but Mr. Bowie's indicated value of C will be used for the second comparative example.

$$Q = C\sqrt{\frac{P}{Le}}$$

where

Q = Quantity of oil in barrels per hour;
C = Constant;
P = Initial pump pressure in pounds per square inch;
L = Length of line;
e = Factor dependent upon the size of the pipe used (for 8-in. pipe is 1).

For 16° Bé., C is 160. P is then 39 lb. per sq.in. per mi.

It should be remembered that this value is the pressure on the pumps. In the first mile out from the station the pressure of the oil may not be more than that of water, but the last mile may be several times that of water, due to the cooling of the oil. The formula gives an integrated value of 39 lb. per sq.in. per mi. for a line 13.1 mi. long. In practice it may be necessary to space the stations all the way from, say, 5 mi. to 25 mi. apart, depending upon the character of the country. The viscosity of the oils testing 17° Bé. and lower is very erratic; and it has been impossible, as far as the writer knows, to obtain an assignable measure of the friction characteristics on any laboratory instrument. The permissible average pressure on a station of 13.1 mi. is 800 lb. divided by 13.1, or 61 lb. The line would have a safety factor of $\frac{61}{25}$, or 2.44. Using the derived value of 39 lb., there would be required a factor of safety of $\frac{61}{39}$, or 1.56.

By the experiments of the writer it had been concluded that the 25° Bé. oil gives a value practically the same as water, which is borne out by comparing the value of C as given by the formula of Mr. Bowie.

The following data are from the Valley pipe line (Shell Co.), recently constructed (*Journal of Electricity, Power and Gas*, September, 1915):

Cost, about $4,000,000.
Length, 170 mi.
Two-thirds of the pipe is of 8-in. diameter.
One-third of the pipe is of 10-in. diameter.
Capacity is 25,000 bbl. per 24 hr. of 16° Bé. oil.
Stations, 15½ mi. apart.

Let it be assumed that the water pressure for 24,000 bbl. per day is 25 lb. per sq.in. per mi. for 8-in. pipe and the pressure for the 10-in. is one-third of that value, or 8⅓ lb. per sq.in. The average pressure then is 19.5 lb. per sq.in. instead of 25 lb. The permissible pressure is 800 lb. at the pumps. The pressure is 51.6 lb. per sq.in. per mi. The factor of safety is $\frac{51.6}{19.5}$, or 2.65.

The important feature as pointed out in this recently constructed line is that, as custom had established the distance between stations as about 13 mi., an improvement had been made by increasing the distance to 15½ mi., offsetting the increased pressure due to the added cooling of the oil and resulting increase in pressure due to viscosity, and saving one pumping station. The saving is estimated at $250,000 in the first cost, as the difference between the $300,000 station and $50,000—the latter being the difference in cost between the 8-in. and 10-in. pipe. This factor of safety can be estimated in dollars. In the foregoing example, to pump water only would require five stations. Then it has required, to take care of the safety factor, six stations aggregating $1,800,000. There is then $1,800,000 out of the total of $4,000,000 which is left to the judgment of the engineer for distribution and expenditure with indefinite data as a basis for the designs, granting that there is no reliable way by which the friction characteristics of the oil to be handled can be accurately measured.

For the summary we have:

Rifled Line:	
Capacity, 24,000 bbl., including 10% water, stations 12 mi. apart.	
Safety factor, by allowable station pressure	2.50
Safety factor by formula, as necessary	2.56
Associated Line (by Mr. Bowie):	
Capacity, 24,000 bbl.	
Safety factor by allowable station pressure	2.44
Safety factor by formula, as necessary	1.56
Difference	0.88
Shell Line:	
Capacity, 24,000 bbl.	
Safety factor of construction	2.60

After considering the improved method of the Shell Co. with reference to the combination of the 8- and 10-in. pipe the engineer no doubt will ask: If it may be considered good practice to increase the length between stations from 14.17 mi. to 15.45 mi. in a line 170 mi. long and in so doing save $250,000, why not increase this distance another 1½ mi. and save a like amount or thereabouts?

The question is likely to remain unanswered until the friction characteristics of the oil that is to be handled are better understood by those to whom the work of constructing and operating the line is intrusted.

Pipe lines, and particularly those which are heated, deteriorate very rapidly. It has been said that the life of the pipe line should be considered as 10 yr. These lines sooner or later, and some of them in the near future, must be completely or in part reconstructed. Again, the demand for capacity on the pipe lines is going to increase rather than decrease.

The oil industry has been allowed to develop with those in charge of the operations little appreciating the value of using the friction characteristics of the oil rather than the gravity, in the solution of their transportation problems, for no other reason than the absence of a better system of grading the oils. Inasmuch as it has been stated that the capacity of a line is determined by its weakest point, the proper grading of the oils for minimum friction qualities will eliminate the peaks of high pressure and cannot help but improve operating conditions.

Electric Traction a Success on C., M. & St. P. Ry.*

The first electric locomotives of the Chicago, Milwaukee & St. Paul Ry. were placed in service on the Three Forks-Deer Lodge division in the Rocky Mountains, Dec. 9, 1915, and electric operation has been maintained since then. Complete success of the new system is reported by the railway officials. In April of this year service was extended to Harlowton, making a total of 220 mi. of electrically operated line. By November, 1916, it is expected that steam traction will be abandoned over the

*From information furnished by the General Electric Co., Schenectady, N. Y., maker of the electrical equipment noted herein.

entire proposed stretch of 440 mi. between Avery, Idaho, and Harlowton, Mont. (four engine divisions). The general engineering features in connection with this project have been described in *Engineering News* (Jan 7, 1915).

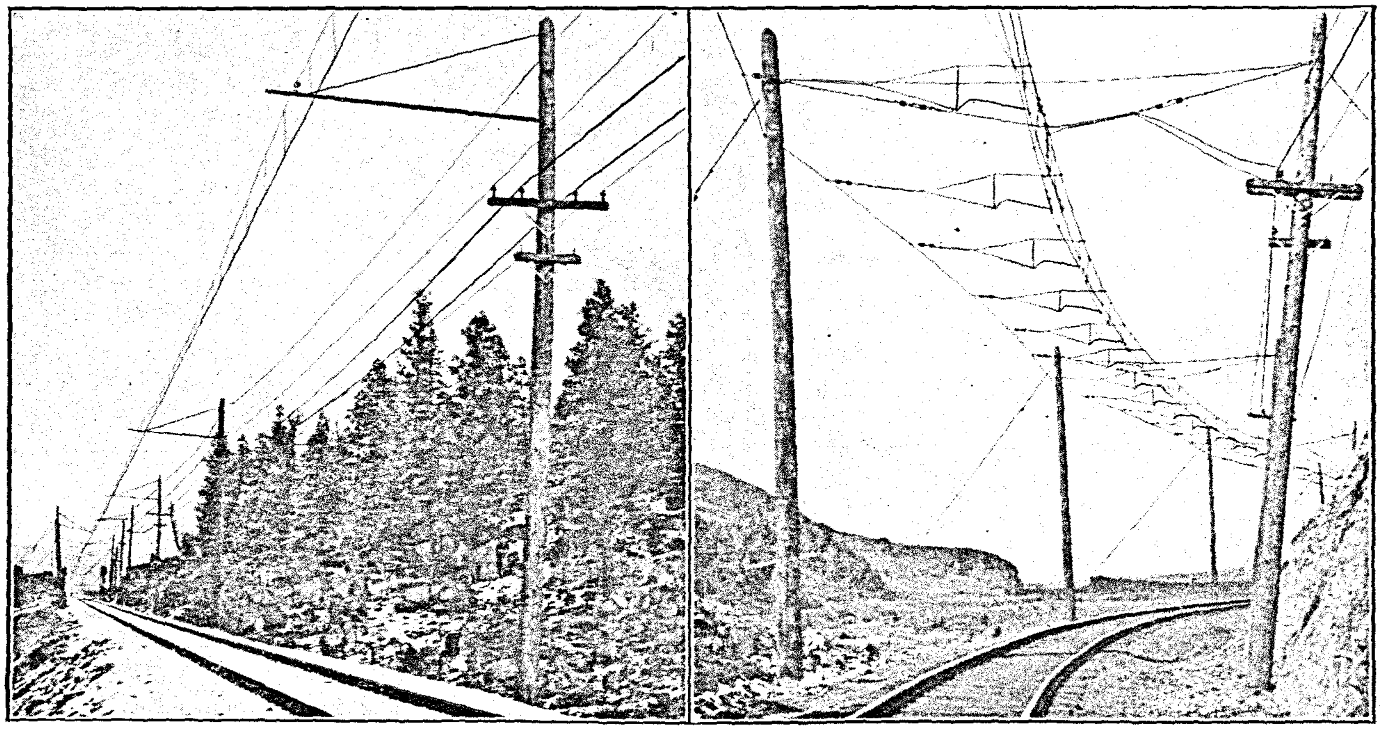
This section is now the longest stretch of trunk line under electric traction in the world. It is the only line where electric locomotives are operating over more than one engine division. The main continental divide is crossed, giving the severest service conditions possible on the entire system of the railroad. In crossing the three mountain ranges included in the electric zone there are several grades of 1% or more, the most difficult of which is the 21-mi. 2% grade between Piedmont and Donald. The longest grade is the 49-mi. 1% grade on the west slope of the Belt Mountains. The curvature is heavy, the maximum being 10°. There are in all 36 tunnels, the longest of which (1½ mi.) is under St. Paul Pass, through the Bitter Root Mountains.

Passenger and Freight Service

The passenger service is comparatively light, consisting of two all-steel transcontinental and one local train in each direction daily. It has been found that on the 21-mi. 2% grade between Piedmont and Donald the electric locomotive can reduce the running time from 1 hr. 5 min. to 40 min. The run from Deer Lodge to Butte has been cut from 1 hr. 20 min. to 50 min. The four through passenger trains (the "Olympian" and the "Columbian") are taken across the two mountain ranges by a single passenger locomotive. These trains consist of eight vestibuled steel coaches weighing 660 tons. Instead of changing locomotives at Three Forks as before, the same locomotive is run through the 220 mi. from Deer Lodge to Harlowton, changing crews midway. The entire electrified division will be covered by passenger trains in approximately 15 hr., including all stops, increasing the attractions of the line for tourists. The local passenger train in the electric zone is handled by a half-unit locomotive.

A large part of the freight traffic consists of through trains made up of an assortment of foreign cars weighing from 11 to 25 tons empty and 70 tons loaded. These are equipped with air brakes variously adjusted for different conditions of service, making the problem of holding long trains on heavy downgrades difficult with air alone. But with the electric locomotives regenerative braking has been resorted to with general success—the locomotive motors become generators and return power to the line, the air brakes being released and held in reserve.

In the freight service on the first division, where steam locomotives require 10 to 12 hr. to make 115 mi., the electric locomotives need a schedule of only 7 to 8 hr. for the same distance. The heavy grades and curves have always offered a serious obstacle to steam-locomotive operation even in summer time, and in winter serious delays have occurred owing to engine failures. In December, 1915, several Mallets were frozen up at different points on the system, and the new electric equipment was rapidly pressed into service to replace them. On several occasions the electric locomotives hauled in disabled steam engines and trains that would have otherwise tied up the line and interrupted the service.



FIGS. 1 AND 2. OVERHEAD 3,000-VOLT LINE CONSTRUCTION, ELECTRIC-TRACTION ZONE, C., M. & ST. P. RY.
Fig. 1—Tangent bracket construction. Fig. 2—Cross-span, pull-off and feeder-tap construction on a 10° curve

Power-Supply System

Trains of 3,000 tons trailing load have been hauled east and 2,800 tons west, using a helper on the heavy grades. All passing tracks are being lengthened to take advantage of longer trains, which are now possible with electric traction. On some runs, where the grades are less than 1%, trains of up to 130 cars and as heavy as 4,000 tons have been hauled by a single unit.

It should be mentioned in passing that the scheme of electrification includes the generation of power at several hydro-electric stations of the Montana Power Co., its transmission by 100,000-volt three-phase 60-cycle current, its conversion in substations to 3,000-volt direct current and its distribution over catenary overhead construction to the electric locomotives. The power company's transmission lines are carried on steel-tower and wooden-pole lines and tap into the railway system at seven different points. The railway company has a transmission line extending the entire length of the system on wooden poles. Each substation may be fed from either direction and also at the tie-in points from a third source of power. There are 14 substations distributed along the route at average intervals of about 32 mi. Each station contains stepdown transformers, motor-generator sets, switchboard and necessary equipment. The 100,000-volt current is first stepped down to 2,300 volts for the synchronous motors, each of which drives two 1,500-volt direct-current generators connected permanently in series.

The overhead construction is comparatively simple. There are two No. 0000 copper wires, flexibly suspended side by side from the same steel messenger cable by independent hangers alternately connected to each wire. Bracket supports are used where the track alignment will permit; cross-span construction is used on passing tracks, switching yards and sharp curves. All the overhead work is supported on 40-ft. wooden poles suitably guyed. A 500,000-circ.mil feeder runs the entire length of the electric zone, and on heavy grades there is a supplementary feeder. The feeders are tapped to the trolley wire at every seventh pole, or approximately each 1,000 ft. On the top of the poles is carried a supplementary No. 0000 negative feeder, which is tapped to the middle point of every second reactance bond (coils placed in the track 5,000 to 6,000 ft. apart, bridging insulated joints in the rails and permitting direct current to pass, but impeding 60-cycle signal currents). Each track is bonded with a 250,000-circ.mil bond at each joint and double bonded on heavier grades to prevent excessive drop in voltage.

Two types of locomotives have been developed—main-line and switching. The main-line locomotives are constructed in two half-units intended to be permanently coupled together; but the halves are duplicates and each is capable of independent operation. The only difference

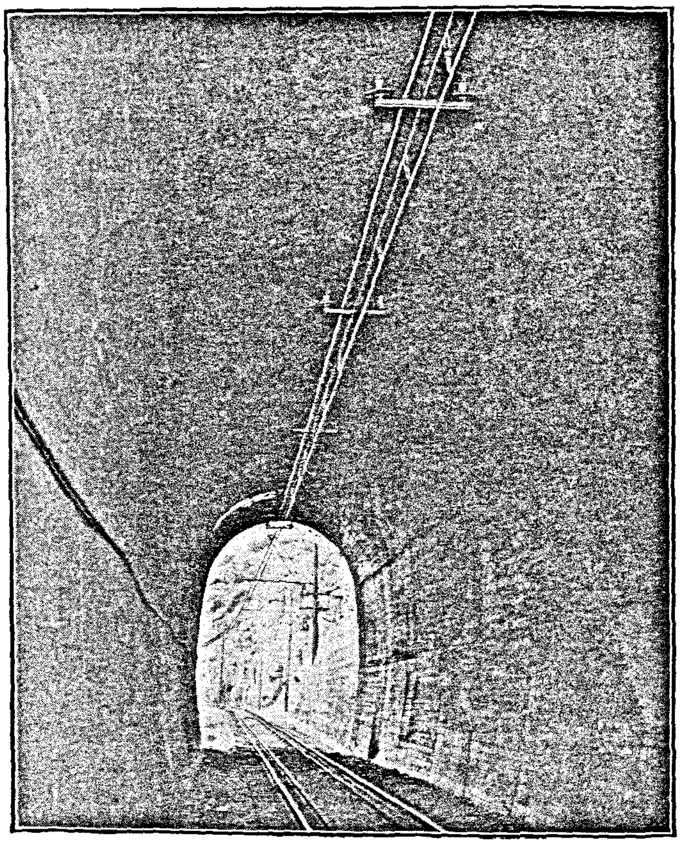


FIG. 3. OVERHEAD CONSTRUCTION IN TUNNELS
Collapsing hangers give flexibility

between passenger and freight units lies in their gear ratios and minor auxiliaries. The freight locomotive

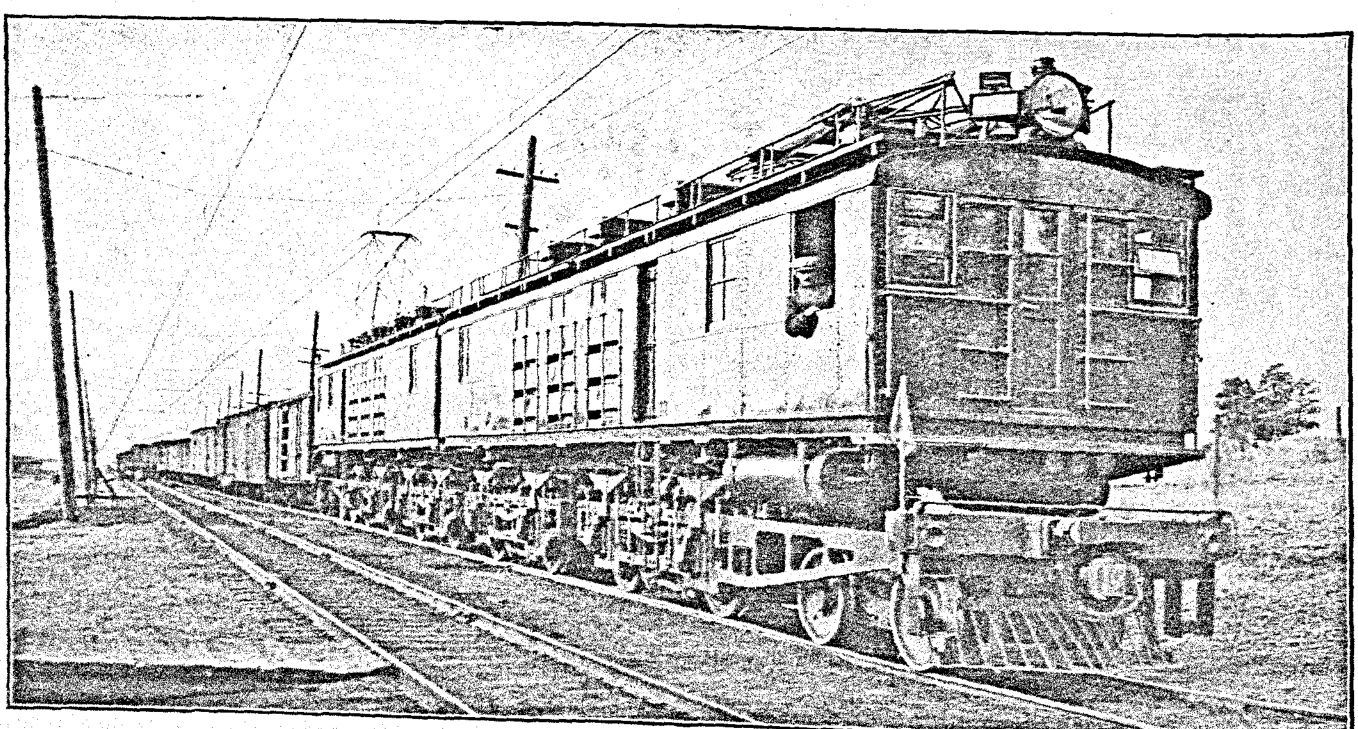


FIG. 4. ONE OF THE 3,000-HP. ELECTRIC LOCOMOTIVES OF THE C., M. & ST. P. RY.

DATA ON C., M. & ST. P. RY. 3,000-VOLT ELECTRIC LOCOMOTIVES

Main-Line Freight Locomotives

Length overall	112 ft.
Total wheel base	102 ft. 8 in.
Rigid wheel base	10 ft. 6 in.
Total weight	564,000 lb.
Weight on drivers	448,000 lb.
Weight per driving axle	56,000 lb.
Weight per guiding axle	29,000 lb.
Diameter of driving wheel	52 in.
Diameter of guiding wheel	36 in.
Number of driving motors	8
Total output (continuous rating)	3,000 hp.
Total output (1-hr. rating)	3,440 hp.
Tractive effort (continuous rating, 15.75 mi. per hr.)	71,000 lb.
Per cent. of weight on drivers (trac. coef.)	15.83
Tractive effort (1-hr. rating, 15.25 mi. per hr.)	85,000 lb.
Per cent. of weight upon drivers (trac. coef.)	19
Tractive effort starting (30% coef.)	136,000 lb.

Switching Locomotives

Length inside knuckles	40 ft.
Height over cab	13 ft. 10 in.
Height—trolley down	16 ft. 8 in.
Width overall	10 ft.
Total wheel base	29 ft. 4 in.
Rigid wheel base	8 ft.
Diameter of wheels	40 in.
Weight—locomotive complete	140,000 lb.
Weight per driving axle	35,000 lb.
1-hr. rating of locomotive	542 hp.
Tractive effort (1-hr. rating, 12 mi. per hr.)	18,400 lb.
Tractive effort (continuous, 13.2 mi. per hr.)	13,480 lb.
Tractive effort, starting (30% coef.)	42,000 lb.

weighs 282 tons, has a starting tractive effort of 136,000 lb. and 85,000 lb. running at normal speed. These figures are to be compared with a weight of 278 tons for the Mallet steam locomotives, which have been relieved and which had a tractive effort of 76,200 lb. At this time 42 main-line units are in service—30 freight and 12 passenger. Each is equipped with eight 1,500-volt motors insulated for 3,000 volts to ground. The motors' normal 1-hr. rating is 430 hp.; the continuous rating is 375 hp. Each motor is twin-geared to its driving axle. The motor has commutating poles and provision for forced ventilation from a blower in the cab. The pantograph shoes are of copper.

The control equipment is of the familiar multiple-unit type; the main control switches are mounted in steel compartments inside the cab with inspection and repair aisles. In each half of the locomotive are a motor-driven air compressor and a motor-generator set furnishing low-voltage current for control circuits, headlights, cab lighting and for charging storage batteries on passenger coaches. (Under steam operation the charging current for these batteries was furnished by a steam-turbine generator set on the locomotive.) This same motor-generator set drives the blower for ventilating the traction motors. On the passenger locomotives are oil-fired steam boilers for heating the cars.

The electric regenerative-braking apparatus automatically controls the speed by regulating the amount of energy put back into the line. The usual speed of a freight train electrically hauled is 15 mi. per hr. ascending, and 17 mi. per hr. descending maximum grades, but with half these speeds the braking can be maintained if required. In case there are no other trains between substations to absorb the power returned to the line by a descending train, this power passes through the substation machinery, is converted from direct to alternating current and fed into the distribution system of the power company. Credit is given for all energy thus returned. The power returned by a 2,500-ton train, running at 17 mi. per hr. down a 2% grade, is about 4,700 hp. In addition to the elimination of difficulties due to the use of air brakes and the prevention of brake-shoe and wheel wear there has been a saving of about 15% in power.

This change from steam to electric traction will cost about $12,000,000. The investment is expected to be self-supporting, through savings in operating expense. C. S. Goodnow, Assistant to the President of the Chicago, Milwaukee & St. Paul Ry., is engineer in charge of the work.

Inspecting Bituminous Road Materials at Refineries

The Bureau of Highways of Philadelphia, Penn., of which William H. Connell is chief, has for over a year been extending its inspection service to the plants and refineries where the materials to be used in bituminous roadwork are manufactured. In his recent annual report on the work of the bureau Mr. Connell states that while it has been customary with many organizations dealing with highway work to inspect or test batches of completed materials at refineries to determine in advance of shipment that they conform satisfactorily to the requirements of specifications, the work of this bureau has made an important step in advance of this by specifying that an inspector should be present during the entire process of producing and combining the materials used, thus making it possible to secure samples of the ingredients as well as of the completed mixture and to determine the method and proportions of combination.

These inspectors made such tests at the plant or refinery as were necessary to control the general character and the consistency of the products, while complete tests on both the ingredients and mixtures were made in the municipal laboratories. It is possible by this means for the city to make complete studies of the desirable properties of such materials and of the variations that should be made in the finished product to suit local conditions rather than to leave these points almost entirely in the hands of the manufacturer, as has largely been the case in the past.

A Ten-Story Building as a Bridge Approach is to be erected by the City of New York on Blackwell's Island, adjoining the Queensboro Bridge. A number of the city institutions are located on the island, approach to which has hitherto been only by boat, although the large bridge crosses the island some 140 ft. in the air. The new building will house some of the necessary institutional services and will contain freight elevators capable of carrying a 5-ton motor truck from the island to the bridge level. Boat service to the island will then be discontinued.

Powdered Coal as Fuel for Locomotives was first tried as long ago as 1901-02, on an engine of the Manhattan elevated railway in New York. The merit of this system of combustion was demonstrated, but its use was not extended, as the means of pulverizing and handling the fuel and controlling the fire were unsatisfactory. In 1914 the New York Central R.R. equipped an engine of the 4 : 6 : 0 class for experimental work. In 1915 the Chicago & Northwestern Ry. equipped a passenger engine of the 4 : 6 : 2 class, which is now in regular service between Chicago and Milwaukee. Early in 1916 the Delaware & Hudson Ry. adopted pulverized fuel for a 145-ton freight engine of the 2 : 8 : 0 class, and installed a plant for drying, pulverizing, storing and supplying the fuel both for locomotives and for stationary boilers, using the waste tailings from anthracite culm banks. The Missouri, Kansas & Texas Ry. is installing a similar plant to supply pulverized coal for both locomotives and stationary boilers. A number of other railways are considering the matter, and the Central Railway of Brazil has decided to adopt the method, after extensive investigation of the work and experience in the United States. This information is taken from a report presented at the annual meeting of the International Railway Fuel Association, held at Chicago, May 15-18. The committee is of opinion that the efficiency of the system has been demonstrated and that there will be marked progress in its use with bituminous and anthracite coals and lignite for locomotives and stationary power plants.