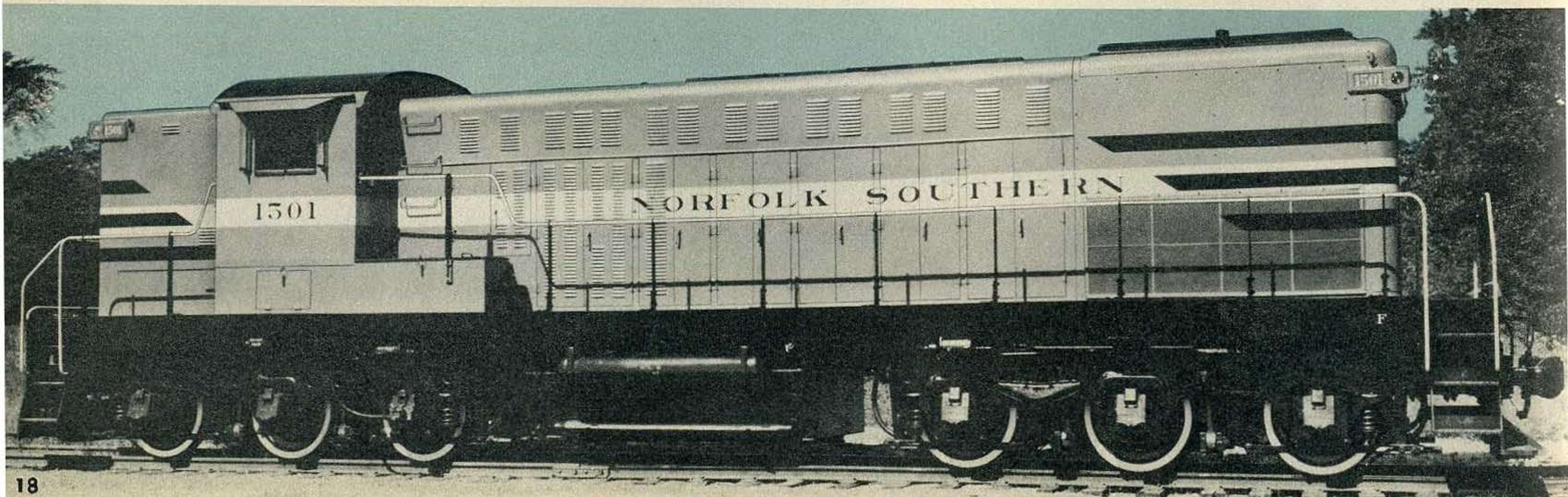
# The Diesel Electric Switching Locomotive

1. For switching service, the diesel electric locomotive has no equal from the standpoint of either performance or economy. It is in switching that the diesel has found its widest usage.

2. The popularity of the diesel electric in switching service is attributable to its over-all economy. Moderate capacity engines can be employed since the torque amplification feature of the electric transmission permits using full engine horsepower at low speeds. High availability allows fewer locomotives to perform a given service. In addition, few facilities for servicing are required, so that initial investment is relatively low. Operating costs are favorable due to low repair costs and minimum fuel costs brought about by low stand-by losses and high thermal efficiency of the engine.

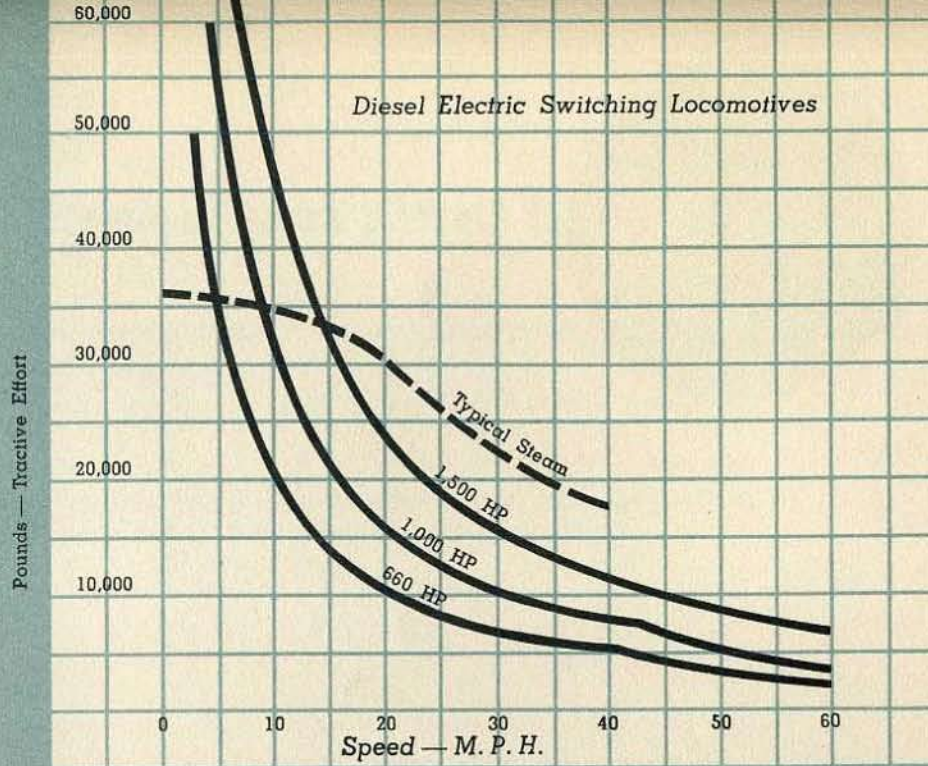
3. Manufacturers have standardized the design of switching locomotives to the point where three sizes satisfy practically all requirements of the railroads. The principal characteristics of these three standard units are as follows:

A 1,500-hp diesel electric switching and transfer locomotive.

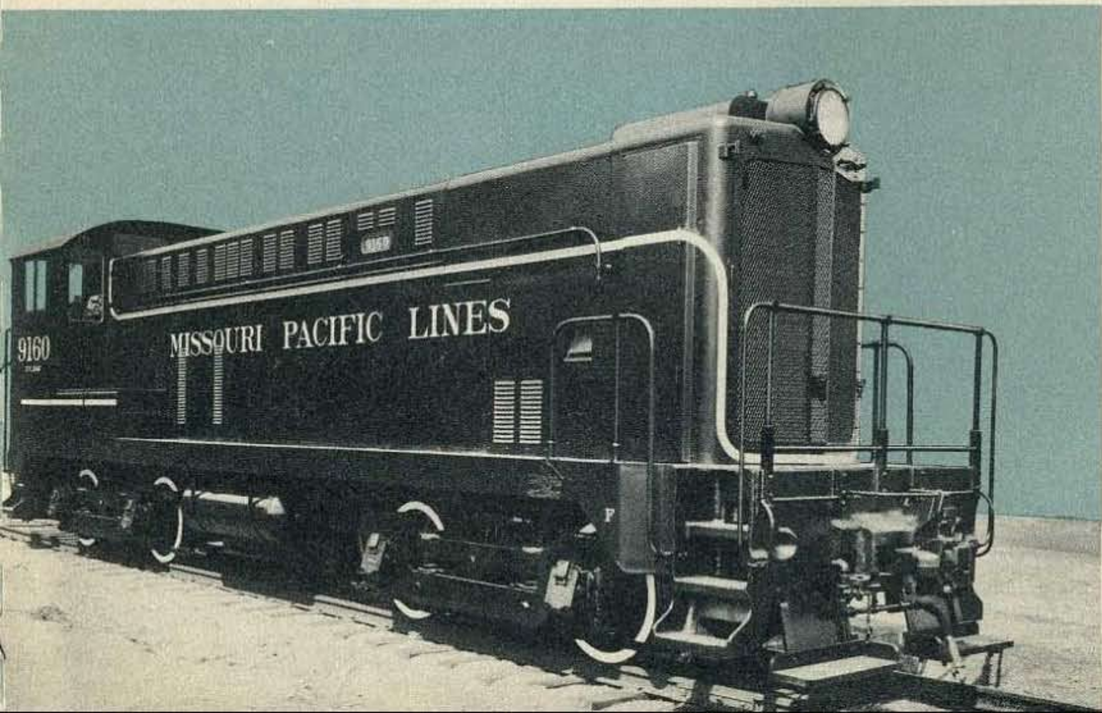


| | | | |
|---|---|---|---|
| Engine HP | 660 | 1,000 | 1,500 |
| Total Locomotive Weight—Tons | 100 | 160 | 125 |
| Wheel Arrangement | 0-4-4-0 | 0-4-4-0 | 0-4-4-0 |
| Over-all Length—Ft | 46 | 46 | 58 |
| Weight Per Driving Axle—Lbs | 50,000 | 60,000 | 62,500 |
| Starting Tractive Effort—33⅓% adh. | 66,700 | 80,000 | 83,300 |
| Continuous Tractive Effort | 34,000 | 34,000 | 42,800 |
| Continuous Speed—MPH | 5.3 | 9.0 | 10.5 |

4. For purely yard switching applications, the 660 or 1,000-hp locomotives are generally ample in capacity. Where yard engines are also required to perform transfer service, 1,500 to 2,000 hp are preferred by many roads to provide higher speed on the main line. The speed tractive effort characteristics of the three locomotives commonly used are shown by the accompanying curves. Superimposed on the diesel curves is that of a very widely used 0-6-0 steam switcher. This comparison illustrates the fundamental difference in the performance between the diesel electric and steam types.




A 1,000-hp diesel electric switching locomotive.



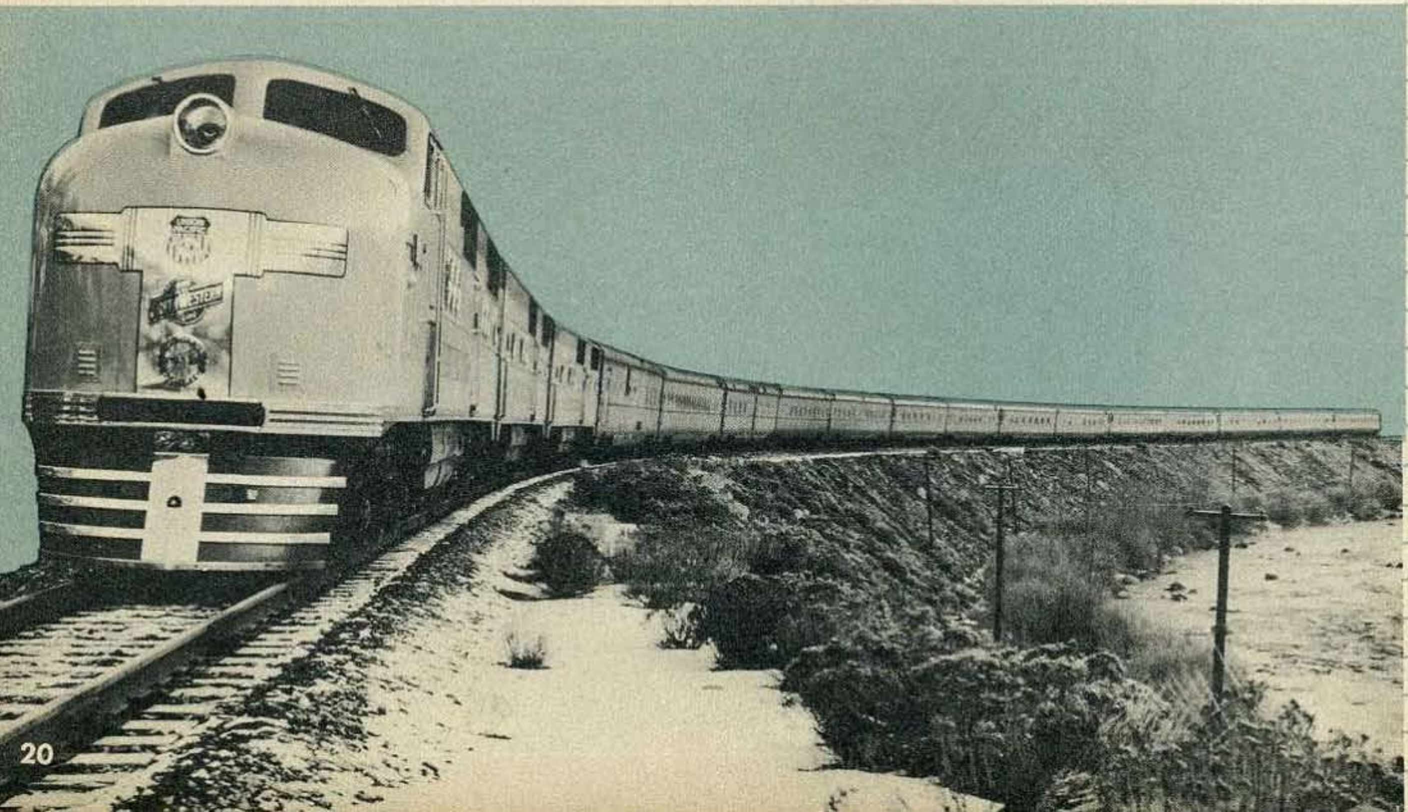

A 1,000-hp diesel electric switching locomotive.

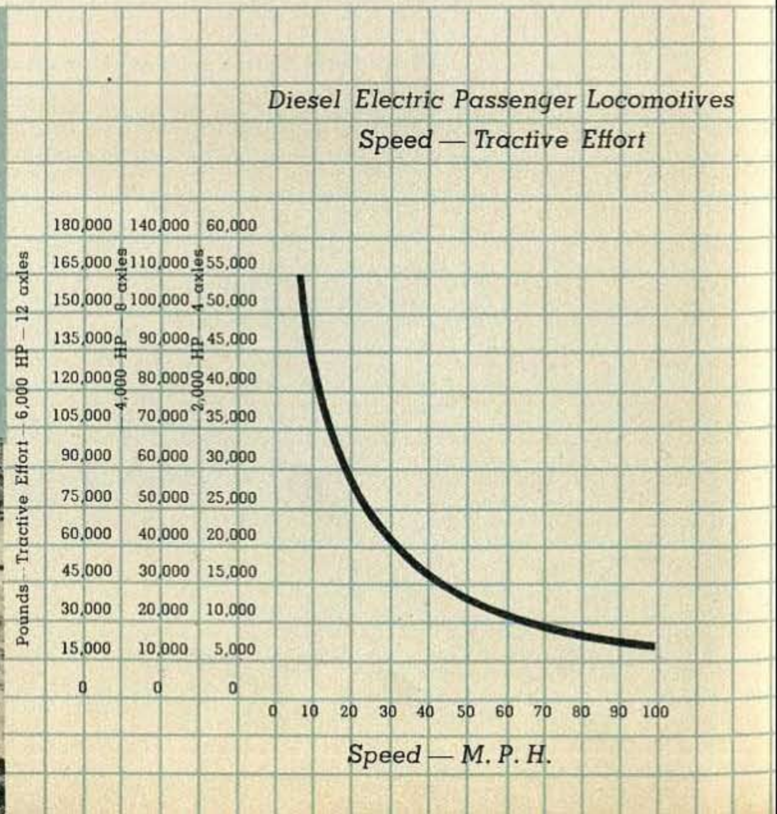
# The Diesel Electric Road Locomotive

Diesel electric locomotives are being used in class I road passenger and freight services in capacities ranging from 1,500 to 6,000 hp. A recent survey showed that units are combined to form road locomotives approximately as follows:

| No. Units | Locomotive HP | % Total Locomotives |
|---|---|---|
| 1 | 1,350-1,500 | 8.0 |
| 1 | 1,800-2,000 | 10.0 |
| 1 or 2 | 2,700-3,000 | 19.0 |
| 2 | 3,600-4,000 | 14.0 |
| 2 or 3 | 4,050-4,500 | 20.0 |
| 2, 3 or 4 | 5,400-6,000 | 29.0 |

An early 5,400-hp diesel electric road locomotive.

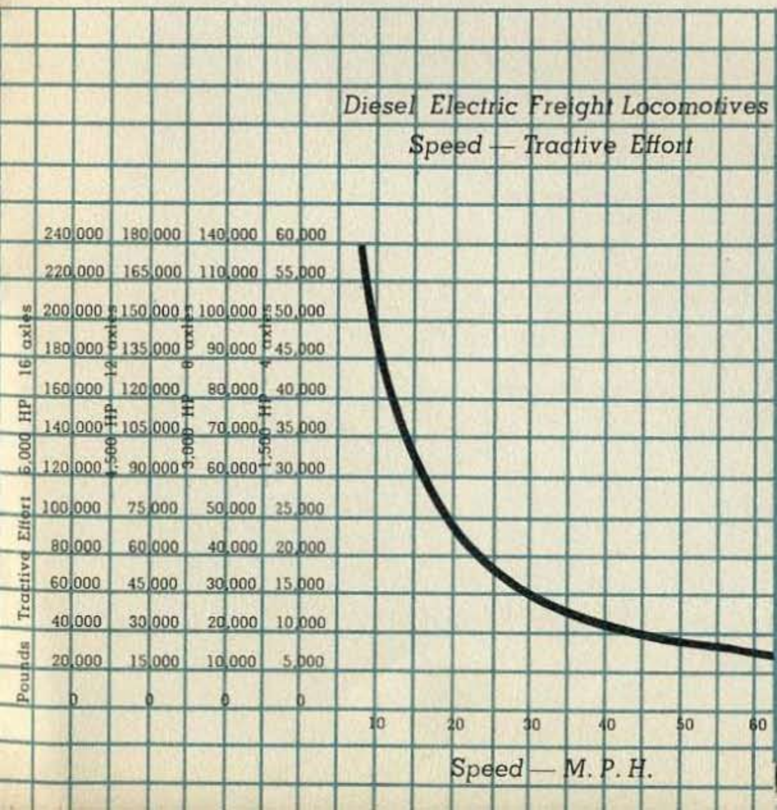




Generally speaking, locomotives of 5,400-6,000 hp are used by those roads which encounter severe grades in the territory served, otherwise, locomotives over 4,500 hp are seldom used and considerable service is supplied by units of lower horsepower.

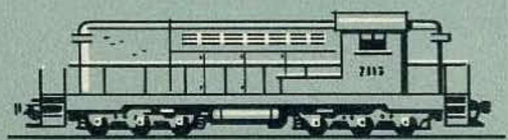
Today, three capacities in single units are in use—1,500 hp, 2,000 hp and 3,000 hp—in both passenger and freight services. As a rule, locomotives made up of 2,000-hp units are preferred in passenger service, and those using 1,500-hp units are more popular for freight service. In freight service, the 1,500-hp units are preferred because greater motor capacity is provided in proportion to the diesel engine horsepower.

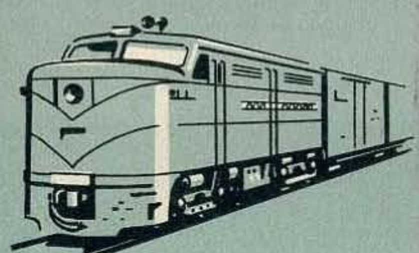
Besides high thermal efficiency, and simplified fueling problems, the diesel electric road locomotive offers high availability, ability for long distance runs, flexible handling of trains and reduction in helper service, even though, in many instances, tonnages may be increased. These features contribute to the increasing popularity of the diesel electric locomotive.

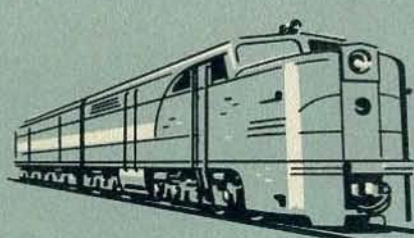


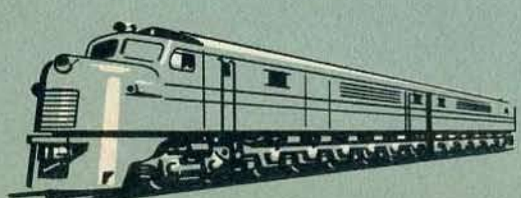

A 6,000-hp diesel electric road locomotive.

# Looking Ahead with Diesel Electric Motive Power



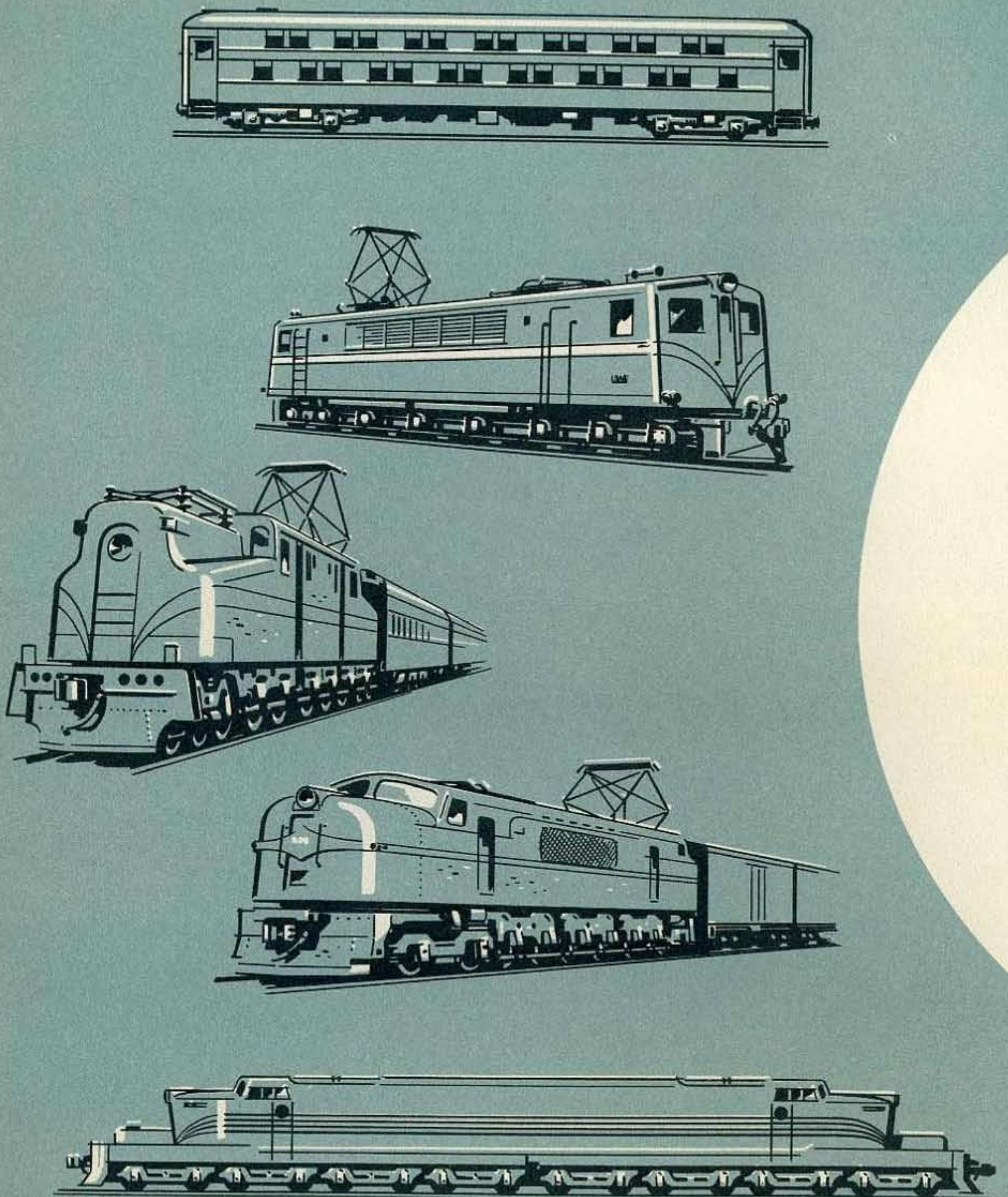






From the time the first diesel electric locomotive entered road service, there has been a demand for increased horsepower from a single engine. Today, locomotives employ engines having a maximum rating of 2,000 hp. Unquestionably, this trend toward a greater concentration of power will continue. With it will likely come higher engine speeds which will permit lighter engines and lighter generators. This may well represent the most striking change in diesel electric locomotives of the future. Progressive improvement in designs and the efficient use of new materials have permitted increasing the capacity of electrical equipment to the point where the possibility of failure through overloading is materially reduced.

Continued improvement in apparatus details are not in themselves particularly spectacular but they have added importance when considered as essentials to high availability and low maintenance on locomotives. Efforts are constantly being directed toward producing the ideal locomotive—one in which there is a practical and economic balance between the factors of self-protection and excess motor capacity. This involves close co-ordination of the engine and electrical equipment.



# ELECTRIC

# MOTIVE POWER . . . . .

## Electric Motive Power

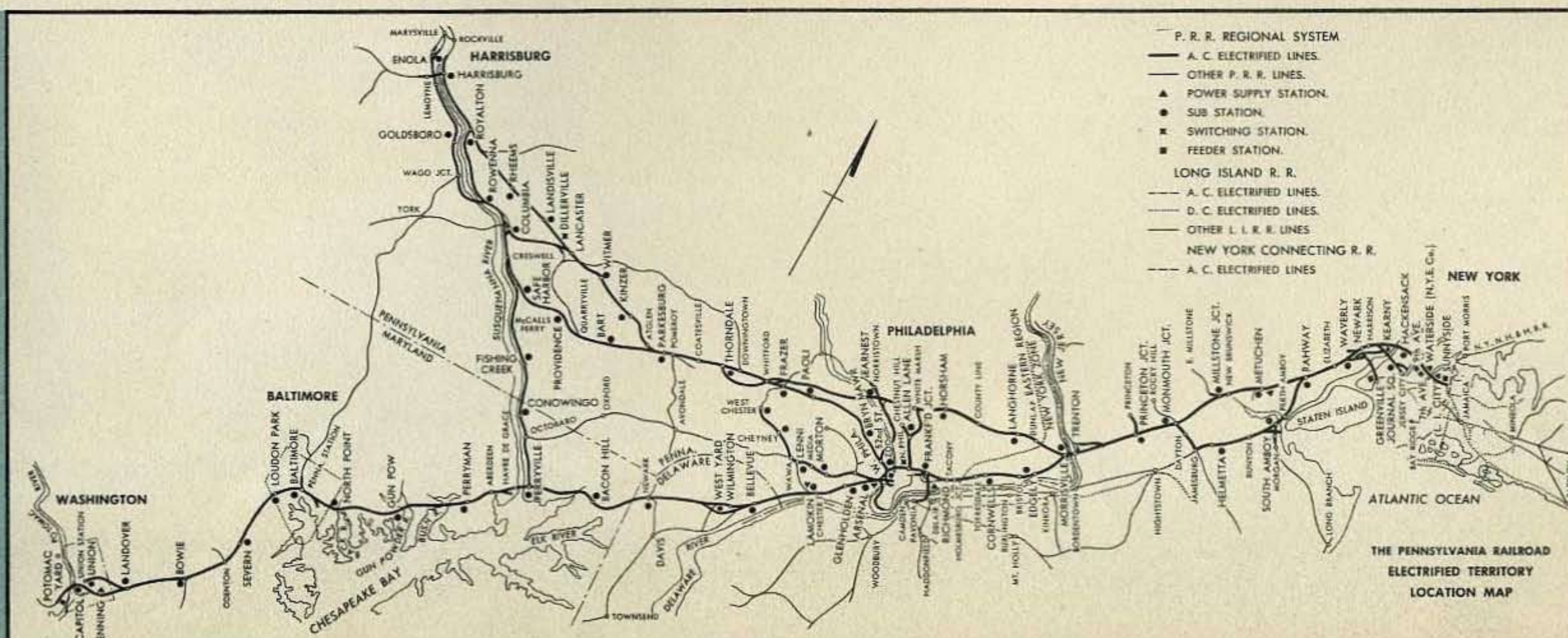
Electrification will continue to play an important role in railroad operation, as with its use a superior class of service is attainable. It offers such advantages as:

1. High continuous speeds for both passenger and freight service and high intermittent overload capacity making it possible to maintain high schedule speeds, important in heavy traffic density.
2. Elimination of shock and vibration incident to reciprocating motions, lowering track and motive power maintenance.
3. Cleanliness and quietness of operation.
4. Minimum, direct-operating expenses.

Two systems of electrification are in common use, the direct-current system with trolley voltages ranging from 600 to 3,000 volts and the alternating-current system, usually with a 12,000-volt trolley. The relative merits of these systems have been the subject of much discussion. Actually either will provide excellent operation and the choice between the two is largely controlled by conditions pertinent to a particular project. Each has been sufficiently proved to insure its success.

To date, the outstanding example of electrified operation is the electrification of the Pennsylvania Railroad between New York-Washington-Harrisburg where the heavy traffic in this area is handled on schedules which would otherwise be impossible.

The service records of electric locomotives in peace and in war have never been excelled. Limitations of more widespread electrification are not traceable to locomotive performance but rather to the economic factor of high capital outlay. In spite of this handicap, the important and interrelated problems of fuel costs, fuel reserves, and imposed operating requirements, that cannot be met in any other way, may combine to accelerate the return of electrification to many American railroads. Increasing availability of comparatively low-cost electric energy from water power sources and highly efficient central station generating plants, using coal or even atomic energy, may have a determining effect upon future electrification projects.




THE PENNSYLVANIA RAILROAD ELECTRIFIED TERRITORY LOCATION MAP

# Alternating-Current Electric Locomotives

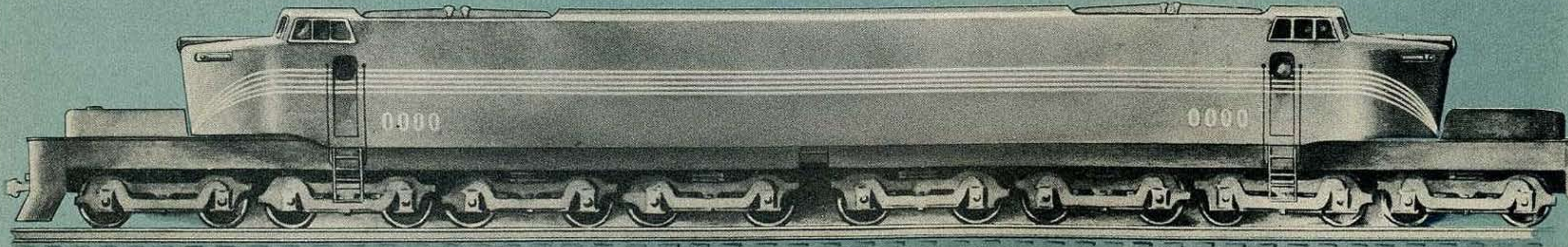
Three types of locomotives have been built to operate from an a-c system, namely, the a-c series motor type, the motor-generator type and the split-phase type. The a-c series motor locomotive is well adapted to any application while the others are primarily best adapted to slow-speed, heavy-grade service.

The finest current examples of the a-c series motor locomotive are the Pennsylvania Class GG-1 and the New Haven Class EF-3. While they are nominally rated at 4,800 continuous hp, each can deliver from 8,000-9,000 maximum hp, if occasion arises. Output in excess of the nominal rating can be delivered, at the rail, over the entire speed range of the locomotive. Combined with this high output is a flexibility of control unmatched by any other type of locomotive. The Pennsylvania Class GG-1 locomotive is synonymous with the best in high-speed passenger power.

Good examples of a-c split-phase locomotives are those on the Norfolk and Western and Virginian Railways. Both the Great Northern and Virginian Railways have modern MG locomotives in service.

The fundamental advantage of the alternating-current system is its ability to use a high-voltage trolley, thus making it possible to

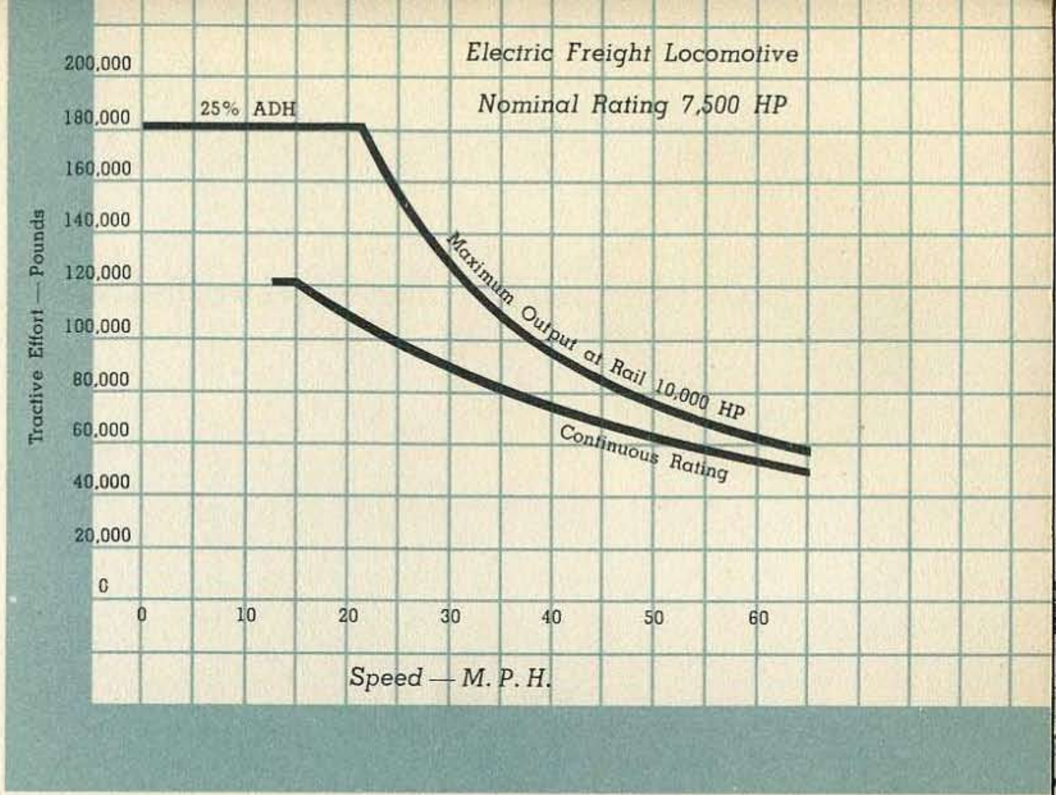
7,500-hp a-c freight locomotive



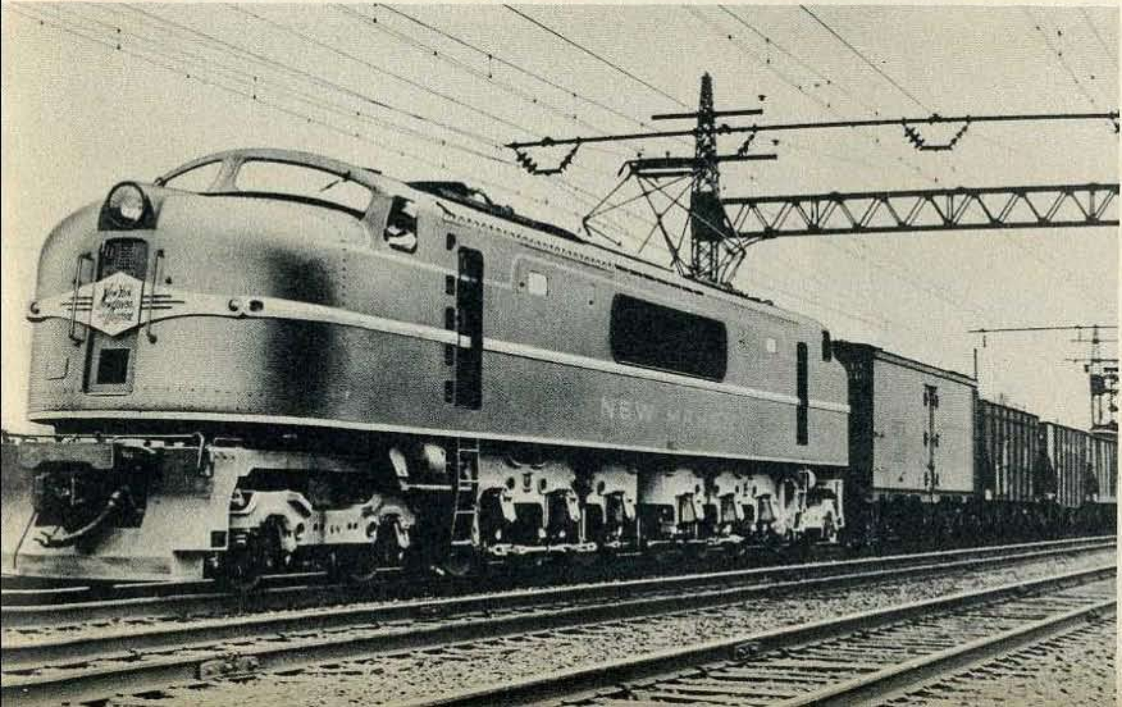
supply economically large blocks of power over long distances for heavy concentrations of traffic.

With modern developments, it is possible to provide 7,500 continuous hp and 10,000 maximum hp in a single unit locomotive. The performance of such a locomotive, when geared for freight service, is shown in the accompanying curve.

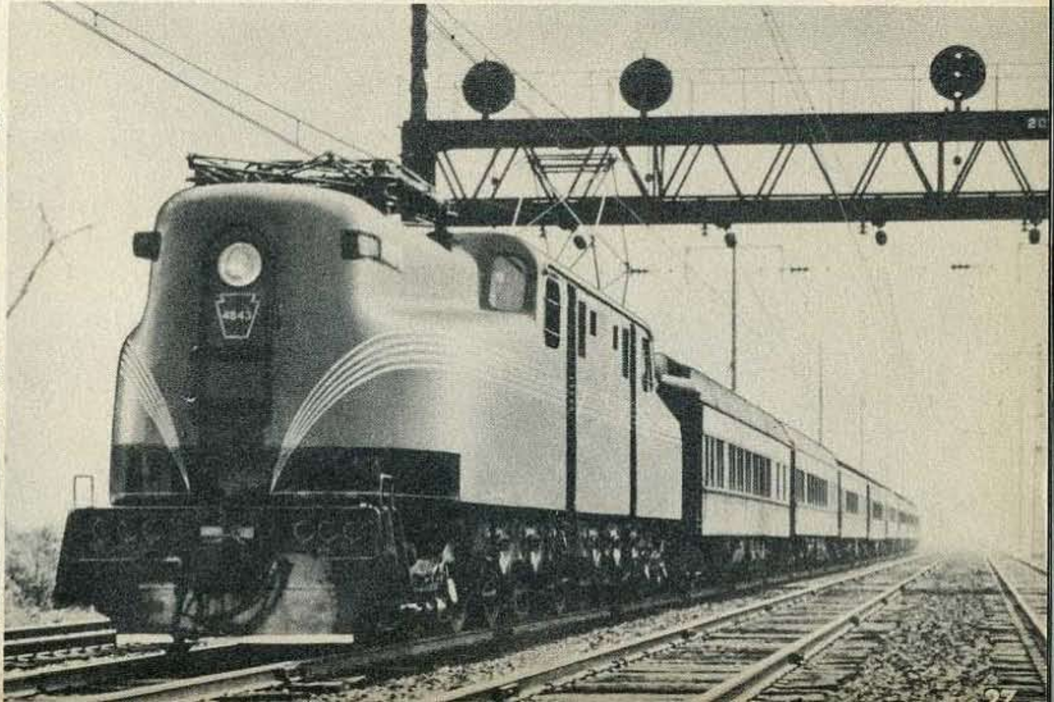
Motive power with such superlative operating characteristics is obtainable only with electrification. Although other types of motive power are steadily becoming more proficient, there are no developments in prospect which will make their performance equal to the best available electrics.




A New York New Haven & Hartford Railroad Class EF-3 electric locomotive.



A Pennsylvania Railroad Class GG-1 electric locomotive.



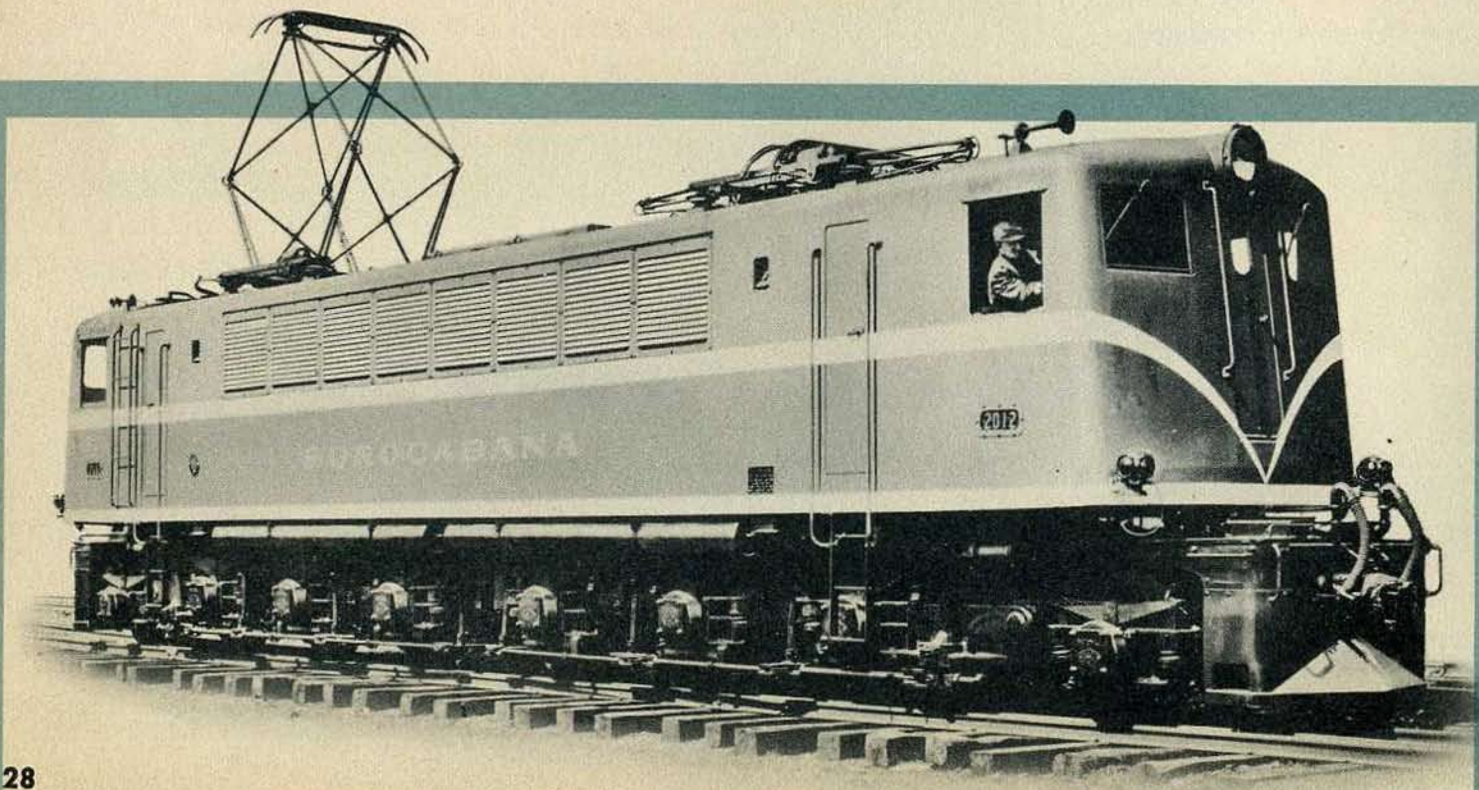
## Direct-Current Electric Locomotives

Locomotives built for direct-current operation have the same general advantages and can be built in the same capacities as a-c types for similar services. While d-c locomotives may have slightly lower first cost, lighter weight and lower maintenance than a-c of equivalent rating, other factors relating to power supply and distribution may more than outweigh these advantages when consideration is being given to the choice of systems.

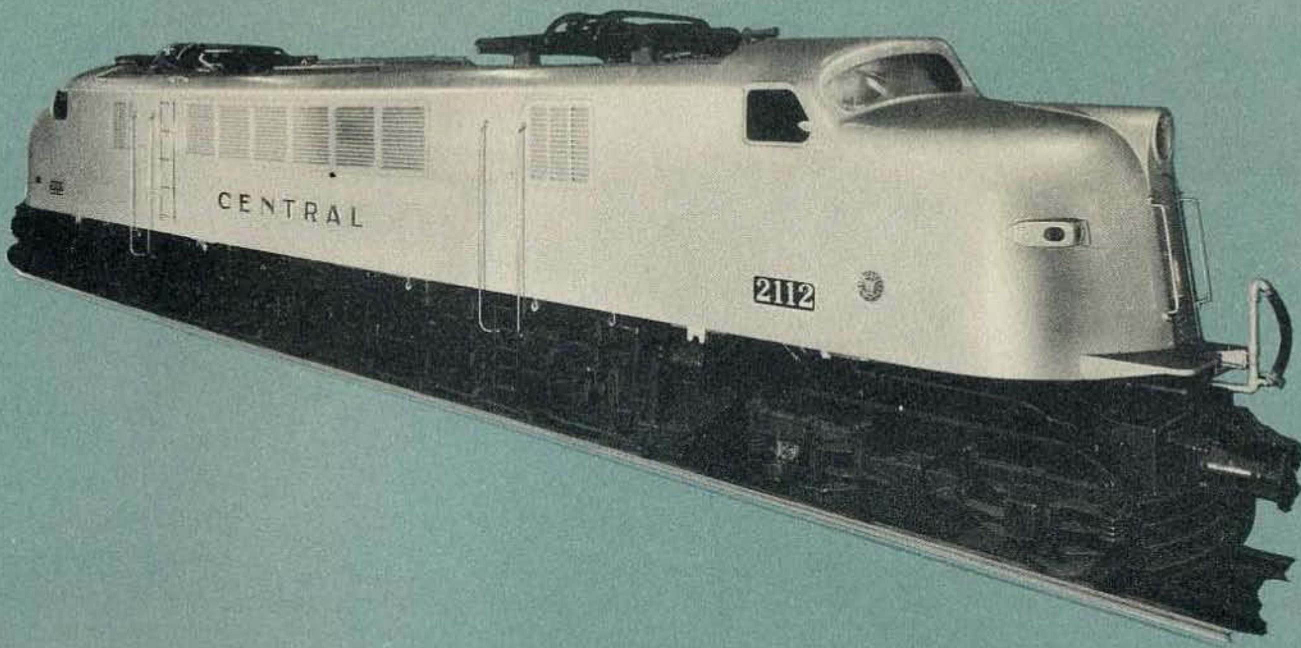
Direct current is particularly well adapted to, and has been largely applied to, those projects which do not involve extreme concentrations of power on individual trains or in particular sections of the railroad. The direct-current system of electrification has been adopted as standard for many countries outside the United States where such conditions prevail. One excellent example is the Sorocabana Railway in Brazil. This meter gauge line has recently been electrified with 3,000 volts, d-c. The capacity of the system, restricted by the narrow gauge and severe grades, has been materially increased and the over-all operating expenses reduced by this electrification. In addition, a very critical fuel problem was overcome.

Direct-current power of larger capacity is well represented by the locomotives for the Central Railways of Brazil. Additional power, of similar proportions, is being constructed for the Chilean State Railways. These locomotives provide a high concentration of horsepower on limited axle loadings.

Another ideal application of d-c motive power is in large open-pit copper mines. Recent locomotives for the Phelps-Dodge Corporation operate from a trolley over the heavy drag sections of the mine and from supplementary diesel power on "temporary" track.



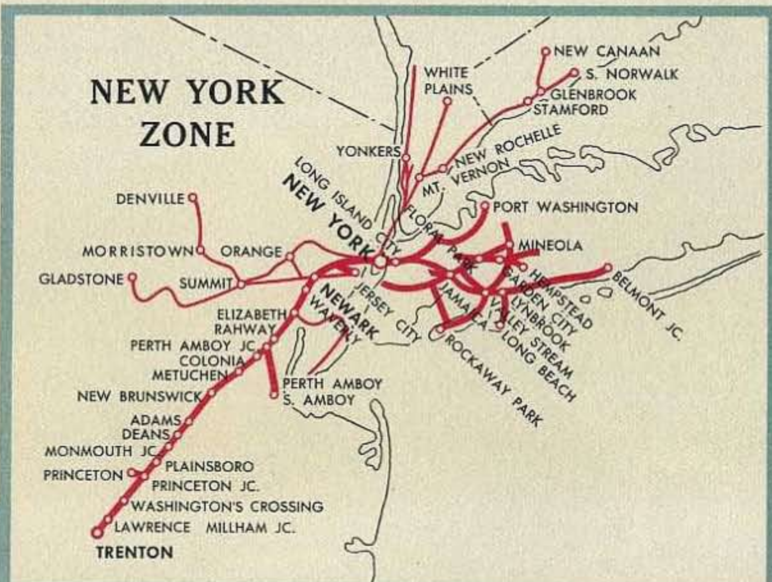

3,000-volt, d-c passenger and freight locomotive—Sorocabana Railway, Brazil.




3,000-volt, d-c passenger and freight electric locomotive—Central Railways of Brazil.


850-volt, d-c trolley-battery electric locomotive for open-pit haulage—Morenci Mine, Arizona.

# Multiple-Unit Cars for Suburban Service

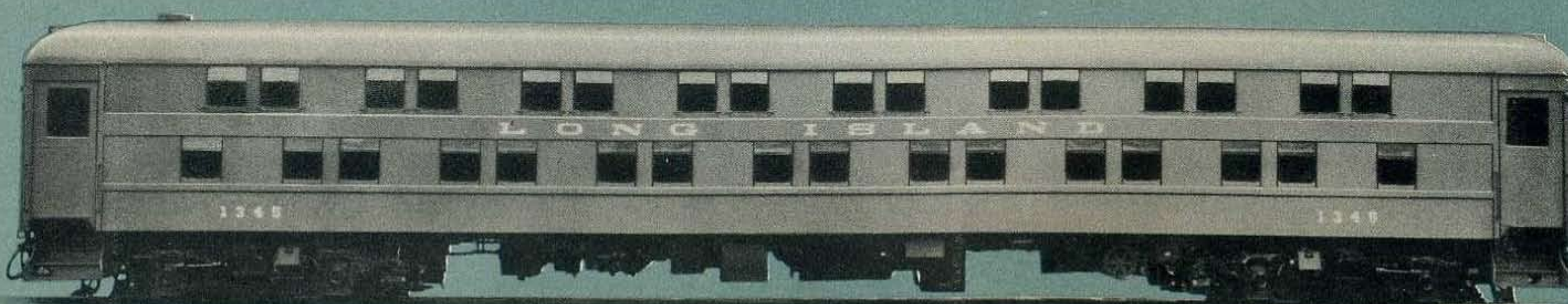



Moving daily, in a relatively short time, large numbers of people to and from their places of business in large metropolitan areas has always been a problem that becomes more difficult to solve as urban populations increase and centers of population move farther away from the business districts. A large share of this type of passenger traffic is handled by major railroad systems which have found electrification a decided advantage.

Multiple-unit trains are the preferred means for handling commuter traffic. In such trains, locomotives are eliminated, terminal

**Map of New York metropolitan area showing electrified suburban lines.**

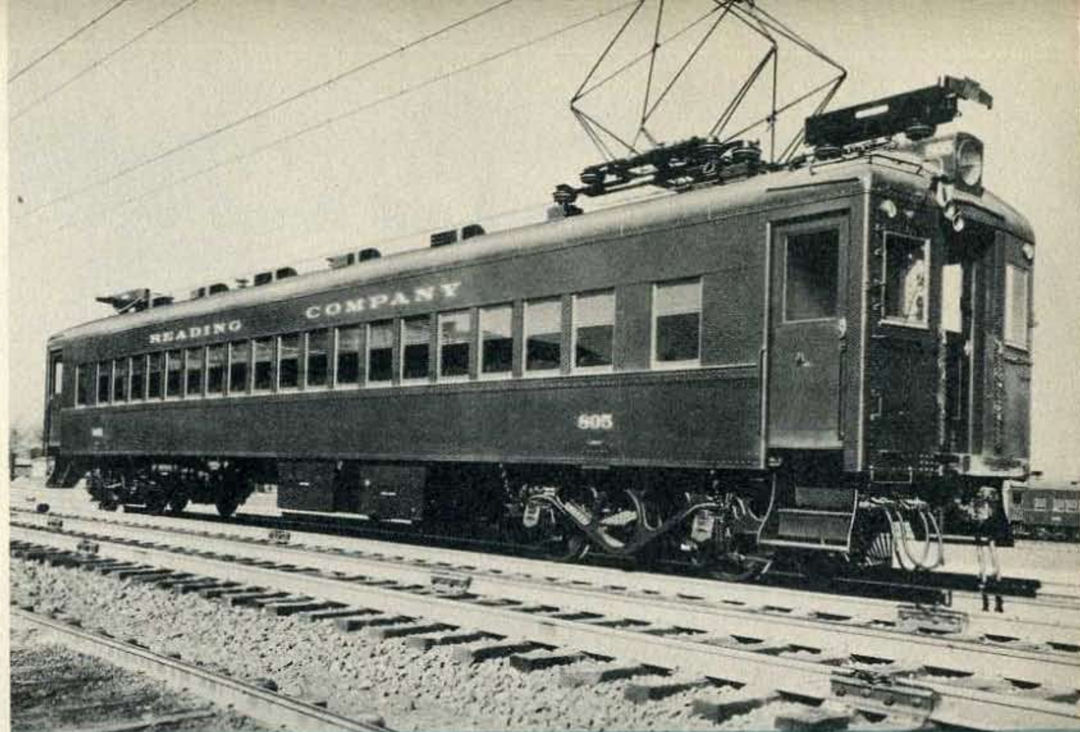
**Double-deck suburban passenger car—Long Island Railroad.**



congestion is alleviated, schedules become independent of the size of train, faster schedules are possible and train consist can be flexibly adjusted to suit traffic conditions.

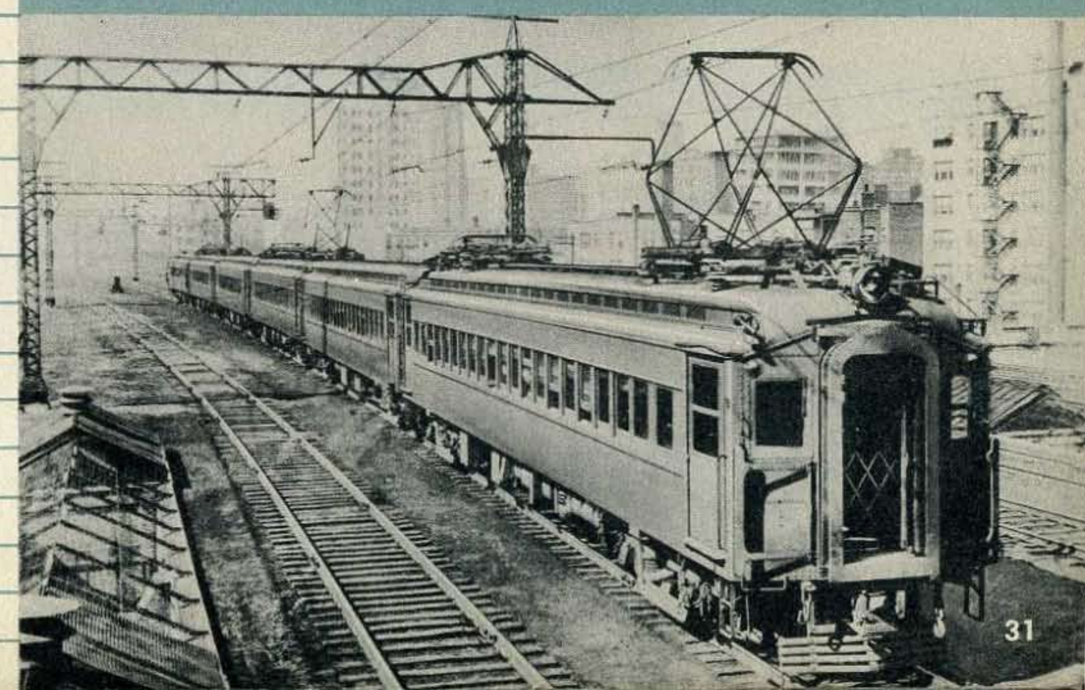
High schedule speeds in suburban service, where the number of stops may average one every mile, are attainable only with fast acceleration. Electrically-operated, multiple-unit trains having many power-driven axles can provide these high accelerations which are far beyond the capabilities of a locomotive-hauled train.

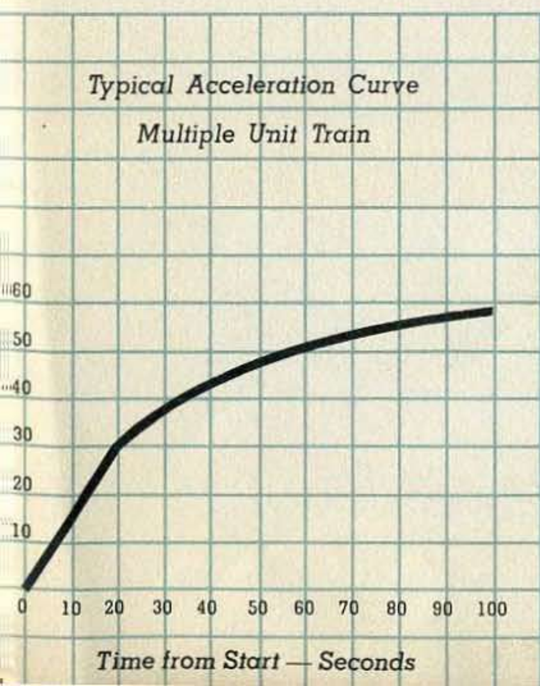
To increase the number of passengers that may be accommodated in suburban traffic, special cars and seating arrangements are being used to increase the passengers per foot of train length. Many roads are using the so-called 3-2 seating arrangement. The Long Island Railroad has installed a number of double-deck cars on its line, and additional cars of this type are being built—each car seating 132 passengers. The magnitude of suburban passenger services is demonstrated by the fact that over 1,200 electrically-operated commuter trains enter or leave New York City daily.

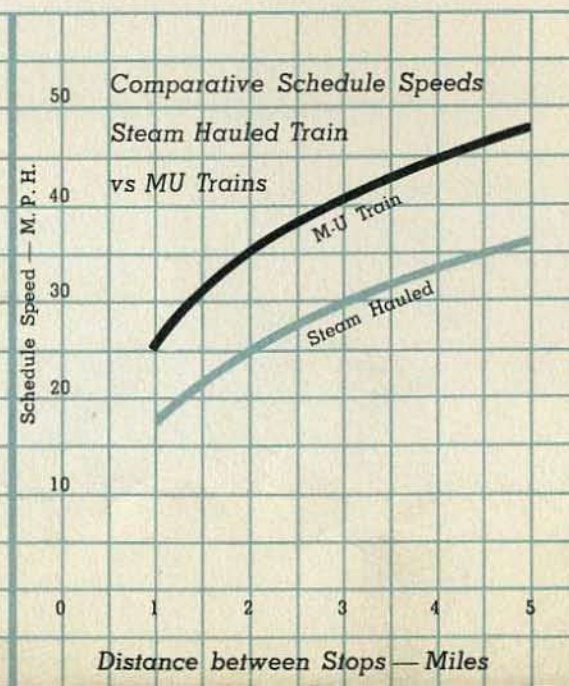


Typical multiple-unit passenger car—Reading Company.

Multiple-unit electric train—Illinois Central Railroad.





# Looking Ahead with Electric Motive Power

Rising costs of all fuels, depletion of oil supplies, increasing number of hydroelectric plants and improved efficiencies of central station generating plants combine to make electric power an increasingly attractive source of energy for locomotives and thus add to the popularity of the electric locomotive which has always been recognized as approaching the ideal motive power unit.

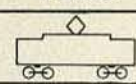
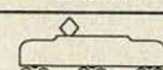
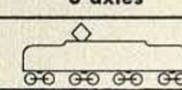
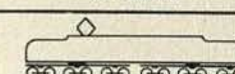
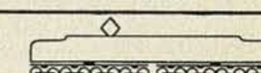
The principal deterrent to more widespread electrification is the high capital expenditure required initially. Possibilities for improvement in this condition lie in greater standardization of overhead distribution systems, substations, protective features, demands for reliability of power supply, control and, finally, the electric locomotives.

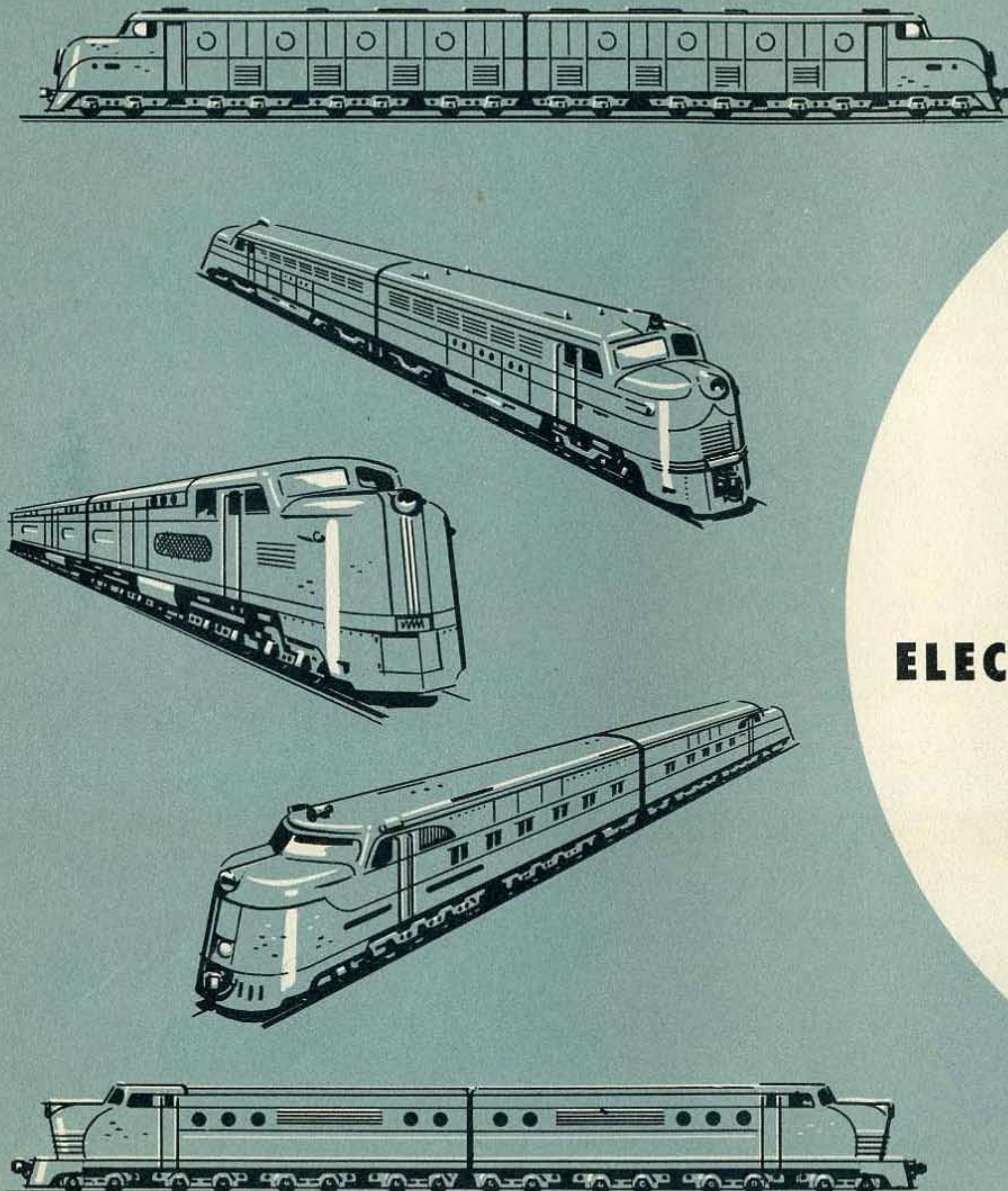
Besides many detailed apparatus improvements made to better the over-all reliability of equipment, future developments will involve greater standardization to reduce first cost and to reduce operating expenses. This trend is well illustrated by the tabulation below, showing the proposed line of locomotives, ranging from 1,875 to 7,500 hp which can be produced with equal facility to operate on either a-c or d-c trolley circuits.

All locomotives would use identical 4-wheel trucks, the number used depending upon the capacity of the locomotive. Identical traction motors would be used throughout for a given type of trolley voltage. In addition, many items of control and auxiliary apparatus remain the same for all sizes of locomotives. Combinations of these various components have also been considered as complete locomotives. All are based on 45,000-pound axle loading and arranged for good tracking at speeds up to 100 miles per hour.

This is a new conception of locomotive design. It has many merits and, in principle, may have a profound influence upon electric locomotives in the future.

**ELECTRIC LOCOMOTIVES — Using standardized (identical) trucks and motors**

| | 4 axles | 6 axles | 8 axles | 12 axles | 16 axles |
|---|---|---|---|---|---|
| **WHEEL ARRANGEMENT** |  |  |  |  |  |
| Nominal HP | 1,875 | 2,813 | 3,750 | 5,625 | 7,500 |
| Total Weight—lbs. | 180,000 | 270,000 | 360,000 | 540,000 | 720,000 |
| On Drivers—lbs. | 180,000 | 270,000 | 360,000 | 540,000 | 720,000 |
| Per Driver—lbs. | 45,000 | 45,000 | 45,000 | 45,000 | 45,000 |
| Length Over-all | 48′ | 67′ | 70′ 4″ | 90′ 10″ | 117′ 2″ |
| Length Cab | 44′ | 64′ | 67′ | 88′ | 90′ |
| Rigid Wheel Base | 8′ 4″ | 8′ 4″ | 8′ 4″ | 8′ 4″ | 8′ 4″ |
| Wheel Dia. Inches | 44 | 44 | 44 | 44 | 44 |
| Number of Motors | 4 | 6 | 8 | 12 | 16 |
| Tractive Effort—25% adh. | 45,000 | 67,500 | 90,000 | 135,000 | 180,000 |
| Continuous Ratings: | | | | | |
| Tractive Effort at 32.5 MPH | 21,625 | 32,437 | 43,250 | 64,875 | 86,500 |
| Maximum Trac. Effort | 30,000 | 45,000 | 60,000 | 90,000 | 120,000 |
| Maximum HP | 2,500 | 3,750 | 5,000 | 7,500 | 10,000 |
| Maximum Speed | 65 | 65 | 65 | 65 | 65 |



# GAS TURBINE
# ELECTRIC MOTIVE POWER.....

# Gas Turbine Electric Locomotive

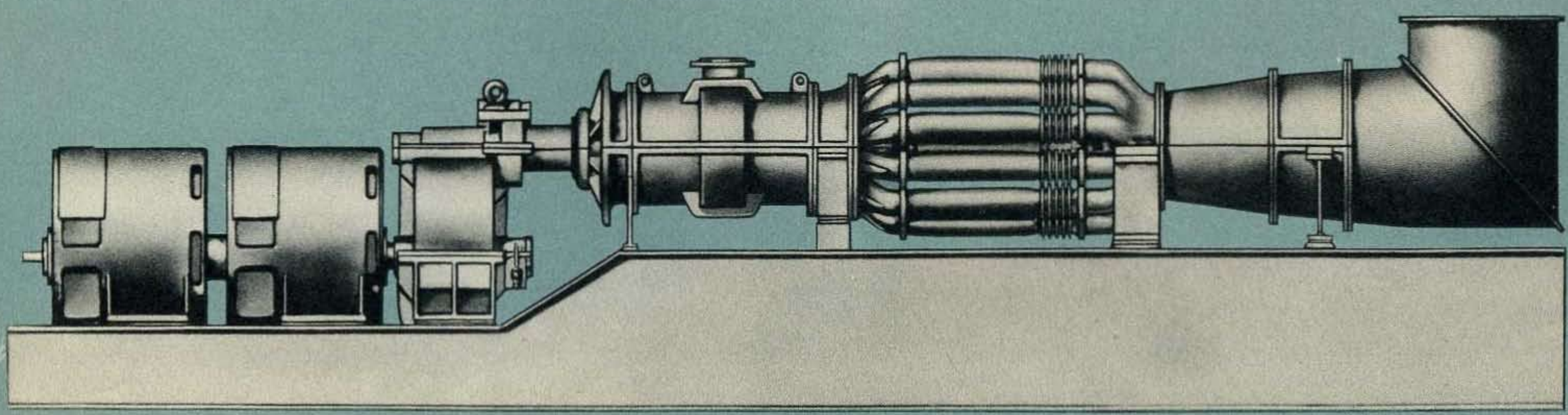
The gas turbine electric locomotive will soon make its appearance on American railroads. Its most economical field of application appears to exist in the larger sizes of road locomotives. As a motive power unit, the gas turbine locomotive offers many outstanding advantages, such as:

1. High horsepower in a minimum of space and with minimum weight.
2. Locomotive simplification throughout.
3. Anticipated low maintenance expense.
4. Favorable fuel costs.
5. Elimination of reciprocating parts, boiler, fuel and water supply problem and ash disposal problem of the steam locomotive; reciprocating parts and cooling details of the diesel locomotive; and power distribution systems of the electric locomotive.

The gas turbine unit in its simplest form consists of an air compressor and fuel combustor and a turbine. A 2,000-hp experimental unit, as operating in a manufacturer's test plant, is illustrated. The gas turbine drives the generator which supplies the power to the traction motors.

The initial locomotive will utilize a simple gas turbine unit as a prime mover. The efficiency of the simple gas turbine is now about 20%, a figure which may be increased by either of two methods—first, by the use of higher temperatures, the realization of which is

A 2,000-hp gas turbine unit showing arrangement of turbine, combustor, compressor, reduction gear and generator.

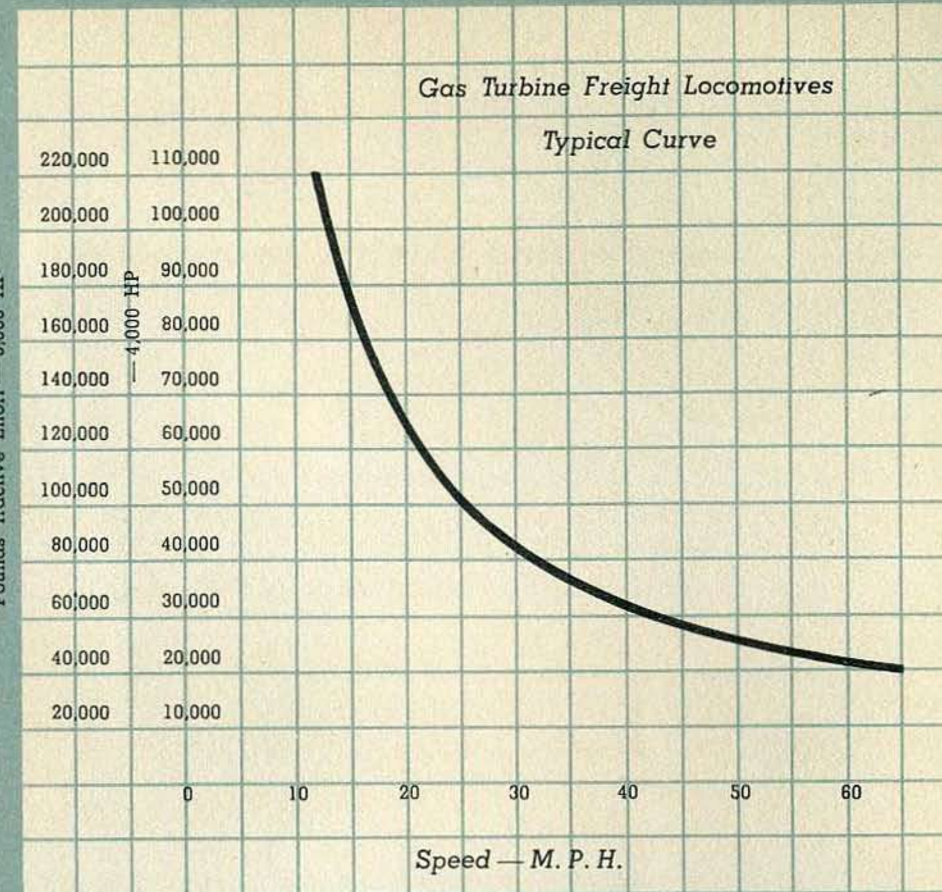


contingent on improved metals and designs and, second, by the use of such auxiliary apparatus as regenerators and reheaters. The latter is undesirable for locomotive service because of weight and space requirements.

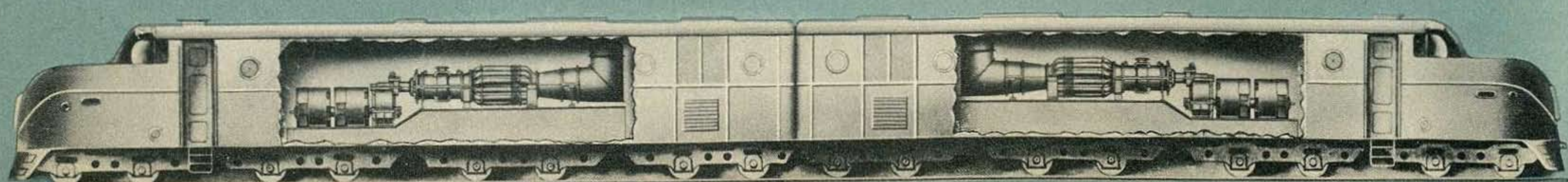
An existing design of 2,000-hp gas turbine unit including generators and reduction gear for electric drive is 26 feet long, 3½ feet wide and 5 feet high. Two may be placed side by side in a locomotive, hence 4,000-hp prime mover capacity can be secured in 26-foot length of locomotive. It seems possible that 8,000 hp may be built in a single unit locomotive. The gas turbine, as a prime mover, utilizes such a small amount of the total available space on a locomotive that the designer is offered many opportunities for making effective layouts to permit accessibility for maintenance, and provide a pleasing appearance.

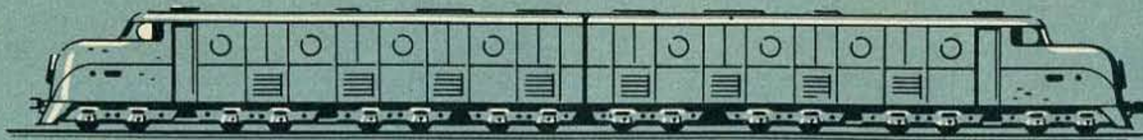
Efforts are being directed toward developing combustor systems for both fuel oil and coal. Oil is the easier of these two fuels to burn. If coal in some form becomes practical as a fuel, the gas turbine locomotive will increase in popularity with the railroads.

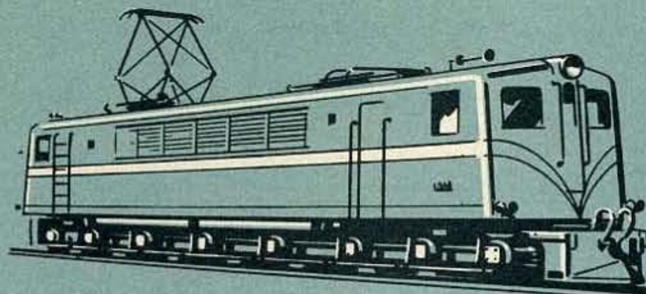
Although a radically new product, the gas turbine locomotive offers outstanding potentialities for successfully competing with other types of motive power, especially in road service.

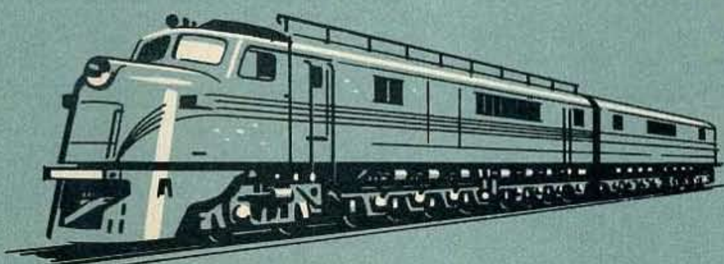


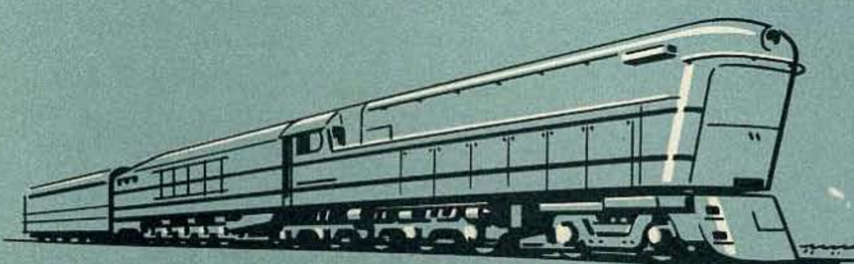

A possible layout for an 8,000-hp gas turbine electric locomotive.











# CHARACTERISTICS OF MODERN MOTIVE POWER . . . . .

# Characteristics of Modern Motive Power

The data given here consists of two classes—comparative locomotive curves and statistical data on modern locomotives. The intent is to show what has been, or can be, accomplished with the different types of locomotives. It is realized that any particular locomotive cannot be selected by statistical data alone. Conditions peculiar to the property are usually controlling in final locomotive selection.

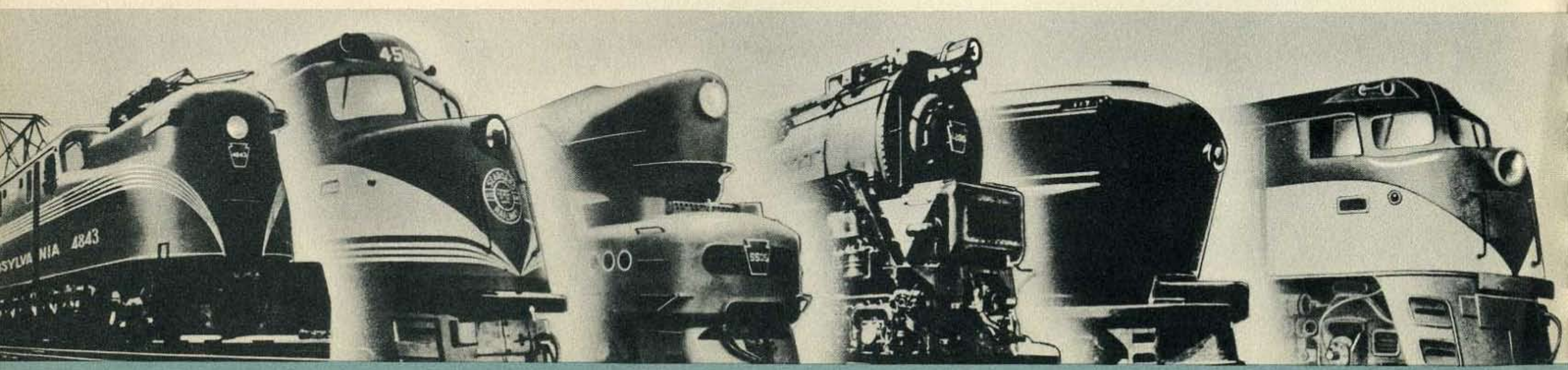
Different methods are used for rating locomotives, and are as follows:

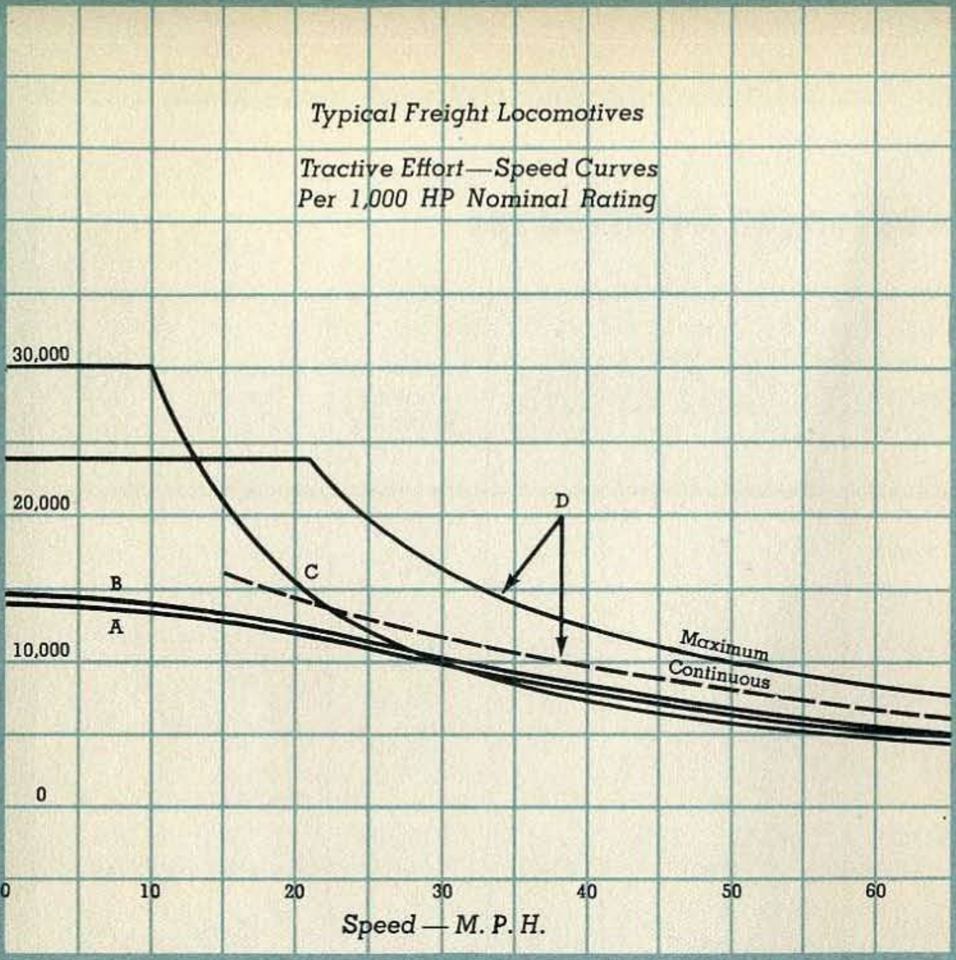
Reciprocating Steam Locomotives.........Cylinder horsepower
Gas and Steam Turbine Locomotives..Turbine shaft horsepower
Diesel Locomotives...................Engine shaft horsepower
Electric Locomotives........................Rail horsepower

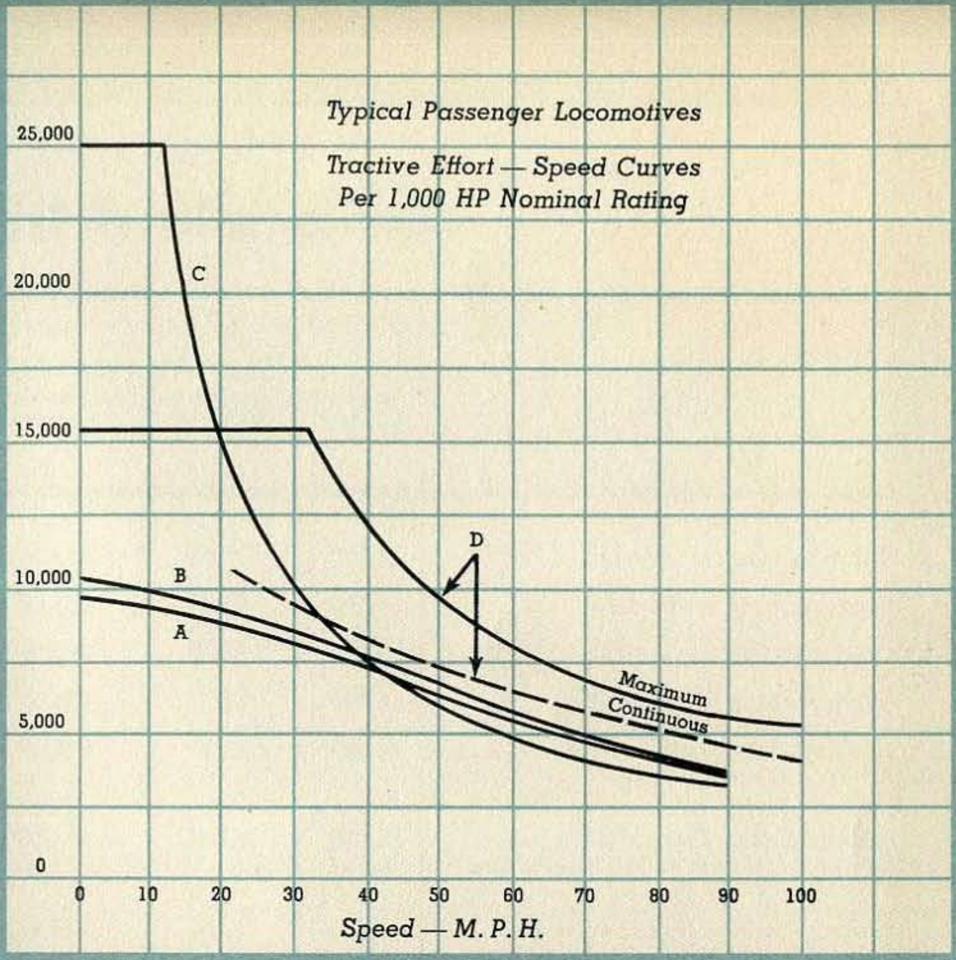
Based on 1,000 hp of nominal rating, curves are shown on Page 39 for Freight and Passenger Locomotives. The curves are typical rather than actual for any particular rating of locomotive. Nominal ratings are not directly comparable but are used here because they represent common practice throughout the industry.

Pages 40 and 41 show specifications for typical modern freight and passenger locomotives. Except in the few instances indicated, the locomotives specified are in service, but to give a more complete picture of all the possibilities for the future, specifications of locomotives yet to be constructed are included.

The United States is favored with the world's best motive power. To maintain this enviable position, all types of locomotives—steam, diesel, gas turbine and electric—should be continually improved and each should be operated in the service to which its over-all characteristics are best suited.






**Legend:**

A. Reciprocating steam locomotives

B. Geared steam turbine locomotives

C. Diesel, steam turbine or gas turbine locomotives with electric transmission

D. Electric locomotives

## Characteristics of Typical Passenger Locomotives

| Type | Nominal HP | Maximum Rail HP | Total Weight Engine and Tender lbs | Weight on Drivers lbs | Weight lbs per Nominal HP | Weight lbs per Max. Rail HP | Lbs on Drivers per Max. Rail HP | Maximum Tractive Effort lbs | Continuous Tractive Effort lbs | Speed at Cont. T.E. MPH |
|---|---|---|---|---|---|---|---|---|---|---|
| Reciprocating Steam 4-6-2 | 4,200 | 3,700 | 565,000 | 217,000 | 134 | 152 | 59 | 45,000 | — | — |
| Reciprocating Steam 4-6-4 | 4,700 | 4,200 | 675,000 | 202,000 | 143 | 160 | 48 | 43,500 | — | — |
| Reciprocating Steam 4-8-2 | 4,600 | 4,100 | 775,000 | 271,000 | 168 | 189 | 66 | 64,550 | — | — |
| Reciprocating Steam 4-8-4 | 6,500 | 5,800 | 891,000 | 275,000 | 137 | 153 | 47 | 69,000 | — | — |
| Reciprocating Steam 4-4-4-4 | 6,600 | 6,000 | 930,000 | 268,000 | 141 | 155 | 45 | 64,650 | — | — |
| Geared Steam Turbine 6-8-6 | 6,900 | 6,500 | 1,004,000 | 260,000 | 146 | 155 | 40 | 70,500 | — | — |
| Steam Turbine Electric 4-8-4-8-4 | 6,000 | 5,100 | 1,194,800 | 538,000 | 199 | 234 | 105 | 98,000 | 48,000 | 40.0 |
| Diesel Electric 0-6-6-0 | 2,000 | 1,660 | 335,000 | 232,000 | 168 | 199 | 137 | 58,000 | 26,300 | 23.6 |
| Diesel Electric 4-8-8-4 | 3,000 | 2,490 | 595,000 | 410,000 | 198 | 241 | 165 | 102,500 | 52,600 | 17.5 |
| Diesel Electric 2 units (0-6-6-0) | 4,000 | 3,320 | 670,000 | 464,000 | 168 | 199 | 137 | 116,000 | 52,600 | 23.6 |
| Diesel Electric 2 units (4-8-8-4) | 6,000 | 4,980 | 1,190,000 | 820,000 | 198 | 241 | 165 | 205,000 | 105,200 | 17.5 |
| Diesel Electric 3 units (0-6-6-0) | 6,000 | 4,980 | 1,005,000 | 696,000 | 168 | 199 | 137 | 174,000 | 78,900 | 23.6 |
| Electric 4-6-6-4 | 4,800 | 8,500 | 477,000 | 303,000 | 99 | 56 | 36 | 75,000 | 25,700 | 70.0 |
| Electric 4-8-4 | 5,000 | 7,500 | 404,000 | 240,000 | 81 | 54 | 32 | 60,000 | 26,750 | 70.0 |

# Characteristics of Typical Freight Locomotives

| Type | Nominal HP | Maximum Rail HP | Total Weight Engine and Tender lbs | Weight on Drivers lbs | Weight lbs per Nominal HP | Weight lbs per Max. Rail HP | Lbs on Drivers per Max. Rail HP | Maximum Tractive Effort lbs | Continuous Tractive Effort lbs | Speed at Cont. T.E. MPH |
|---|---|---|---|---|---|---|---|---|---|---|
| Reciprocating Steam 4-8-2 | 5,400 | 4,800 | 777,000 | 266,000 | 144 | 162 | 56 | 60,000 | — | — |
| Reciprocating Steam 4-8-4 | 6,500 | 5,800 | 891,000 | 275,000 | 137 | 153 | 47 | 69,000 | — | — |
| Reciprocating Steam 2-10-4 | 7,000 | 6,200 | 987,000 | 380,000 | 141 | 159 | 61 | 95,000 | — | — |
| Reciprocating Steam 4-4-6-4 | 7,900 | 6,800 | 1,053,000 | 388,000 | 133 | 155 | 57 | 101,000 | — | — |
| Reciprocating Steam 2-6-6-4 | 7,100 | 6,300 | 949,000 | 430,000 | 133 | 151 | 69 | 107,000 | — | — |
| *Geared Steam Turbine 4-8-4-8 | 8,500 | 8,000 | 960,000 | 560,000 | 113 | 120 | 70 | 140,000 | — | — |
| *Steam Turbine Electric (2 units) | 6,000 | 5,100 | 1,236,000 | 960,000 | 207 | 243 | 188 | 240,000 | 160,000 | 11.5 |
| Diesel Electric 0-4-4-0 | 2,000 | 1,660 | 250,000 | 250,000 | 125 | 151 | 151 | 62,500 | 42,800 | 14.5 |
| Diesel Electric 2 units (0-4-4-0) | 3,000 | 2,490 | 460,000 | 460,000 | 153 | 185 | 185 | 115,000 | 85,600 | 10.9 |
| Diesel Electric 2 units (0-4-4-0) | 4,000 | 3,320 | 500,000 | 500,000 | 125 | 151 | 151 | 125,000 | 85,600 | 14.5 |
| Diesel Electric 3 units (0-4-4-0) | 4,500 | 3,735 | 690,000 | 690,000 | 153 | 185 | 185 | 172,500 | 128,400 | 10.9 |
| Diesel Electric 3 units (0-4-4-0) | 6,000 | 4,980 | 750,000 | 750,000 | 125 | 151 | 151 | 187,500 | 128,400 | 14.5 |
| Diesel Electric 4 units (0-4-4-0) | 6,000 | 4,980 | 920,000 | 920,000 | 153 | 185 | 185 | 230,000 | 171,200 | 10.9 |
| Electric 4-6-6-4 | 4,780 | 8,500 | 492,000 | 360,000 | 103 | 58 | 42 | 90,000 | 46,000 | 39.0 |
| *Electric 4-4-4-4-4-4-4-4 | 7,500 | 10,000 | 720,000 | 720,000 | 96 | 72 | 72 | 180,000 | 86,500 | 32.5 |

*Based on Designs.

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