Serial Report

ELECTRIFICATION OF STEAM RAILROADS COMMITTEE

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ELECTRIFICATION OF STEAM RAILROADS COMMITTEE—1927-1928

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ELECTRIFICATION OF STEAM RAILROADS

The Committee on Electrification of Steam Railroads has continued its activities through the past year in conformity with the program adopted in 1926 and stated in last year's report as follows:

1. To study railroad electrification in a general way, avoiding technical details.
2. To analyze railroad electrifications already made and to develop the fundamental reasons for, and the results of, these electrifications.
3. To promote cooperation between the executives of railway and power companies in order to develop a clearer understanding of each other's problems and requirements in connection with railroad electrification.

It was recognized at the outset that this program would require a number of years for its development and completion. During the last year the Committee succeeded in getting its work better organized and made real progress in the development of its program. The three principal items of accomplishment this year are: (1) the employment of a secretary, (2) the extension of the statistical studies, and (3) a special report on one of the outstanding railroad electrifications of this country made by an independent investigator.

Employment of a Secretary

When the program of the Committee was definitely decided upon it was realized that the work must be continually prosecuted without any lapses and that it would be necessary to arrange for some one to devote practically all of his time to making the requisite studies. It was finally decided to employ a permanent secretary and establish a regular office from which to conduct the Committee's work. The Committee was fortunate in securing the services of Horace H. Field, who has had many years' experience in the electrical and public utility industries, including a great deal of economic research and involved statistical studies. During the last ten years most of his time has been used in research for various committees of the National Electric Light Association so that he is well-known to many of the members.

The secretary's office is established in Chicago at the same address as the Chairman, which is conducive to keeping all branches of the work in proper harmony. The new arrangement will enable the Committee to render continuous and effective work throughout the year and permit the broadening of its activities on a scope that would otherwise be impossible in following the development of electrification all over the world.

It is the intention of the Committee to make its office a collecting point for all valuable information in regard to electrification. It should become, in time, one of the principal depositories for complete and authentic general information on the subject. The information collected will be kept readily available for the use of both railroad and public utility industries and for others who are properly interested in such research.

Extension of Statistical Studies

Two editions of the 1927 report of this Committee have been printed. The report was given wide circulation in both railroad and power industries. Copies were mailed to the presidents of all important railroads in this country and to all electrified railroads in foreign countries with request for comment and suggestions. Many replies have been received expressing approval and offering cooperation, also requesting copies for associates. The statistical tables developed for the report in particular have been the subject for comment, as was hoped by the Committee.

The Condensed Analysis of Railroad Electrifications (Table I), which appeared in last year's report for the first time, has been considerably amplified by the addition of more roads and mileage. This table was originally compiled through the medium of technical publications covering the 33 years of history of electrification. During the last year a great deal of additional information has been accumulated and work begun on securing such information directly from the railroads. The information regarding United States railroads has all been submitted by the railroads themselves. This is also true of some of the foreign roads, although considerable dependence has been placed on other statistical sources for foreign information. Ultimately the statistics developed by this Committee will all represent original data secured directly from the proper parties.

A new table is submitted in this year's report entitled "Physical Characteristics of Operation on Electrified Sections of Steam Railroads" (Table II). This table is complete for the United States and Canada. All of the American railroads replied to requests for this information. Replies from abroad are being gradually received, and those on file have been tabulated. The 1929 report should be nearly complete for all countries of the world with authentic information supplied by the railroads themselves.

Special Report on Electrified Road

It is the intention of the Committee to submit each year some special analysis or investigation of one of the outstanding types of railroad electrification. For this year's report The Virginian Railway was chosen on account of the popular interest which attaches to heavy tonnage operation.

As it was desired particularly to have the views of an independent investigator who had not been connected with this project, a railroad executive from another part of the country was selected. F. L. Johnson, of the Chicago, Burlington & Quincy Railroad, kindly consented to examine and report on the operations of The Virginian Railway. Mr. Johnson has the background of 50 years of operating and executive experience on one of the largest and most efficient railroad systems of the Middle West. He spent a week examining the electric and steam operating divisions of the railroad, accompanied by a small group from the Committee. Mr. Johnson's report is submitted as an appendix and represents entirely his views and conclusions.

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Recent Progress of Electrification

The history of electrification from 1895 to 1927 was well covered in last year's report to which reference is made for details.

The past year has seen an extension of electrification in the United States, most of the larger European countries, South America, Australia, India and Japan. Initial installations are being made in some of the smaller countries like Costa Rica, Czechoslovakia and Siam. Several of the European countries are at work on programs for electrification which will take years to complete but on which substantial progress is recorded every year.

Foreign Countries

In Great Britain electrification is still confined for the most part to suburban passenger traffic. No through service has been electrified as yet but extensions of the suburban systems are constantly being made. In Holland considerable additional track has been electrified for passenger service only. Sweden recently completed electrification of one long line for general traffic purposes.

France, Germany, Switzerland and Italy continue to extend electrification to new sections. At the end of 1927 Germany had 750 miles of road electrified and was proceeding with 185 miles more. Switzerland had 1250 miles of standard gage routes electrified and 150 more miles scheduled for 1928. Italy had about 750 miles of electrified routes in 1927 with 200 miles scheduled for completion in 1928 and expectation of about 1400 miles by the end of 1930.

Lines operating into Warsaw, Poland, and Prague, Czechoslovakia, are being electrified and may be in operation by the time this report is printed. Three new standard gage lines are projected between France and Spain across the Pyrenees. Some of the work is now under way, and it is reported that two of the lines (at least) will be electrified. Several of the smaller European countries are reported to be making studies of electrification, particularly in the vicinity of their capitals or largest cities.

The Indian Government is working on ambitious plans for electrification of a large amount of the principal lines in that country. Two railroads are already operating by electric power in the vicinity of Bombay, the first going into service in 1925 and the second in 1928. Both these roads plan to keep on extending their electrified sections for several years.

In Central and South America, there have been several extensions of electrification. The Mexican Railway Company has extended its electrification. The Paulista Railway of Brazil has extended also, and the Western Minas Railway has ordered its first electrical equipment. The Transandine Railways in Chile and Argentina, which are operated as a unit, are electrifying and the Chilean section has been completed.

In Canada, the Canadian National Railways have announced that they will build a new terminal at Montreal and use electric traction in the city.

United States

In 1927 the Milwaukee Railroad completed the extension of its electrification from Black River to Seattle. This extension was about 10 miles of double track, and brought the total length of track electrified up to 878 miles.

The Illinois Central Railroad completed in 1927 the first full calendar year of electrical operation on its Chicago suburban service. Electrical operation began in August, 1926. The last steam schedule was for 396 trains per day. The number has been gradually increased up to 566 trains on week days in April, 1928. Express service has been added on some lines and more frequent service to most stations. The running time of the different services has been shortened by 11 to 28 per cent. The response of patronage showed about 19 per cent more rides in 1927 than in 1926.

The Virginian Railway also completed its first calendar year of electrification in 1927. The first short section of electrification was placed in operation in September, 1925, but the entire electric zone was not in service until September, 1926. Operation on The Virginian is treated in an appendix to this report. It is sufficient to state here that officials of the road express satisfaction with the new motive power which has greatly facilitated their movement of heavy tonnage trains over mountain grades.

The Pennsylvania Railroad is engaged in a large electrification project at Philadelphia. A new passenger station for through traffic is being built on the west side of the Schuylkill River. An underground station for suburban traffic is being built in the heart of the city near the old Broad Street Station. All operation into the underground station will be electric, and the electric trains will connect the two new stations with each other through a four-track subway. Two suburban services to Chestnut Hill and Paoli have been electrified for several years. Two additional suburban routes are now in process of electrification and are expected to be completed in 1928. One line extends to Chester and Wilmington, 28 miles south of Philadelphia. Electric operation on this line is scheduled to begin about the middle of the year. The other line extends westward from Philadelphia to West Chester via Media, a distance of 27 miles. This electrification is expected to be ready by early autumn.

The Great Northern Railway, on May 1, 1928, holed through its new Cascade Tunnel. This tunnel was described by President Ralph Budd in an appendix to this Committee's 1927 report. The tunnel is nearly eight miles long and the longest in the Americas. It is within the Great Northern's electric zone and will be equipped for 11,000-volt overhead contact like the old tunnel which it replaces. The old tunnel was originally electrified by itself in 1909 with three-phase alternating current. This was changed in 1927 to the present single-phase system in anticipation of establishing an electrified division extending about 75 miles. It is expected that the new tunnel and approaches will be ready for service in the fall of 1928.

The Reading Company has been engaged for some time in drafting plans for the electrification of its Philadelphia suburban service.

The Boston, Revere Beach and Lynn Railroad has announced that it will electrify. This is a high-speed, narrow-gage road carrying suburban traffic between East Boston and its terminals at Winthrop and Lynn, Mass.

The Detroit, Toledo and Ironton Railroad has been operating by electricity over 18 miles of its route between Fordson and Flat Rock, Mich. Electrification is now being extended a distance of 27 miles from Flat Rock to Petersburg Junction.

During April, 1928, the Delaware, Lackawanna and Western Railroad announced plans for electrification of its New York suburban service. The electrification will follow the main line from Hoboken to Dover (via Newark and Summit) with two branches to Montclair and Gladstone. The total mileage is said to be 78 miles of route and 173 miles of track. Detailed specifications have not been announced but it is estimated that construction will be completed in about two years.

This project has an interesting and rather unusual feature in the support being given by the communities affected. Representatives of civic organizations in all these communities, with a population around 1,250,000, presented a petition to the railroad asking for electrification and pledging cooperation with the railroad in securing an advance of commutation fares to support the improvement of transportation facilities.

The Cleveland Union Terminals Company, which is constructing a new union station in Cleveland, Ohio, has ordered 20 electric locomotives for use in 1930. The locomotives will weigh 200 tons each and operate on 3000 volts direct current.

Systems of Electrification

There are many systems of electrification in use at various places throughout the world as shown by the tables accompanying this report. The various systems were tabulated in a supplementary table last year. Although this year's report lists many more railroads, there are no new systems of electrification to report.

Some countries have taken definite steps to standardize on a system for all future work and in certain cases have gone so far as to rebuild previous electrifications to conform with the new standard. In general it may be said that the central European and Scandinavian countries favor low-frequency alternating current at a high voltage. The standard system in these countries uses single-phase energy at 16-2/3 cycles with 15,000 volts at the trolley wire. A secondary standard is used in Germany for suburban service with direct current at 800 volts.

England and the western countries of Europe are using direct current at voltages from 600 to 1500, with third rail for suburban lines and overhead trolley for the longer lines. The English colonies are following the lead of the home country, as also are those railroads in South America which look to England for their technical advice.

Italy has had a long experience with the use of three-phase energy at 3300 volts and is proceeding with the general electrification of long distance lines on this basis. It is interesting to note that experimental installations are being made with high-voltage direct current and higher voltages for three-phase.

In a report to the Second World Power Conference in 1926 Monsieur H. Parodi of the Paris-Orleans Railway gives his view of the adoption of standard systems in Europe. He states that the two general choices of system have grown up around different and distinct conceptions of the relationship which will be carried out in the future between the railroad and power industries. France, England, Belgium, Holland, Japan, South America, Africa, India and Australia have followed the policy of utilizing the power stations producing three-phase current for industry and of distributing the power for railroads and industries through a single system of high-tension lines. Germany, Switzerland, Austria, Norway and Sweden have followed the policy of creating two separate systems of generation and transmission for industrial power and for transportation, the railroad power system being single-phase with a frequency of 16-2/3 cycles while the general power system is three-phase and 50 cycles. He notes that the countries in which the railroads are privately owned have paid most attention to the general interests of the country, while the countries where the railroads are government owned have neglected the advantages which might accrue from a single, unified or interconnected, power-supply system.

In the United States, of course, conditions are quite different from most of the European countries. Electrification has been adopted here for specific purposes in widely separated parts of the country. Each railroad has attempted to employ the system best adapted to its own particular problem. The results have been generally satisfactory with whatever system has been adopted, as is testified by the operators in each case.

There has not yet developed a general need for standardization on account of the overlapping of the various installations or of the necessity for interchanging equipment. This has resulted in the United States retaining an important position as a proving ground for all the best and latest improvements in electrification. Both direct current and alternating current are being extensively used and the voltages vary from ordinary street-car practice up to 22,000 volts.

In the last 20 years there have been developed a number of locomotives of quite different characteristics, yet having a certain amount of interchangeability. The New York, New Haven & Hartford Railroad started the interchangeable feature, in 1907, when it made its locomotives and motor cars adaptable to either 11,000 volts single-phase or 600 volts direct current. Since then all single-phase electrifications in this country have been made at 11,000 volts and 25 cycles, except one at 22,000 volts, so that most of the single-phase equipment can run on any of the different lines. The locomotives that have been built for 22,000 volts can be used with 11,000 volts, and some intended for original operation at 11,000 are also capable of running on 22,000 volts. Among the equipment which can be used on any existing 11,000 volt system are the New Haven locomotives with series motors, the New Haven locomotives with motor-generator sets, the Norfolk and Western locomotives with induction motors, the Virginian locomotives with induction motors, the Great Northern locomotives with motor-generator sets, and the Detroit, Toledo & Ironton locomotives with motor-generator sets.

Thus there are in this country five widely separated roads performing entirely different services with locomotives of special type developed for their individual needs but which could, if required, operate over the same electrified system. Taking power in similar form, they have the separate advantages of single-phase, three-phase, and direct-current motors for their respective duties. One railroad has locomotives adapted to run on either 11,000 volts single-phase or 600 volts direct current, and another has locomotives operating on 600 volts direct current so built that they may be revised for 11,000 volts alternating current. The motor-generator locomotives with 600-volt traction motors can also be adapted to run on a 600-volt direct-current supply. There is no present indication that the several well established systems of electrification are going to decline in favor. It is not unlikely, however, that there will be further developments in the interest of interchangeability between roads, as there have been in different motive-power equipment for varied duty on different divisions of the same road.

Characteristics of Electrical Operation in the United States

A study of Table I, "Condensed Analysis of Installations," shows the same prevailing reasons for electrification which were emphasized last year; namely, to increase capacity, to improve service, and to promote general economy. Long tunnels, mountain grades and the congestion of city terminals are underlying causes in the United States.

Up to date there have been installations of electrical operation on 19 railroads in this country. The total mileage operated by electricity is about 1800 miles of line and about 4000 miles of track. Of all the roads concerned, this is about 2.5 per cent of the miles of line and 3.0 per cent of the miles of track. For the whole United States it is about 0.7 per cent of the miles of line. For comparison with the United States, there are in the world about 100 railroads with electrified sections in operation or under construction, distributed through 35 countries in all continents.

Examination of the United States roads listed in Table II, "Physical Characteristics of Operation," shows many interesting facts. It should be borne in mind while consulting this table that the operations described are conducted on the most difficult portions of the roads concerned. This is particularly true of the mountain sections electrified by the Chicago, Milwaukee, St. Paul & Pacific, the Great Northern, the Norfolk & Western, and The Virginian.

Road and Track

Of the 19 roads, 12 are engaged in suburban and terminal operation around large cities. Seven operate over heavy grades and through long tunnels. Most of the terminal roads also have one or two tunnels ranging from a few hundred up to several thousand feet in length, the tunnels of the Pennsylvania Railroad under the Hudson River at New York being considerably longer than any of the others. The curvature on the terminal roads is only moderate.

The mountain roads have 89 tunnels aggregating 327,000 ft. This is equivalent to an average of 3700 ft. per tunnel, or 47,000 ft. of tunnel per road. The grades likewise are long and steep with ruling gradient as high as 2.2 per cent. The average ruling grade is 1.5 per cent for an average distance of more than 46,000 ft. In general the curvature on ruling grade begins near the upper limit of the terminal roads and runs up as high as 12 degrees.

Equipment

Of the 19 roads, 3 operate passenger service only with electric power; 4 operate freight service only; and 12 operate both passenger and freight service. Sixteen of the roads employ locomotives and 10 have multiple-unit cars. This means that seven use both. All the roads operating freight service by electric power use locomotives. Ten of the fifteen roads operating passenger service use locomotives for this purpose. There are also 10 that have multiple-unit cars. In other words, five of the heaviest traffic roads use both for passenger service.

The statistics for locomotives and motor cars are for the largest equipment on each road. Passenger locomotives are more nearly uniform in size than the freight locomotives and the horsepower varies from 1000 to 4000. The heaviest passenger engines are on the Great Northern Railway with weight of 715,000 lb. Freight engines vary widely on account of some roads having only switching and way freight service. The freight locomotives for trunk line service range from 262,000 lb. up to 1,282,000 lb. and from 1300 to 7000 horsepower. The heaviest locomotives are those of The Virginian, which are larger than any others in existence, either steam or electric.

Motor cars vary considerably in weight and seating capacity. The weights vary from 62,000 to 176,000 lb. When used with trailers they are motored with 400 to 1000 h.p. and without trailers with 240 to 470 h.p. About two-thirds of the roads use trailers with their motor cars.

Traffic

The traffic of the electrified railroads in the United States has been classified from Table II, so far as possible, into the three groups of suburban passenger, general passenger, and freight service. The three groups are shown in three small tabulations below, arranged for each group in the order of car-miles for passenger service and in the order of gross ton-miles for freight service. The car-miles, or gross ton-miles, per mile of route for the year 1927, have been calculated in the column at the right in each case.

The annual car-miles of suburban passenger service range in general between 90,000 and 300,000 per mile of route. The annual car-miles of general passenger service range in two groups, (1) between 3000 and 80,000, and (2) between 200,000 and 350,000 per mile of route. It should be noted, however, that considerable suburban passenger service is included in the figures for some of the passenger roads, due to inability to separate effectually the different varieties of passenger service when conducted over the same trackage. The annual gross ton-miles of freight service on the electrified sections range in general between 3,500,000 and 21,000,000 with more than half the roads between 13,000,000 and 21,000,000 gross ton-miles per mile of route electrified.

SUBURBAN PASSENGER-TRAIN OPERATION

Railroad	Miles Route	Average No. Trains Daily	Average No. Cars Daily	Car-Miles per Year	Schedule Speed M.p.h.	Car-Miles per Year per Mile of Route
Long Island R.R. Co.	138.08	895	5,370	40,011,720	32.0	289,500
Illinois Central R. R. Co.	37.80	497	2,100	9,361,914	25.0	247,700
Pennsylvania R. R. Co., Philadelphia Suburban Lines.	36.16	...	....	4,301,659	30.0	118,900
Southern Pacific Co.	50.03	804	1,484	4,181,158	17.7	83,600
New York, Westchester & Boston Railway Co.	26.62	259	550	3,408,500	32.0	128,100
Baltimore & Ohio R.R., Staten Island Lines	28.00	418	874	2,699,858	22.5	96,400
Erie Railroad Co.	33.76	24	58	537,756	28.0	15,930

GENERAL PASSENGER-TRAIN OPERATION

Railroad	Miles Route	Average No. Trains Daily	Average No. Cars Daily	Car-Miles per Year	Schedule Speed M.p.h.	Car-Miles per Year per Mile of Route
New York, New Haven & Hartford R.R. Co. (a)	151.72	453	3,001	31,333,205	36.0	206,500
New York Central R.R. Co.	63.10	497	4,800	21,879,280	31.5	346,700
Chicago, Milwaukee, St. Paul & Pacific R.R. Co.	658.77	4	40	9,602,010	30.8	14,570
Pennsylvania Railroad Co., Camden to Atlantic City.	75.00	...	....	4,185,900	...	55,800
Ft. Dodge, Des Moines & Southern R.R. Co.	147.12	36	36	472,753	28.0	3,210
Michigan Central R.R. Co.	4.60	38	357	364,900	15.3	79,330
Boston & Maine R.R. Co.	7.92	12	81	211,289	28.8	26,680
Butte, Anaconda & Pacific Railway Co.	37.38	4	12	116,038	30.4	3,110

NOTE: (a) Nantasket Beach line not included.

FREIGHT TRAIN OPERATION

Railroad	Miles Route	Average No. Trains Daily	Average No. Cars Daily	Gross Ton-Miles per Year (b)	Schedule Speed M.p.h.	Gross Ton-Miles per Year per Mile of Route
Chicago, Milwaukee, St. Paul & Pacific Railroad Co.	658.77	..	254	2,308,702,289	13.0	3,500,000
New York, New Haven & Hartford R. R. Co.	151.72	85	3,680	2,084,887,413	20.0	13,740,000
The Virginian Railway Co.	134.00	20	1,434	2,058,497,280	...	15,350,000
Norfolk & Western Railway Co.	63.70	37	1,678	836,346,367	...	13,130,000
Butte, Anaconda & Pacific Railway Co.	37.38	6	514	187,971,439	13.4	5,030,000
Boston & Maine R.R. Co.	7.92	30	1,556	168,386,610	15.0	21,260,000
Ft. Dodge, Des Moines & Southern R.R. Co.	147.12	9	204	90,341,557	15.0	614,000
Michigan Central Railroad Co.	4.60	47	1,617	68,223,900	8.5	14,830,000
Long Island R.R. Co.	138.08	..	....	11,307,960	...	82,000

NOTE: (b) Excluding locomotives.

Power

The electric power used by 17 of the 19 roads in 1927 amounted to 1,585,000,000 kw-hr. The generated power is slightly more in quantity than the purchased power, but there are more roads purchasing power than generating it. Twelve of the United States roads purchase all their power, while five generate all their power. The remaining two purchase about one-third of their power and generate the balance.

The energy used for passenger-train service varies about the same as in city and interurban railway service, between 1½ and 7 kw-hr. per car mile. The power used in freight service was reported by six of the railroads. These results vary from 25 to 100 kw-hr. per 1000 gross ton-miles, indicative of considerable difference in the service performed by the roads and in the character of the country through which they operate. Five of the roads have locomotives equipped for regenerative braking, but only two report the proportion of regenerated power as, respectively, 9 and 16 per cent of the total.

Conclusion

Tables I and II following, on which comments have just been made, epitomize the data in the Committee's files. They are entitled, "Condensed Analysis of Installations" and "Physical Characteristics of Operation." Table II is new this year and not as complete for foreign railroads as Table I. These tables will be improved from year to year with the cooperation of the railroads themselves. This cooperation has been cordially given and is greatly appreciated by the Committee.

Plans in view for next year's activity of the Committee include a special study of electrification practice abroad which will involve the sending of a subcommittee to Europe. It is also the intention to make a study of central-station contracts now used in this country for the sale of power to steam railroads.

TABLE

CONDENSED ANALYSIS OF INSTALLATIONS OF

Railroad	Location	Electric Mileage Route	Electric Mileage Track	System of Electrification Installed
UNITED STATES:				
Baltimore & Ohio Railroad	Baltimore Tunnel	3.60	7.96	675 volt d.c.; third rail (A)
	Staten Island Rapid Transit Lines	28.00	50.00	600 volt d.c.; third rail
Boston & Maine Railroad	Hoosac Tunnel, Massachusetts	7.92	21.38	11,000 volt a.c.; 1 phase, 25 cycle; overhead
Butte, Anaconda & Pacific Ry	Butte, Anaconda, Rocker, Montana	37.38	122.75	2,400 volt d.c.; overhead
Chicago, Mil., St. Paul & Pacific	Harlowton, Mont.—Avery, Idaho; Othello—Tacoma & Seattle, Wash	658.77	878.47	3,000 volt d.c.; overhead
	Great Falls Yard	0.00	6.20	1,500 volt d.c.; overhead
	Gallatin Valley Branch	18.80	25.38	600 volt d.c.; overhead
Delaware, Lackawanna & Western	Wallabout freight terminal, Brooklyn, N. Y	0.00	1.08	600 volt d.c.; overhead
Detroit, Toledo & Ironton R.R	Fordson, Flat Rock; Michigan	16.58	50.05	22,000 volt a.c.; 1 phase, 25 cycle; overhead
Erie Railroad	Rochester, Mt. Morris; New York	33.76	36.23	11,000 volt a.c.; 1 phase, 25 cycle; overhead
Ft. Dodge, Des Moines & Southern	Fort Dodge, Des Moines, Rockwell; Iowa	147.12	193.95	1,200 volt d.c.; overhead
Great Northern Railway	Cascade Tunnel—Skykomish; Washington	25.50	31.70	11,000 volt a.c.; 1 phase, 25 cycle; overhead (B)
Illinois Central Railroad	Chicago—Richton; Illinois	37.80	127.10	1,500 volt d.c.; overhead
Long Island Railroad	New York and Brooklyn to western part of Long Island	138.08	424.40	650 volt d.c.; third rail
Michigan Central Railroad	Detroit, Michigan—Windsor, Ontario	4.60	28.55	650 volt d.c.; third rail
New York Central Railroad	Grand Central Station—Croton—White Plains; N.Y.	63.10	326.64	650 volt d.c.; third rail
N. Y., N. H. & H. R. R	Nantasket Jc. to Pemberton, Mass	6.87	16.61	650 volt d.c.; third rail and overhead
	Providence, Warren, Bristol, Fall River	23.91	48.50	650 volt d.c.; overhead
	New York to Woodlawn (C)	11.95	48.71	650 volt d.c.; third rail
	Woodlawn, N. Y., to New Haven, Ct., including Harlem River Branch	75.22	509.88	11,000 volt a.c.; 1 phase, 25 cycle; overhead
	Stamford to New Canaan, Connecticut	7.92	9.78	11,000 volt a.c.; 1 phase, 25 cycle; overhead
	South Norwalk to Danbury, Connecticut	23.72	31.01	11,000 volt a.c.; 1 phase, 25 cycle; overhead
	Port Morris to Fresh Pond and Sunnyside Yards; New York	9.00	25.80	11,000 volt a.c.; 1 phase, 25 cycle; overhead
N. Y., Westchester & Boston Ry	Bronx, Harrison, White Plains; New York	26.62	83.10	11,000 volt a.c.; 1 phase, 25 cycle; overhead
Norfolk & Western Railway	Bluefield—Iager, West Virginia and branches	63.70	209.54	11,000 volt a.c.; 1 phase, 25 cycle; overhead
Pennsylvania Railroad	Camden—Atlantic City; New Jersey	75.00	150.38	650 volt d.c.; third rail
	New York, N. Y.; Manhattan Transfer, N. J	13.41	110.08	675 volt d.c.; third rail
	Philadelphia, Paoli, Chestnut Hill; Pennsylvania	36.16	124.65	11,000 volt a.c.; 1 phase, 25 cycle; overhead
Southern Pacific Railroad	Oakland, Alameda, Berkeley; California	50.03	118.28	1,200 volt d.c.; overhead
Virginian Railway	Mullens, West Virginia—Roanoke, Virginia	134.00	231.00	11,000 volt a.c.; 1 phase, 25 cycle; overhead
ARGENTINA:				
Buenos Aires & Western Railroad	Buenos Aires, Moreno	25.38	78.30	800 volt d.c.; third rail and overhead (E)
Central Argentine Railway	Buenos Aires, Victoria, Tigre	35.17	53.77	800 volt d.c.; third rail
AUSTRALIA:				
New South Wales Government Ry	Sydney and suburbs	......	143.60	1,500 volt d.c.; overhead
Victorian Railways	Melbourne and suburbs	162.88	404.50	1,500 volt d.c.; overhead
AUSTRIA:				
Austrian Federal Railways	St. Polten, Mariazell, Gusswerk	56.78	......	5,000 volt a.c.; 3 phase, 25 cycle; overhead
	Vienna, Hainburg (to border near)	37.76	......	550 volt d.c. and 15,000 volt a.c.; 1 phase, 16⅔ cycle; overhead
	Stainach-Irdning, Attnang-Puchheim	66.74	......	15,000 volt a.c.; 1 phase, 16⅔ cycle; overhead
	Bregenz, Feldkirch, Innsbruck (also Buchs, Switzerland)	132.05	138.42	15,000 volt a.c.; 1 phase, 16⅔ cycle; overhead
	Innsbruck, Worgl, Kufstein	45.30	82.34	15,000 volt a.c.; 1 phase, 16⅔ cycle; overhead
Vienna City Railway	Vienna	16.70	......	750 volt d.c.; overhead
BRAZIL:				
Paulista Railway	Jundiahy, Campinas, Tatu, Rio Claro	83.90	111.90	3,000 volt d.c.; overhead
Western Minas Railway	State of Minas	45.00	......	1,500 volt d.c.; overhead

UNITED STATES

A—Originally overhead; changed to third rail in 1901.

B—Cascade Tunnel electrified with 3-phase in 1909; changed to 1-phase and extended in 1927.

C—Operates on tracks of New York Central.

I

Electrical Operation on Steam Railroad Lines

Year Electrified	Traffic Affected	Reasons for Electrification	Results of Electrification
1895	Freight and Passenger	Eliminate smoke in tunnel	Capacity increased; operating costs lowered; smoke eliminated.
1925	Suburban Passenger	Legislation; tunnel operation; terminal switching	Facilities increased; operating economies.
1911	Freight and Passenger	Increase capacity; eliminate smoke in tunnel	Tunnel operation facilitated; capacity increased.
1913	Freight and Passenger	Increase capacity; general economy	100% increase in tonnage hauled in 1915.
1[illegible]27	Freight and Passenger	General economy; increase capacity; heavy grades; tunnels	Capacity increased; traffic increased; operating economies.
[illegible]	Freight Switching		
....	Freight Switching		
1926	Freight Switching	City ordinance; eliminate smoke	Smoke eliminated.
1926	Freight	Increase facilities; eliminate smoke; Detroit city ordinance	Smoke eliminated; efficiency increased.
1907	Freight and Passenger	Increase capacity	Capacity and facilities increased.
1906-1912	Freight and Passenger	Increase facilities; reduce operating costs	
1909-1927	Freight and Passenger	Increase capacity; eliminate smoke in tunnel; prospective operation through longer tunnel	Smoke eliminated; pusher service eliminated; time of trains reduced one-half.
1926	Suburban Passenger	Increase facilities; eliminate smoke; agreement with Chicago city	Higher speed; more trains accommodated; increased patronage.
1905-1926	Freight and Passenger	Improve suburban service; facilitate terminal operation; tunnels; legislation	Smoke eliminated; facilities increased; faster service.
1910	Freight and Passenger	Eliminate smoke in tunnel	Capacity and speed improved; operating economies.
1906-1926	Passenger	Operation through tunnel; improve service; increase facilities	Smoke eliminated; capacity increased; air rights developed.
1895	Suburban Passenger	Increase traffic by improved service	Service improved and traffic increased.
1900	Passenger	Increase traffic by improved service	Service improved.
1907	Passenger	Legislation prohibiting steam operation in tunnel; terminal operation; increase facilities	Facilities increased.
1907-1914	Freight and Passenger	Increase facilities; general economy	Facilities increased.
1908	Freight and Passenger	Increase facilities; general economy	Facilities increased.
1925	Freight and Passenger	Increase facilities; general economy	Facilities increased.
1912-1927	Freight and Passenger	Increase facilities; general economy	Facilities increased.
1912	Suburban Passenger	Increase facilities	
1915-23-25	Heavy freight	Grades; tunnels; increases capacity	Capacity increased; operating economies.
1906	Passenger	Increase traffic by improved service and facilities	Revenue increased by increased traffic; operating economies.
1910	Passenger	Legislation; tunnel; new terminal in New York	
1914-1918	Freight and Passenger	Increase capacity of Broad Street Terminal	Capacity increased.
1911	Passenger	Increase facilities; eliminate smoke	
1926	Heavy Freight	Increase capacity; heavy grades; tunnels	Increased facilities; reduced fuel and operating costs.
1923	Snburban and Freight	Improve service; increase capacity; tunnel operation	Traffic increased by improved service and capacity increased
1916	Suburban Passenger	Better service with faster schedules	Capacity increased; faster schedules; general economy; increase in traffic.
[illegible]928	Suburban Passenger	Increase capacity	
1919-1923	Suburban Passenger	Increase facilities; general economy	
1911	Freight and Passenger	Increase capacity; grades; tunnels; conserve fuel; use water power	Operating economics; increased facilities.
1914	Freight and Passenger	Increase traffic	Traffic increased.
1924	Freight and Passenger	Tunnels and heavy grades; utilize water power	
1920-23-24	Freight and Passenger	Increase capacity; tunnels and heavy grades; conserve fuel	Smoke eliminated; capacity increased.
1927	Freight and Passenger	Increase capacity; tunnels and heavy grades; conserve fuel	Smoke eliminated; capacity increased.
1925	Passenger	Agreement in lease-contract with city	Smoke eliminated.
1921-1926	Freight and Passenger	Coal scarcity; heavy grades; increase capacity	Capacity increased; operating economies.
1927	Freight and Passenger		

E—Overhead in Port zone for locomotives.

TABLE

CONDENSED ANALYSIS OF INSTALLATIONS OF

Railroad	Location	Electric Mileage Route	Electric Mileage Track	System of Electrification Installed
CANADA:				
Canadian National Railways	St. Clair Tunnel; Port Huron, Michigan; Sarnia, Ontario	3.00	16.00	3,300 volt a.c.; 1 phase, 25 cycle; overhead
	Mt. Royal Tunnel, Montreal, P. Q.	8.20	20.16	2,400 volt d.c.; overhead
Montreal Harbor Commission	Montreal Yards	19 00	56.00	2,400 volt d.c.; overhead
CHILE:				
Anglo-Chilean Cons. Nitrate Corp.	Tocopilla, Nitrate Deposits	25.00	......	1,500 volt d.c.; overhead
Bethlehem Chile Railway	Tofo, Cruz Grande	15.00	24.00	2,400 volt d.c.; overhead
Chile Exploration Co.	Chuquicamata	15 34	20.37	600 volt d.c.; third rail
Chilean Nitrate Railways	Iquique, Las Carpas	20.00	......	
Chilean State Railways	Valparaiso, Los Andes, Santiago	144.00	233.00	3,000 volt d.c.; overhead
Chilean Transandine Railway	Los Andes, Chilean-Argentine Border (D)	43.70	......	3,000 volt d.c.; overhead
CHINA				
South Manchuria Railway	Fushun, Colliery	25.00	43.00	1,200 volt d.c.; overhead
CUBA:				
Hershey Cuban Railway	Havana-Mantanzas	86.00	136.00	1,200 volt d.c.; overhead
United Railways of Havana	Havana and Suburbs	77.00	101.50	600 volt d.c.; overhead
CZECHOSLOVAKIA:				
State Railways	Tabor, Bechyn	14.50	......	700 volt d.c.; overhead
	Prague and vicinity	16.00	40.00	1,500 volt d.c.; overhead
DUTCH EAST INDIES:				
Java State Railway	Tandjong Priok, Meester Cornelis, Weltevreden	31.00	75.00	1,500 volt d.c.; overhead
FRANCE:				
Midi Railway	Bordeaux, Dax, Toulouse and branches	478.00	1,120.00	1,500 volt d.c.; overhead (F)
Paris, Lyons and Mediterranean	Culoz, Modane	84.00	......	1,500 volt d.c.; overhead
Paris-Orleans Railway	Paris, Vierzon and branches	149.00	588.00	1,500 volt d.c.; overhead (G)
State Railway of France	Paris, Versailles, and other suburbs	58.10	150.00	650 volt d.c.; third rail
GREAT BRITAIN:				
Great Western Railway	Bishop's Road, Westbourne Park, Hammersmith	4.02	9.88	600 volt d.c.; 3 and 4 rail
	Ealing, Wood Lane	4.19	8.74	550 volt d.c.; third rail
London, Midland & Scottish Ry.	Liverpool, Southport	38.00	92.50	600 volt d.c.; 4 rail
	Campbell Road Junction, Barking (N)	4.62	13.94	600 volt d.c.; 4 rail
	Heysham, Morecambe, Lancaster	9.16	19.20	6,600 volt a.c.; 1 phase, 25 cycle; overhead
	London and suburbs	32.75	74.00	600 volt d.c.; 4 rail
	Manchester, Bury, Holcombe Brook	13.50	27.25	1,200 volt d.c.; third rail
London & North Eastern Railway	Newcastle, Tynemouth	31.75	80.50	600 volt d.c.; third rail
	Newport, Shildon	18.50	48.25	1,500 volt d.c.; overhead
Mersey Railway	Liverpool, Birkenhead	4.78	11.86	650 volt d.c.; 4 rail
Southern Railway	London, Dartford, Orpington	182.00	501.00	650 volt d.c.; third rail
	London, Coulsdon, Sutton	40.00	132.00	6,600 volt a.c.; 1 phase, 25 cycle; overhead
GERMANY:				
German Government Railways	Bavaria near Munich	372.00	......	15,000 volt a c.; 1 phase, 16⅔ cycle; overhead
	Silesia near Breslau	160.00	......	15,000 volt a.c.; 1 phase, 16⅔ cycle; overhead
	Middle German Brown Coal District near Leipzig	114.00	......	10,000 volt a.c.; 1 phase, 15 cycle; overhead
	Baden near Basel	34.00	......	
	Berlin and Hamburg Suburban	70.00	......	800 volt d.c.; third rail
HOLLAND:				
Netherlands Railways	Rotterdam, Amsterdam, The Hague	84.52	169.04	1,500 volt d.c.; overhead
INDIA:				
Bombay, Baroda & Cen. India Ry.	Borivli, Bombay, Colaba	23.00	67.70	1,500 volt d.c.; overhead
Great Indian Peninsular Railway.	Harbor Branch and Bombay-Kalyan local lines	44.80	102.90	1,500 volt d.c.; overhead
ITALY:				
Italian State Railways	Milan, Varese	35.10	70.20	650 volt d.c.
	Lecco, Sondrio, Chiavenna	65.80	65.80	3,400 volt a.c.; 3 phase, 15 cycle; overhead
	Bozen, Mendel	32.00	......	1,200 volt d.c.; overhead
	Giuvi, Vecchia	13.70	27.50	3,000 volt a.c.; 3 phase, 15 cycle; overhead

CHILE

D—Will operate in unison with electric traction of Argentine Transandine when the latter road has completed its electrification.

FRANCE

F—Electrification started in 1910 with 12,000 volts, 1-phase, 16-2/3 cycles. Four short sections totaling 72 miles were electrified but have since been changed to 1500 volts d.c.

G—First electrification made in 1900 from Paris to Juvisy with 600 volts d.c. Changed to 1500 volts in 1924.

GREAT BRITAIN

N—On London, Tilbury & Southend Line, and operated jointly with the District Railway.

I—(*Continued*)

Electrical Operation on Steam Railroad Lines

Year Electrified	Traffic Affected	Reasons for Electrification	Results of Electrification
1908	Freight and Passenger	Grades; smoke in tunnel; increase capacity	Capacity increased 100%; tunnel operation improved.
1915	Freight and Passenger	Operation in tunnel and resideuce section	Tunnel operation facilitated; capacity increased.
1924	Freight		
1927	Freight and Passenger	Heavy grades; difficult to obtain water; high cost of fuel	
191[illegible]	Freight and Passenger	Heavy grades; scareity of fuel	
[illegible]	Freight	Reduce operating costs	Cost per ton-mile greatly reduced.
	Freight	Heavy grades; difficult to obtain water; high cost of fuel	
1924	Freight and Passenger	Increase capacity; heavy grades; scarce coal	Capacity inereased; operating economies
1927	Freight and Passenger	Heavy grades; tunnel operation	
1914	Freight and Passenger		
1920	Freight and Passenger	Grades; high cost of fuel	
....	Freight and Passenger	High cost of fuel	
1903	Freight and Passenger	Increase capaeity; conserve fuel	
1928	Freight and Passenger	Tunnel operation; eliminate smoke	
1925-1926	Freight and Passenger	Conserve fuel by using water power	
1910-1925	Freight and Passenger	Increase capaeity and speed on heavy grades	Capacity increased; fuel sved.
1927	Freight and Passenger	Scarcity of fuel; grades and tunnels	
1900-1924	Freight and Passenger	Inerease capacity and facilities; reduce consumption imported coal	Capacity increased; annual coal consumption reduced 200,000 tons.
1900-1928	Passenger	Improve service; increase capacity	Traffic increased by improved service and increased capacity.
1906	Suburban Passenger	Increase capacity	Capacity increased.
1920	Suburban Passenger		
1904-06-13	Suburban Passenger		
1905-1906	Suburban Passenger		
1908	Passenger		
1914	Suburban Passenger		
1916	Suburban Passenger		
1904	Freight and Passenger	Improve service in effort to increase traffie	Traffic inereased
1915	Freight	Great density of traffic	Capacity increased.
1903	Passenger	Tunnel; grades; heavy expense	Business increased; operating economies.
1915-1925	Suburban Passenger	Conserve fuel; increase traffic; increase capacity	Traffic more than doubled 1915-1920.
1909-1922	Suburban Passenger	Increase capacity	
1925	Freight and Passenger	Utilize water power	
19[illegible]27	Freight and Passenger		
1911-1925	Freight and Passenger	Use brown coal not suitable for steam locomotives	
....	Freight and Passenger		
1924	Suburban Passenger	Increase capacity; eliminate smoke; general economy	
1908-26-27	Passenger	General economy	
1928	Suburban Passenger		
1925	Freight and Passenger	Grades; capacity; reduce operating costs	
1901	Freight and Passenger	Increase capacity; conserve fuel	Capacity increased; operating costs lowered.
1902	Freight and Passenger	Increase capacity; tunnels; heavy grades	Capacity and tonnage increased; operating economies
1904-1912	Freight and Passenger	Increase capacity; heavy grades	Operating economies through increased facilities.
1910-1913	Freight and Passenger	Increase capacity; grades; tunnels	Capacity increased; operating economies.

TABLE

CONDENSED ANALYSIS OF INSTALLATIONS OF

Railroad	Location	Electric Mileage Route	Electric Mileage Track	System of Electrification Installed
ITALY:				
	Modane Bussoleno	35.00	59.40	3,300 volt a.c.; 3 phase, 16⅔ cycle; overhead
	Ceva, Savona, Genoa	52.90	52.90	3,700 volt a.c.; 3 phase, 16⅔ cycle; overhead
	Monza, Lecco	23.00	27.40	3,400 volt a.c.; 3 phase, 15 cycle; overhead
Valli di Lanzo Railway	Turin, Ceres	26.10	......	4,000 volt d.c.; overhead
Italian State Railways	Genoa, Bussoleno	145.00	......	3,000 volt a.c.; 3 phase, 16⅔ cycle; overhead
	Genoa, Pisa, Leghorn	115.00	......	3,000 volt a.c.; 3 phase, 16⅔ cycle; overhead
	Rome, Tivoli, Sulmona	108.00	......	10,000 volt a.c.; 3 phase, 45 cycle; overhead
	Foggia, Benevento	63.00	......	3,000 volt d.c.; overhead
	Florence, Pistoia, Bologna	82.00	......	
	Naples, Pozzuoli	8.00	......	850 volt d.c.; third rail
JAPAN:				
Chichibu Railway	Kumagya, Kagemori	35.00	......	1,200 volt d.c.; overhead
Imperial Government Railways	Usui Pass	7.00	7.00	650 volt d.c.; third rail—overhead
	Tokyo, Yokohama, Yokosuka	60.00	120.00	1,500-1,200-600 volt d.c.; overhead
	Tokyo towards Osaka	89.00	151.00	1,500 volt d.c.; overhead
Yoshino Railway	Yoshino, Yoshinoguchi	7.20	......	1,500 volt d.c.; overhead
MEXICO:				
El Potosi Railway	El Potosi Mine, Morse Smelter	15.54	20.88	600 volt d.c.; overhead
Mexican Railway	Esperanza, Orizaba, Paso del Macho	64.00	70.23	3,000 volt d.c.; overhead
MOROCCO:				
Moroccan Railways	Casablanca, Kourigha	86.50	......	3,000 volt d.c.; overhead
NEW ZEALAND:				
New Zealand Government Rys.	Otira, Arthurs Pass	8.40	13.40	1,500 volt d.c.; overhead
NORWAY:				
Norwegian State Railways	Narvik, Riksgrensen (P)	26.10	40.39	15,000 volt a.c.; 1 phase, 15 cycle; overhead
	Oslo, Drammen	31.69	62.14	15,000 volt a.c.; 1 phase, 15 cycle; overhead
	Oslo, Lillestrom	13.05	50.95	15,000 volt a.c.; 1 phase, 15 cycle; overhead
	Notodden, Tinnoset	18.64	22.37	10,000 volt a.c; 1 phase, 16⅔ cycle; overhead
Rjukan Railway	Rjukan, Moel	10.00	......	10,000 volt a.c.; 1 phase, 16⅔ cycle; overhead
Thamshavn Railway	Thamshavn, Lokken	15.00	......	6,000 volt a.c.; 1 phase, 25 cycle; overhead
SPAIN:				
Spanish Northern Railway	Ujo, Busdongo	38.53	49.72	3,000 volt d.c.; overhead
SWEDEN:				
Swedish State Railways	Riksgrensen, Kiruna, Lulea (P)	287.00	......	15,000 volt a.c.; 1 phase, 15 cycle; overhead
	Stockholm, Gothenburg	286.00	......	16,000 volt a.c.; 1 phase, 16⅔ cycle; overhead
Halsingborg Railway	Halsingborg, Raa, Ramlosa	5.00	......	600 volt d.c.
Stockholm Roslagens Railway	Stockholm, Djursholm	9.40	......	600 volt d.c.
Mellersta Ostergotland Railway	Linkoping, Vadstena, Motala	44.70	......	10,000 volt a.c; 1 phase, 25 cycle; overhead
Nordmark Klaralvens Railway	Filipstad, Karlstadt and branches	101.37	123.32	16,000 volt a.c.; 1 phase, 25 cycle; overhead
Stockholm Saltsjon Railway	Stockholm, Saltsjobaden	11.20	......	1,200 volt d.c.
Lund Bjarred Railway	Lund, Bjarred, Malmo	6.80	......	16,000 volt a.c.; 1 phase, 16⅔ cycle; overhead
SWITZERLAND:				
Bernische Dekrets Railway	Schwarzenburg, Bern, Thun, Spiez, Zweisimmen	59.00	......	15,000 volt a.c.; 1 phase, 16⅔ cycle; overhead
Bernese Alps Railway	Bonigen, Spiez, Brig, Simplon	73.40	......	15,000 volt a.c.; 1 phase, 16⅔ cycle; overhead
Burgdorf-Thun Railway	Burgdorf, Thun	25.50	......	750 volt a.c.; 3 phase, 40 cycle; overhead
Emmenthal Railway	Burgdorf, Langnau	13.70	......	750 volt a.c.; 3 phase, 40 cycle; overhead
Freiburg Railway	Freiburg, Murten, Ins	20.50	......	840 volt d.c.;
Martigny, Orsieres Railway	Martigny, Orsieres	12.40	......	8,000 volt a.c.; 1 phase, 15 cycle; overhead
Montreux Oberland Railway	Montreux, Lenk	53.45	59.66	1,000 volt d.c.; overhead
Rhaetian Railway	Chur, Filisur, St. Moritz	172.00	......	11,000 volt a.c.; 1 phase, 16⅔ cycle; overhead
Sihlthal Railway	Zurich, Wadenswd	11.20	......	15,000 volt a.c.; 1 phase, 16⅔ cycle; overhead
Swiss Federal Railways	Simplon Tunnel	12.45	......	3,000 volt a.c.; 3 phase, 16⅔ cycle; overhead
	Lucerne, Rupperswil	34.20	......	5,500 volt a.c.; 1 phase, 25 cycle; overhead
	General System	810.00	......	15,000 volt a.c.; 1 phase, 16⅔ cycle; overhead
UNION OF SOUTH AFRICA:				
Government Railways	Pietermaritzburg, Glencoe	171.00	287.00	3,000 volt d.c.; overhead
VENEZUELA:				
LaGuaira & Caracas Railway	LaGuaira, Caracas	22.70	......	1,500 volt d.c.; overhead

NORWAY AND SWEDEN
P—The line Narvik-Riksgrensen, in Norway, with the line Riksgrensen-Kiruna-Lulea, in Sweden, form a unified system from the Atlantic to the Gulf of Bothnia.

I—(*Concluded*)

Electrical Operation on Steam Railroad Lines

Year Electrified	Traffic Affected	Reasons for Electrification	Results of Electrification
1912-1914	Freight and Passenger	Increase capacity; conserve fuel	Capacity increased; operating costs lowered.
1914-1921	Freight and Passenger	Heavy grades; tunnels; water power	
1914	Freight and Passenger		
1921	Freight and Passenger		
1922-1926	Freight and Passenger	National policy; conserve coal; use water power	
1926	Freight and Passenger	National policy; conserve coal; use water power	
1927	Freight and Passenger	National policy; conserve coal; use water power	
[illegible]	Freight and Passenger	National policy; conserve coal; use water power	
1927	Freight and Passenger	National policy; conserve coal; use water power	
1927	Suburban Passenger	National policy; conserve coal; use water power	
1922	Freight and Passenger	Heavy grades	
1910	Freight and Passenger	Increase capacity; grades; tunnels	
1910-1923	Freight and Passenger	Increase capacity	Capacity increased.
1924-1928	Freight and Passenger	Heavy grades	
1922-1923	Freight and Passenger	Heavy grades	
1924	Freight	Capacity; grades; regeneration; economy	Capacity increased; operating economies.
1924-1927	Freight and Passenger	Heavy grades; conserve fuel	Operating economies; service more satisfactory.
1924			
1924	Freight and Passenger	Heavy grades; 5 miles of tunnels	Capacity increased; smoke in tunnel eliminated.
1923	Freight and Passenger	Grades; save coal; use water power	
1922	Freight and Passenger	National policy; save coal; use water power	
1925	Freight and Passenger	National policy; save coal; use water power	
1912	Freight and Passenger		
1911-1912	Freight and Passenger		
1908	Freight	Heavy grades; high cost of fuel	
1924	Freight and Passenger	Heavy grades; 16 miles of tunnels; increase capacity	Capacity multiplied about 3 times.
1915-1923	Freight and Passenger	Save fuel; use water power	
1925-1926	Freight and Passenger	Save fuel; use water power	
1906			
1893	Suburban Passenger		
1908-1915	Freight and Passenger		
1921	Freight and Passenger	Reduce transportation charges	Most favorable.
1913	Suburban Passenger		
1916	Passenger		
1920-1923			
[illegible]	Freight and Passenger	Utilize available water power	
[illegible]	Freight and Passenger	Increase capacity; conserve fuel	
1919			
1903			
1910	Passenger		
1901	Freight and Passenger		
1913-1922	Freight and Passenger	Save coal; heavy grades; increase capacity	
1924			
1906	Freight and Passenger	Heavy grades; tunnel; save coal; use water power	
1910			
1918-1927	Freight and Passenger	National policy; save coal; use water power	
1926	Freight and Passenger	Increase capacity over heavy grades	Reduction in running time; better service.
1927	Freight and Passenger	Increase speed to compete with motorbuses	

TABLE II

PHYSICAL CHARACTERISTICS OF OPERATION ON ELECTRIFIED SECTIONS OF STEAM RAILROADS

PART 1: UNITED STATES—YEAR 1927

Name of Railroad	Track		Tunnels		Ruling Grade			Electric Passenger Locomotives			Electric Freight Locomotives			Electric Passenger Motor Cars			Passenger Trailers		Car Capacity	
	Gage	Total Length Electrified	Number	Aggregate Length	Against Heaviest Traffic	Length Against Heaviest Traffic	Maximum Curve on Ruling Grade	Number	Maximum Weight	Maximum Power	Number	Maximum Weight	Maximum Power	Number	Maximum Weight	Maximum Power	Number	Maximum Weight	Passengers Seated	Freight Tons
	Ins.	Miles	No.	Ft.	%	Ft.	Deg.	No.	Lb.	H.P.	No.	Lb.	H P.	No.	Lb.	H.P.	No.	Lb.	No.	Tons
BALTIMORE & OHIO RAILROAD:																				
Staten Island Lines	56 5	50 00	1	609	1.82	3,000	3.0	...	...	...	...	...	...	90	95,750	400	10	83,265	71	...
Baltimore Tunnel (b)	56.5	7 96	9	9,601	1.32	1,000	5 7	8	242,000	1,100	(a)	...	...	...	...	...	...	...	S	S
Boston & Maine Railroad Co.	56 5	21 38	1	25,080	0 75	9,500	4.0	(a)	...	...	7	261,800	1,260	...	...	...	...	...	S	S
Butte, Anaconda & Pacific Railway Co.	56.5	122.75	5	1,656	0.30	31,680	5.0	1	160,500	1,280	27	160,500	1,280	...	...	...	...	...	72	50
Chicago, Milwaukee, St. Paul & Pacific	56 5	878.47	41	243,936	1.74	100,320	10.0	15	620,000	4,200	42	576,000	3,440	...	...	...	...	...	S	S
Delaware Lackawanna & Western R.R. (k)	56 5	1.08	...	...	...	...	46.0	...	...	...	1	102,840	220	...	...	...	...	...	...	S
Detroit, Toledo & Ironton Railroad Co.	56 5	50.05	...	...	0.25	1,900	...	...	...	...	2	372,000	...	...	...	...	...	...	...	S
Erie Railroad Co.	56.5	36 23	...	...	0.88	2,620	4.0	...	...	...	...	...	...	8	117,100	400	4	66,000	76	...
Fort Dodge, Des Moines & Southern R.R.	56 5	193.95	...	...	1.50	6,600	8.2	...	...	...	12	120,000	880	13	84,000	300	...	...	48	25
Great Northern Railway Co.	56.5	31.70	6	20,803	2.20	95,040	10.0	4	715,400	4,330	(a)	...	...	...	...	...	...	...	S	S
Illinois Central Railroad Co.	56.5	127.10	...	...	...	...	...	...	...	...	...	...	...	130	141,301	1,000	130	88,546	84	...
Long Island Railroad Co.	56.5	424.40	1	3,500	1.30	5,800	4.0	8	313,000	2,130	7	316,000	1,460	742	129,650	900	250	75,000	80	S
Michigan Central Railroad Co.	56.5	28.55	1	8,368	1.50	4,805	2 0	12	240,000	1,120	(a)	...	...	...	...	...	...	...	S	S
New York Central Railroad Co.	56.5	326.64	2	12,460	0.57	1,970	...	83	285,000	2,000	9	354,000	2,660	325	133,000	240	...	...	100	S
N. Y., N. H. & HARTFORD RAILROAD:																				
Woodlawn to New Haven incl. Harlem River Branch	56.5	509.88	...	...	0 74	1,715	3 0	71	356,000	2,508	70	282,000	1,345	63	176,000	680	103	103,600	120	S
New York to Woodlawn (e)	56.5	48.71	1	9,150	0 74	1,980	6.0	(f)	...	...	(f)	...	...	(f)	...	...	...	...	...	...
Stamford to New Canaan	56 5	9.78	...	...	1.40	528	...	(f)	...	...	(f)	...	...	(f)	...	...	...	...	...	...
South Norwalk to Danbury	56.5	31.01	...	...	1.27	1,584	1.0	(f)	...	...	(f)	...	...	(f)	...	...	...	...	...	...
Port Morris to Fresh Pond and Snnnyside Yards	56.5	25.80	...	...	1.22	1,056	...	(f)	...	...	(f)	...	...	(f)	...	...	...	...	...	...
Providence to Fall River	56.5	48.50	...	...	1.29	1,056	6.0	...	...	...	...	...	...	24	102,000	...	41	...	77	...
Nantasket Beach (g)	56.5	16.61	...	...	0.38	1,452	9.0	...	...	...	...	...	...	8	61,800	320	...	...	56	...
New York, Westchester & Boston Ry. Co.	56.5	83.10	1	4,000	2.60	1,500	4.0	...	...	...	1	160,000	768	70	125,000	340	5	88,000	80	S
Norfolk & Western Railway Co.	56.5	209.54	17	16,800	2.00	18,480	12.0	...	...	...	16	864,000	3,000	...	...	...	...	...	...	100
PENNSYLVANIA RAILROAD CO.:																				
Philadelphia Terminal	56.5	124.65	...	...	...	...	...	1	408,600	3,070	3	516,000	4,000	158	118,600	450	...	...	72	...
New York Terminal	56.5	110.08	6	...	2.00	...	...	50	396,600	3,730	...	...	...	...	...	...	...	...	S	...
Camden to Atlantic City	56.5	150.38	...	...	...	...	...	...	...	...	...	...	...	107	106,000	470	...	...	72	...
Southern Pacific Co.	56.5	118.28	1	467	5.25	1,940	15.0	...	...	...	...	...	...	87	117,400	560	60	67,200	116	...
The Virginian Railway Co.	56.5	231.00	19	18,480	2.07	63,360	12.0	...	...	...	14	1,282,380	7,125	...	...	...	...	...	...	120

PART 2: COUNTRIES OTHER THAN UNITED STATES—YEAR 1927

Name of Railroad	Gage	Total Length Electrified	Tunnels Number	Tunnels Aggregate Length	Against Heaviest Traffic	Length Against Heaviest Traffic	Maximum Curve on Ruling Grade	Elec. Pass. Loco. Number	Maximum Weight	Maximum Power	Elec. Freight Loco. Number	Maximum Weight	Maximum Power	Elec. Pass. Motor Cars Number	Maximum Weight	Maximum Power	Pass. Trailers Number	Maximum Weight	Passengers Seated	Freight Tons
ARGENTINA:																				
Buenos Aires & Western Railway	66.0	78.30	2	19,685	3.8	410	7.0	...	...	...	2	137,812	920	61	123,480	800	97	78,280	93	...
Central Argentine Railway	66 0	53.77	...	...	0.8	5,914	2.1	...	...	...	...	...	...	73	113,100	500	54	80,000	94	...
AUSTRALIA:																				
New South Wales Gov. Railways (j)	56.5	143.60	...	...	...	...	...	...	...	...	...	...	...	251	[illegible]9,760	720	251	...	81	...
Victorian Railways	6[illegible]	404.50	3	1,075	2 5	...	4.3	...	...	...	2	112,000	760	384	[illegible]360	560	460	61,600	92	45

AUSTRIA:																				
St. Polten, Mariazell, Gusswerk	30 0	*56.78	21	14,810	2.5	...	21.8	16	108,927	450	(a)	...	...	...	...	...	...	...	...	...
Vienna, Hainburg	56 5	*37.76	...	...	3.0	...	7.0	15	116,865	800	(a)	...	...	7	30,000	118	9	17,200	28	...
Stainach-Irdning, Attnang-Puchheim	56 5	*66.74	10	10,066	2.5	...	7.0	14	134,505	1,360	6	172,430	1,620	...	...	...	...	...	...	...
Bregenz, Innsbruck, etc	56 5	138.42	15	49,343	3.1	...	7.0	32	259,749	2,480	29	172,430	1,620	...	...	...	...	...	...	...
Innsbruck, Worgl,-Kufstein (z)	56.5	82.34	21	24,220	2.3	...	...	(z)	...	...	(z)	...	...	...	...	...	...	...	...	...
CANADA:																				
Canadian National Railways:																				
St. Clair Tunnel	56.5	16.00	1	6,025	2.00	4,899	0.0	...	...	...	7	141,000	720	...	...	...	...	...	83	S
Mt. Royal Tunnel, Montreal, P. Q.	56.5	20.16	1	16,632	0.60	15,576	2.0	6	166,000	1,260	...	...	...	2	164,000	500	...	...	86	...
CHILE:																				
Chile Exploration Co.	56.5	20.37	...	...	2.6	...	12.2	...	...	...	9	152,000	560	...	...	...	...	...	...	70
DUTCH EAST INDIES:																				
Java State Railway (j)	42.0	75.00	...	...	...	...	...	4	174,000	1,510	3	154,500	1,220	15	...	460	15	...	...	...
FRANCE:																				
Midi Railway Co. (j)	56.5	1,120.00	...	...	...	...	...	10	229,320	2,100	90(a)	158,760	1,400	31	99,225	...	...	...	...	...
Paris-Orleans Railway Co	56.5	588.00	2	14,320	0.60	11,590	0.0	5	260,000	4,400	148(a)	154,000	1,720	80	130,000	990	80	75,400	143	15
GREAT BRITAIN:																				
Mersey Railway Co.	56.5	11.86	3	18,876	3.70	1.175	0.0	...	...	...	...	...	...	28	91,728	500	40	64,288	64	...
London & North Eastern Railway:																				
Newcastle, Tynemouth	56.5	80.50	6	5,343	2.1	264	4.8	...	...	...	2	125,440	700	71	92,288	300	55	57,344	72	...
Shildon, Newport	56.5	48.25	0	...	0.6	528	0.0	...	...	...	10	166,880	1,100	...	...	...	...	...	...	...
Southern Railway Co																				
London-Dartford-Orpington	56.5	501.00	18	26,000	...	...	...	...	...	...	...	...	...	488	91,840	600	452	61,600	90	...
London-Coulsdon-Sutton	56.5	132.00	5	5,136	...	...	...	...	...	...	...	...	...	71	138,880	1,000	164	58,240	82	...
HOLLAND:																				
Netherland Railways	56.5	169.04	...	...	...	...	5.8	...	...	...	...	...	...	115	132,300	800	115	88,200	88	...
MEXICO:																				
The Mexican Railway Co., Ltd.	56.5	70.23	16	3,563	4.00	154,288	17.5	10	340,600	2,700	(a)	...	...	...	...	...	...	...	180	50
El Potosi Railway	30.0	20.88	...	...	2.50	9,820	44.0	...	...	...	6	52,000	400	...	...	...	...	...	...	17
MOROCCO:																				
Moroccan Railways (j)	56 5	*86.50	...	...	...	...	...	...	...	...	10	...	1,400	10	...	700	...	...	...	...
NEW ZEALAND:																				
New Zealand Government Railways	42.0	13.40	1	28,050	3.0	36,960	5.8	(a)	...	...	5	112,000	680	...	...	...	...	...	...	...
NORWAY:																				
Norwegian State Railways:																				
Narvik, Riksgrensen	56.5	40.39	23	15,257	0.0	...	0.0	...	...	...	8	299,880	2,800	...	...	...	...	...	...	...
Oslo, Drammen	56.5	62.14	5	1,506	1.4	27,560	6.2	2	170,888	1,150	22	135,166	940	...	...	...	...	...	...	...
Oslo, Lillestrom	56.5	50.95	0	...	2.5	9,187	2.2	(a)	...	...	9	147,294	1,400	...	...	...	...	...	...	...
Notodden, Tinnoset	56.5	22.37	3	1,644	2.7	...	...	...	...	...	3	101,430	500	...	...	...	...	...	...	...
SPAIN:																				
Spanish Northern Railway Co.	66 0	49.72	70	83,650	2.00	162,500	8.7	(a)	...	...	12	178,600	1,620	...	...	...	...	...	92	22
SWEDEN:																				
Nordmark Klaralvens Railway	35.1	123.32	1	163	1.2	15,027	5.8	(a)	...	...	15	89,500	485	1	60,400	120	...	...	90	20
SWITZERLAND:																				
Montreux-Bernese-Oberland Railway	39.4 31.5	59.66	18	13,964	7.30	...	44.0	3	30,870	240	(a)	...	...	30	79,380	600	...	...	68	17
UNION OF SOUTH AFRICA:																				
South African Railways (j)	42.0	287.00	...	...	1.5	...	...	(a)	...	...	95	147,840	1,200	...	...	...	...	...	...	...

GENERAL NOTES

Length of Electric Track includes Main Track, Yard, and Siding Track in electric zone (so far as equipped for electric operation).

Ruling Grade refers to grade against heaviest traffic and to curves on this grade.

Maximum Weight, Maximum Capacity, and Maximum Horsepower refer to the largest equipment used in electric operation and not to conditions of loading. The horsepower is generally the one-hour rating.

Average Number Trains Daily is number run in both directions.

Number Cars Moved Daily is total cars in all trains, both directions.

Figures expressing length have been converted to (1) the English Foot, and. (2) the Mile of 5,280 ft.

Figures expressing weight have been converted to (1) the Pound Avoirdupois, and (2) the Ton of 2,000 lb. This applies likewise to the Ton-Miles and Kilowatt-hours per Ton-Mile.

TABLE II—(*Continued*)

PHYSICAL CHARACTERISTICS OF OPERATION ON ELECTRIFIED SECTIONS OF STEAM RAILROADS
PART 1: UNITED STATES—YEAR 1927

Name of Railroad	Average No Trains Daily		Cars Moved Daily		Average Schedule Speed		Car-Miles in Year		Freight Service	Energy Supplied			Energy Used				
	Passenger	Freight	Passenger	Freight	Passenger	Freight	Passenger Train	Freight Train	Excluding Locomotives	Generated	Purchased	Delivered to Contact Line	Per Passenger-Train Car-Mile	Per Freight-Train Car-Mile	Per 1,000 Gross Ton-Miles of Freight Service	Point of Measurement of Energy Used	% Regenerated Power of Delivered Power
	No.	No.	No.	No.	M.p.h.	M.p.h.	No.	No.	Gross Ton-Miles	Kw-hr.	Kw-hr.	Kw-hr.	Kw-hr.	Kw-hr.	Kw-hr.		%
BALTIMORE & OHIO RAILROAD:																	
Staten Island Lines	418	...	874	...	22.5	...	2,699,858	...	...	...	15,232,372	...	3.30	...	...	T	0.0
Baltimore Tunnel (b)	19	20	152	900	...	...	...	...	...	...	7,576,850	...	...	...	...	...	0.0
Boston & Maine Railroad Co.	12	30	81	1,556	28.8	15.0	211,289	3,623,189	168,386,610	...	7,497,225	7,379,000	...	...	...	P.S.	0.0
Butte, Anaconda & Pacific Railway Co.	4	6	12	514	30.4	13.4	116,038	4,887,338	187,971,439	...	19,252,657	...	1.60	3.93	102.4	S.S.	0.0
Chicago, Milwaukee, St. Paul & Pacific	4	...	40	254	30.8	13.0	9,602,010	61,077,169	2,308,702,289	...	148,560,111	(c)90,085,420	2.35	0.98	25.9	T.	16.4
Delaware, Lackawanna & Western R.R. (k)	...	...	...	...	...	...	...	...	...	...	56,750	...	...	...	...	...	0.0
Detroit, Toledo & Ironton Railroad Co.	...	8	...	...	...	...	...	...	...	...	...	...	...	...	...	...	(h)
Erie Railroad Co.	24	...	58	...	28.0	...	537,756	...	...	...	2,396,376	2,059,879	3.83	...	...	S.S.	0.0
Fort Dodge, Des Moines & Southern R.R.	36	9	36	204	28.0	15.0	472,753	2,596,095	90,341,557	34,785,000	...	...	...	...	...	...	0.0
Great Northern Railway Co.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	(h)
Illinois Central Railroad Co.	497	...	2,100	...	25.0	...	9,361,914	...	...	...	48,785,223	48,785,223	(d)5 20	...	...	S.S.	0.0
Long Island Railroad Co.	895	...	5,370	...	32.0	...	40,011,720	...	11,307,960	...	202,255,000	151,200,000	4.59	...	...	S.S.	0.0
Michigan Central Railroad Co.	38	47	357	1,617	15.3	8.5	364,900	21,241,100	68,223,900	...	11,686,125	4,005,400	...	...	...	...	0.0
New York Central Railroad Co.	497	135	4,800	1,900	31.5	13.5	21,879,280	...	...	218,193,262	...	152,420,190	...	...	...	...	0.0
N. Y., N. H. & HARTFORD RAILROAD:																	
Woodlawn to New Haven incl. Harlem River Branch	189	55	1,487	2,400	40.0	20.0	23,665,853	55,876,980	1,913,752,019	136,850,000	55,868,500	154,926,800	3.50	0.85	24.7	T.	0.0
New York to Woodlawn (e)	161	...	1,120	...	30.0	...	5,774,665	...	...	...	22,380,700	18,667,400	2 80	...	...	T.	0.0
Stamford to New Canaan	30	2	72	10	26.0	15.0	208,050	28,835	980,390	(f)	(f)	(f)	(f)	(f)	(f)	...	0.0
South Norwalk to Danbury	11	6	51	100	26.0	15.0	441,285	867,780	29,504,520	(f)	(f)	(f)	(f)	(f)	(f)	...	0.0
Port Morris to Fresh Pond and Sunnyside Yards	16	22	173	1,170	20.0	20.0	315,855	4,186,201	140,650,484	...	5,402,000	5,402,000	3.50	0.94	27.5	T.	0.0
Providence to Fall River	46	...	92	...	23.0	...	927,497	...	...	...	5,677,000	5,677,000	...	...	...	...	0.0
Nantasket Beach (g)	36	...	114	...	27.0	...	...	...	...	...	376,000	376,000	...	...	...	...	0.0
New York, Westchester & Boston Ry. Co.	259	2	550	30	32.0	15.0	3,408,500	21,350	...	...	20,315,596	20,315,596	5.68	14.01	...	T.	0.0
Norfolk & Western Railway Co.	...	37	...	1,678	...	...	...	...	836,346,367	82,586,022	5,900	72,846,128	...	...	87.0	P.S.	(b)
PENNSYLVANIA RAILROAD CO.:																	
Philadelphia Terminal	...	...	...	...	30.0	...	4,301,659	...	...	...	48,708,600	31,402,111	7.30	...	...	S.S.	0.0
New York Terminal	200	...	1,800	...	40.0	...	...	...	...	(i)264,185,040	43,390,350	75,999,208	...	...	...	S.S.	0.0
Camden to Atlantic City	...	...	...	...	...	...	4,185,900	...	...	...	39,987,600	18,673,841	4.46	...	...	S.S.	0.0
Southern Pacific Co.	804	...	1,484	...	17.7	...	4,181,158	...	...	28,634,400	...	22,277,300	5.33	...	...	P.S.	0.0
The Virginian Railway Co.	...	20	...	1,434	...	...	...	33,780,954	2,058,497,280	114,245,000	...	107,966,440	...	3.20	52.5	P.S.	9.1

PART 2: COUNTRIES OTHER THAN UNITED STATES—YEAR 1927

Name of Railroad	Passenger Trains	Freight Trains	Passenger Cars	Freight Cars	Passenger Speed	Freight Speed	Passenger Train Car-Miles	Freight Train Car-Miles	Excluding Locomotives	Generated	Purchased	Delivered to Contact Line	Per Passenger-Train Car-Mile	Per Freight-Train Car-Mile	Per 1,000 Gross Ton-Miles of Freight Service	Point of Measurement of Energy Used	% Regenerated Power of Delivered Power
ARGENTINA:																	
Buenos Aires & Western Railway	317	5	1,609	70	27.6	...	7,728,936	564,882	...	27,076,764	...	23,614,498	3.00	...	...	S.S.	0.0
Central Argentine Railway	202	...	...	...	35.2	...	6,732,868	...	...	28,127,644	...	(t)24,474,695	3.64	...	...	P.S.	0.0
AUSTRALIA:																	
New South Wales Gov. Railways (j)																	
Victorian Railways	2,5[illegible]	[illegible]	12438	44	22.0	...	38,954,040	452,429	6,242,751	179,755,507	29,067	118,10[illegible]	3.71	0.62	44.6	P.S.	0.0

AUSTRIA:																	
St. Polten, Mariazell, Gusswerk											3,200,000	3,200,000				S.S.	0.0
Vienna, Hainburg											2,400,000	2,400,000				S.S.	0.0
Stainach-Irdning, Attnang-Puchheim	13	5					2,235,175	2,482,493	82,858,380		6,700,000	6,700,000				S.S.	0.0
Bregenz, Innsbruck, etc	19	9					9,010,300	13,857,220	437,587,200	38,000,000		38,000,000				S.S.	0.0
Innsbruck, Worgl, Kufstein (z)										7,500,000	1,500,000	9,000,000				S.S.	0.0
CANADA:																	
Canadian National Railways:																	
St. Clair Tunnel	9	37	63	1,218	12.0	12.0	116,260	2,223,330	89,353,470	17,305	5,153,400	3,753,017	1.99	1.21	42.0		0.0
Mt. Royal Tunnel, Montreal, P. Q.	44		72		25.0		319,657				2,500,137		7.80				0.0
CHILE:																	
Chile Exploration Co		87		1,094		10.0		616,616	29,886,025	(t)2,886,300		2,077,036		4.68	96.5	(t)S.S.	0.0
DUTCH EAST INDIES:																	
Java State Railway (j)					37.3												0.0
FRANCE:																	
Midi Railway Co. (j)																	
Paris-Orleans Railway Co	450	119	6,430	6,822	45.0	22.0	55,880,800	56,988,060	885,668,500		93,051,012	82,654,707	1.07	0.40	184.0	S.S.	0.0
GREAT BRITAIN:																	
Mersey Railway Co	463		2,119		20.0		2,134,152			7,947,020		5,983,601	2.81			P.S.	0.0
London & North Eastern Railway:																	
Newcastle, Tynemouth	178	23	1,024	170	20.6	12.0	5,132,301	53,897	629,828		12,425,132	10,059,571	2.40	1.18	222.6	S.S.	0.0
Shildon, Newport		11		639		17.0		3,826,252	59,504,354		1,364,983	1,364,983		0.36	23.0	S.S.	0.0
Southern Railway Co.:																	
London-Dartford-Orpington	1,666				25.0		55,834,000			76,240,230	75,419,750	121,091,997	2.17			S.S.	0.0
London-Coulsdon-Sutton	544				24.0		13,874,439				37,338,170	37,083,336	2.67			S.S.	0.0
HOLLAND:																	
Netherland Railways					59.0		(m)2,796,768				(n)50,000,000		49.60(o)			P.S.	0.0
MEXICO:																	
The Mexican Railway Co., Ltd	4	8	22	85	18.0	15.0	57,698	175,690	57,647,079	8,845,800	35,076,000	8,108,600	1.02	2.68	105.6(p)	P.S.	35.0
El Potosi Railway		20		250		19.0		321,044	4,953,023		1,262,850	1,071,600		3.92	242.4(q)	S.S.	12.0
MOROCCO:																	
Moroccan Railways (j)																	
NEW ZEALAND:																	
New Zealand Government Railways	1	12	12	277	18.2	15.9	30,006	693,684	6,483,330	1,382,610		1,382,610	4.56	1.81	193.7	P.S.	0.0
NORWAY:																	
Norwegian State Railways:																	
Narvik, Riksgrensen												6,440,200					10.0(v)
Oslo, Drammen												8,423,600					0.0
Oslo, Lillestrom																	0.0
Notodden, Tinnoset											1,920,739						0.0
SPAIN:																	
Spanish Northern Railway Co	4	22	22	297	26.0	19.0			71,851,271		9,400,600	8,460,540			100.6(q)	S.S.	10.0(v)
SWEDEN:																	
Nordmark Klaralvens Railway	16				28.0	18.6			(r)30,998,255		3,128,900	3,128,900			100.9(r)	P.S.	0.0
SWITZERLAND:																	
Montreux-Bernese-Oberland Railway	18	1	45	5	16.0	12.0	404,000	43,500	1,849,223		5,000,000	5,000,000	11.25			P.S.	0.0
UNION OF SOUTH AFRICA:																	
South African Railways (j)	8	37			21.0	21.0					(x)60,069,918						19.0(v)

SPECIAL NOTES

*—Route miles
a—Passenger and Freight Locomotives
b—Electric service one direction only
c—Measured at Locomotive
d—Includes Electric Heating
e—Operates on tracks of New York Central
f—Included in Woodlawn—New Haven Section
g—Summer service only
h—Regeneration not computed
i—Power sold to other companies
j—Information from technical journals
k—Electric operation of isolated freight yard
l—Third class
m—Train miles
n—Estimated for 1928
o—Per 1000 ton-miles passenger service
p—Freight and passenger service
q—Net ton-miles
r—Gross ton-miles freight and passenger service
t—High tension at Power Station or Substation
v—Approximate figure by test
x—For six months, June-November, 1927
z—Placed in service during year. Equipment included in section Bregenz, Innsbruck, etc.
S—Standard railroad equipment
T—At train
P.S.—At Power Station
S.S.—At Substations

APPENDIX I

ELECTRIFICATION OF THE VIRGINIAN RAILWAY FROM A TRANSPORTATION STANDPOINT

BY F. L. JOHNSON, *Assistant to Vice-President*
Operating Dept., Chicago, Burlington & Quincy Railroad Company

The main line of the Virginian Railway extends from Deepwater, W. Va., where connection is made with the Chesapeake & Ohio Railway, to Sewalls Point at Norfolk, Va., a distance of 442.4 miles. The rich New River and Pocahontas coal fields lie near the western terminus and are served by the main line and numerous branch lines between Deepwater and Mullens, W. Va. The coal from nearly all of these mines is collected in Elmore Yard, just east of Mullens, and is handled from this point to tidewater at Norfolk. The line is single tracked, except from Mullens to Matoaka, 22 miles, which is double tracked and includes the maximum grades, and except from Carolina Jct., Va., near Norfolk, to Sewalls Point, Va., which is also double tracked.

The division from Mullens to Roanoke, a distance of 133.7 miles, traverses a rough, mountainous territory and contains nineteen tunnels, the aggregate length of which is approximately three and one-half miles, grades up to 2.07 per cent and innumerable curves, the sharpest of which are twelve degrees. This division presented very serious operating difficulties under steam power and has, therefore, been electrified for the purpose of eliminating some of these difficulties and of increasing its capacity.

Numerous articles have been written and reports made covering the electrified operations of the Virginian Railway Company, almost wholly from the standpoint of power plant, substation, overhead construction, and electric locomotives. Reference is made to Circular No. DV 463, issued by the Mechanical Section of the American Railway Association, covering report of Committee on Electric Rolling Stock, dated May 9, 1926; also to Circular No. DV 536, of the American Railway Association, report of Committee on Electric Rolling Stock, dated May 7th, 1927.

It is felt that the above features have been quite fully covered; hence, this paper will give consideration to the operation of the railway from a transportation standpoint.

Traffic Problem Unique

The reader should understand in the beginning that the conditions as to class of traffic handled and its destinations are, to a very great extent, peculiar to the Virginian Railway, and perhaps have no counterpart in this country (unless it be the movement of iron ore by the Great Northern Railway from the mines to "Head of the Lakes"), in that the tonnage eastbound consists very largely of coal originating at mines located on its western subdivision north and west of Mullens and moving to tidewater at Norfolk, while westbound the movement is very largely empty coal cars.

The fact that such a large percentage of their eastbound traffic consists of coal moving to tidewater makes it, from a transportation standpoint, not only easy but very desirable, as an economical operation, to handle it in the largest units possible with safe operation; hence, the Virginian Railway has used very high capacity equipment for the handling of coal, having several hundred coal cars with a capacity of 70 tons and something over 2000 with a capacity of 120 tons, none of its coal carrying equipment having less than 55 tons capacity.

The use of such equipment has naturally called for special design as to trucks, draft rigging, drawbars, and air brakes. The cars of 120-ton capacity are not interchanged with connections but are used exclusively between the mines and tidewater. The same is true, to a very large extent, of cars of 70-ton capacity.

The track of the Virginian Railway is laid with 100-lb. and 130-lb. rail and is rock ballasted, bridges and everything connected with maintenance of way being constructed and maintained on a basis that permits the safe handling of not only cars of large capacity but heavy power and heavy tonnage trains.

Between Roanoke and Mullens, curves are numerous, with a number as sharp as 12 deg.

No high speeds are attained, for the following reasons:

1. The traffic conditions do not demand same.
2. It would not be possible to handle safely trains of the length and tonnage handled on the Virginian Railways at such speeds as many railroads handling a diversified business find it necessary to do.
3. The electric locomotives in service have but two constant speeds, viz., 14.2 and 28.4 miles per hour, and the maximum safe speed at which they can operate is 30 miles per hour.

Coal from mines located on the main line between Deepwater and Mullens and on the various branches of the New River division is handled from the mines to Elmore Yard (Mullens) by steam locomotives, and at Elmore consolidated for main line movement to tidewater. During the year 1924 (which was the full year immediately preceding beginning of electrification of the section from Mullens to Roanoke) the Virginian Railway handled 7,440,832 net tons of coal, while during the year 1927 (the first full year after completion of electrification) it handled 11,825,101 net tons of coal.

In the movement of eastbound traffic from Elmore Yard to Clarks Gap, Mile Post 361.5, summit of the Allegheny Mountains, a distance of approximately fourteen miles, the maximum grade is 2.07 per cent and the average grade for the entire distance is 1.85

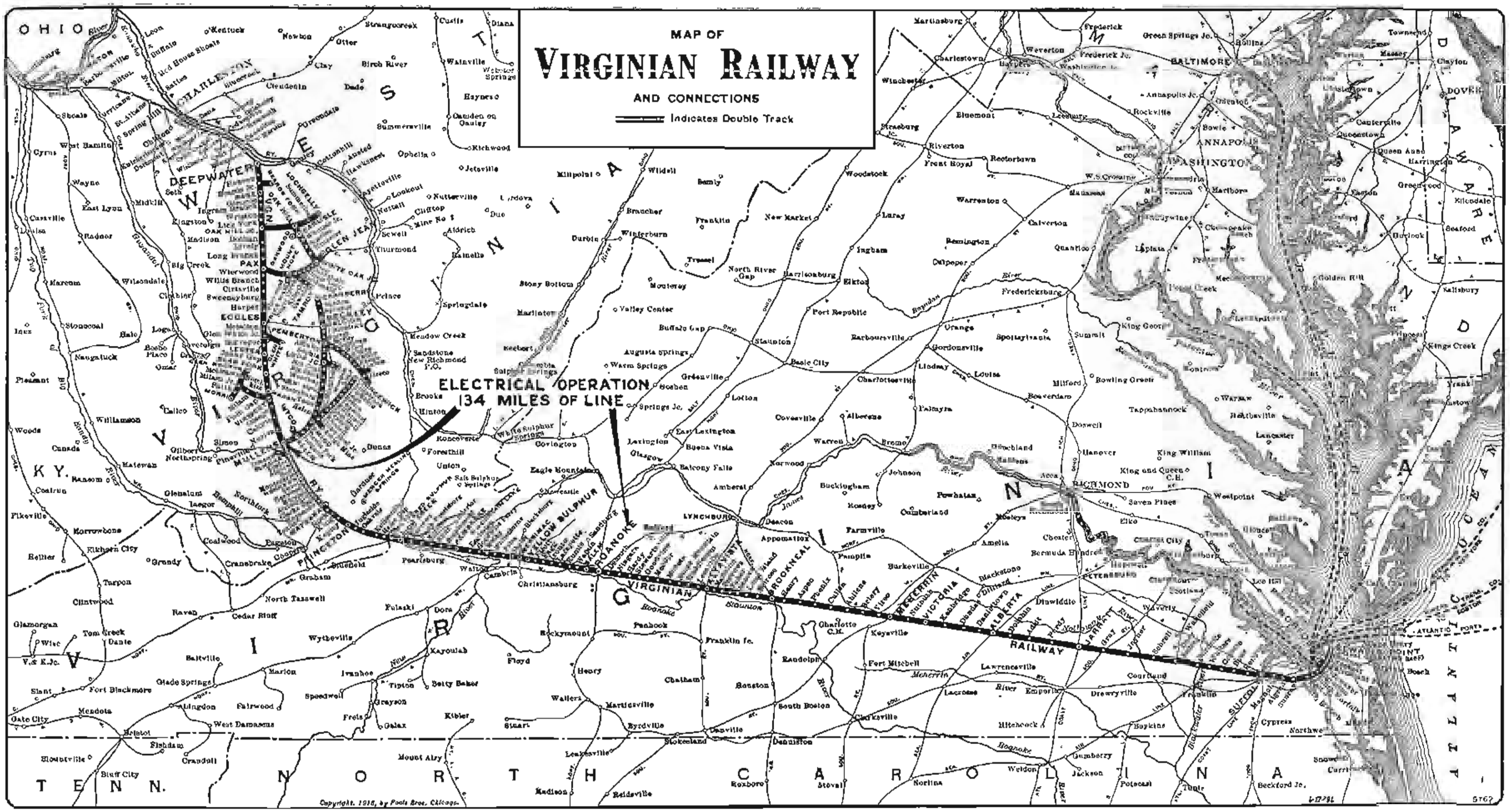
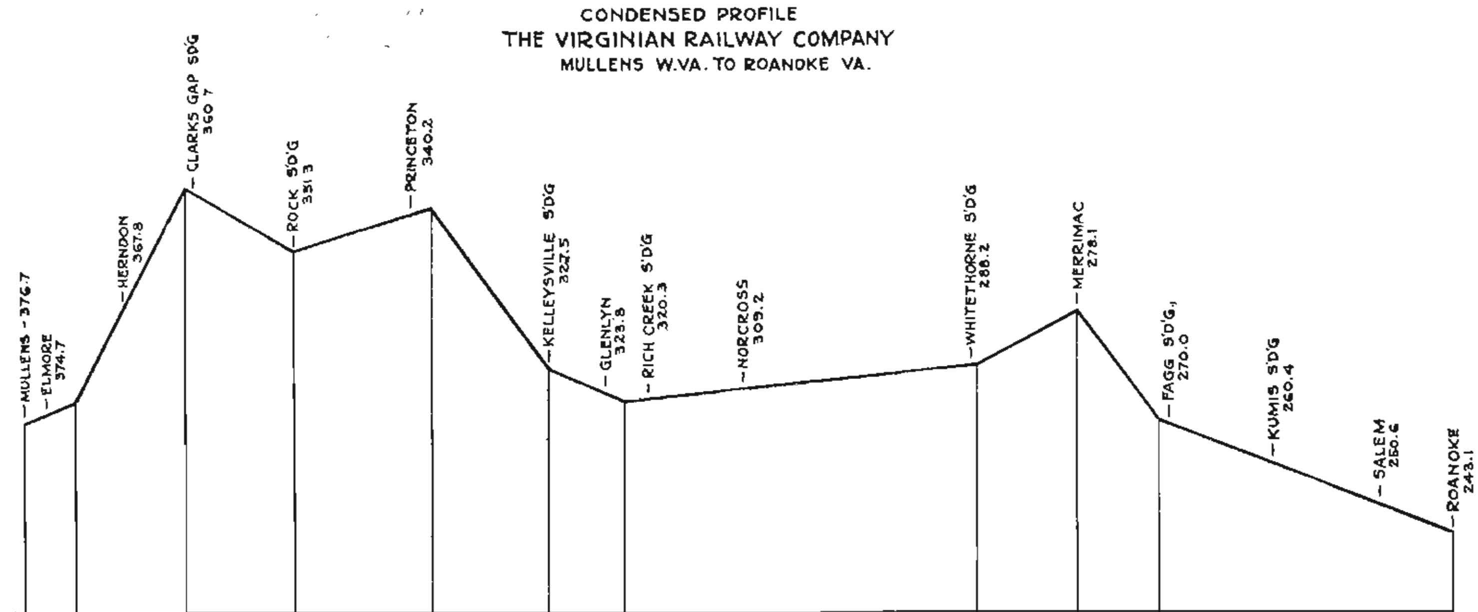


FIG. 1—VIRGINIAN RAILWAY—MAP OF ENTIRE ROAD.



MILES *		5.06	10.32	10.05	12.97	10.90	7.21	32.72	9.51	7.43	27.56
ELEVATION	1427.03	1528.42	2525.99	2132.61	2438.16	1674.13	1534.26	1700.65	1966.37	1445.86	926.0
COMPENSATED GRADE PER CENT	EAST	+.531	+1.979	−.396	+.402	−1.259	−.340	+.168	+.583	−1.252	−.313
	WEST	−.228	−1.681	+ 710	−.198	+1.395	+.391	−.024	− 475	+1.400	+.401
MAXIMUM GRADE %		1.21	2.11	1.25	0.60	1.50	0.808	0.20	0.60	1.5	0.9
AVER. CURVE DEG.		3.79	3.73	3.93	2.55	1.70	0.64	1.80	1.35	1.85	1.10
MAX. CURVE DEG.		12°	12°	12°	8°	8°-10'	3°	8°	8°	8°	8°
MILES FROM NORFOLK (FROM MILE POSTS)	376.73	371.67	361.36	351.33	338.40	327.49	320.29	287.59	278.10	270.67	243.11

* SURVEY EQUATIONS INCLUDED

FIG. 2—VIRGINIAN RAILWAY—CONDENSED PROFILE OF ELECTRIFIED DIVISION FROM MULLENS, W. VA., TO ROANOKE, VA.

FIG. 3—Virginian Railway—Showing Type of Country and Difficulties of Operation on Electrified Division.

FIG. 4—Virginian Railway—Innumerable Short Radius Curves Increase Difficulties of Train Operation.

per cent, while descending to the east the maximum grade from Mile Post 361.5 to Mile Post 352, a distance of nine and one-half miles, is 1.25 per cent, with an average over the entire distance of 0.575 per cent. From Mile Post 352 to Mile Post 338.6, a distance of 13.4 miles, there is an ascending grade of a maximum of 0.6 per cent, while from Mile Post 338.6 there is a maximum descending grade to Mile Post 328, a distance of 10.6 miles, of 1.5 per cent, with an average of 1.35 per cent, and from Mile Post 325.4 to Mile Post 321.4, four miles, there is a maximum descending grade of 0.80 per cent, with an average of 0.689 per cent. Otherwise, the maximum grade against eastbound traffic is 0.2 per cent.

The capacity of the Virginian Railway to move eastbound business is, due to the origin of its tonnage, practically limited to that which can be moved from Elmore to Clarks Gap. Before electrification, it required one 2-8-8-2 locomotive, with tractive effort of 101,300 pounds, and two 2-10-10-2 locomotives, with tractive effort of 147,200 pounds each, as helpers, to move a train of 5500 tons from Elmore to Clarks Gap, and the time in transit was from two hours to, in some instances, five hours. From Clarks Gap to Princeton, one 2-8-8-2 locomotive handled 5500 tons. At Princeton the train was filled to 10,000 tons, was given helper engine from Prineeton to Oney Gap Tunnel, a distance of two miles, and another helper engine from Whitethorne to Merrimac, a distance of nine miles. From Roanoke to Victoria, a Mikado type 2-8-2 locomotive, with traetive effort of 60,800 pounds, handled 7000 tons, while from Victoria to Norfolk the same type locomotive handled 7700 tons.

Owing to the heavy tonnage handled and the different classes of equipment used, it was necessary to classify the cars accordiug to capacity, placing the 120-ton capacity cars on the head end, 70-ton capacity cars next, and lighter capacity cars on the rear. This situation has not been changed by electrification.

The first move to increase the capacity of the line was the purchase of heavier motive power, later followed by the construction of a second track from Mullens to Mataoka, a distance of 22.02 miles, and, still later, the electrification of the Mullens-Roanoke subdivision. With the present electric locomotives, the Virginian Railway is handling from Elmore Yard to Clarks Gap, with one electric road locomotive and one electric helper locomotive, trains of 6000 tons. At Clarks Gap, trains are filled to 9000 tons and are handled by the one electric road locomotive from that point to Roanoke, a distance of 118 miles.

Since electrification, the 2-10-10-2 engines formerly used as helpers between Elmore and Clarks Gap have been assigned to the Roanoke-Victoria subdivision and are handling 12,000 gross tons, while the 2-8-8-2 USRA engines have been assigned to the Victoria-Norfolk subdivision and handle 11,500 gross tons.

Between Norfolk and Roanoke two local passenger trains each way daily and one local freight train each way daily except Sunday are operated; between Roanoke and Princeton one local passenger train in each direction daily and one local freight train in each direction daily except Sunday are operated; and between Princeton and Elmore, a distance of 35 miles, three passenger trains each way daily and one local freight train each way daily except Sunday are operated. Thus it will be seen that the through freight traffic has little interference. It is the operating practice to put passenger trains, local freight trains, and westbound through freight trains on the passing track at meeting points.

On a trip which I recently made over the Virginian Railway, the train left Elmore Yard at 8:06 a. m. with 6000 tons, with an electric road locomotive and a helper, arrived Clarks Gap, a distance of about 14 miles, at 9:03 a. m., filled train to a total of 9000 tons, departed Clarks Gap at 9:40 a. m., and made the run from Clarks Gap to Roanoke, a distance of 118 miles, without stop, arriving Roanoke at 4.08 p. m. It is the usual practice for eastbound freight trains to stop at Whitethorne for an inspection of the train, but in this instance such stop was not made, as, between Clarks Gap and Whitethorne, we had met both the passenger train and the local freight train, whose crews evidently inspected train as we passed and reported same in satisfactory condition.

Constant Speed Locomotives

Due to the constant speed of the electric locomotives, it is said that when a train leaves Clarks Gap the train dispatcher can tell at exactly what time it will pass various telegraph stations, and its arriving time at Roanoke within five or ten minutes, barring delays due to hot boxes or drawbar trouble. As previously stated, these locomotives have two constant speeds, viz., 14.2 or 28.4 miles per hour. They will occasionally slightly exceed this speed when regenerating on down grade, but 29 to 30 miles per hour is the maximum speed which they attain. In the movement from Clarks Gap to Roanoke, the air was not applied at any point, except in approaching Roanoke Yard and bringing the train to a stop after having been pulled into clear, the train being held on descending grades by regeneration. Hence, there is little brake shoe wear, little trouble due to brake beams down, and little trouble from overheated wheels. This situation is due to two causes: first, the brakes are seldom used, and, second, owing to their operating conditions, brakes and brake rigging are maintained at a high standard at all times.

The following morning, we left Roanoke at 8:10 a. m., with 113 cars, 12,077 gross tons, with a 2-10-10-2 engine, with tractive effort of 147,200 pounds, and arrived Victoria, 123.4 miles, at 6:30 p. m. Stops were made at Goodview, Huddleston, Phoenix, and Abilene for water, and at Seneca for coal and water, a total of five stops. One of the remarkable features in connection with the handling of this train was the absence of jars in stopping or starting. As a matter of fact, in spotting for coal and water automatic air was not used, but only the straight air on the engine, and, with one exception, namely, Seneca, the spotting for water was done

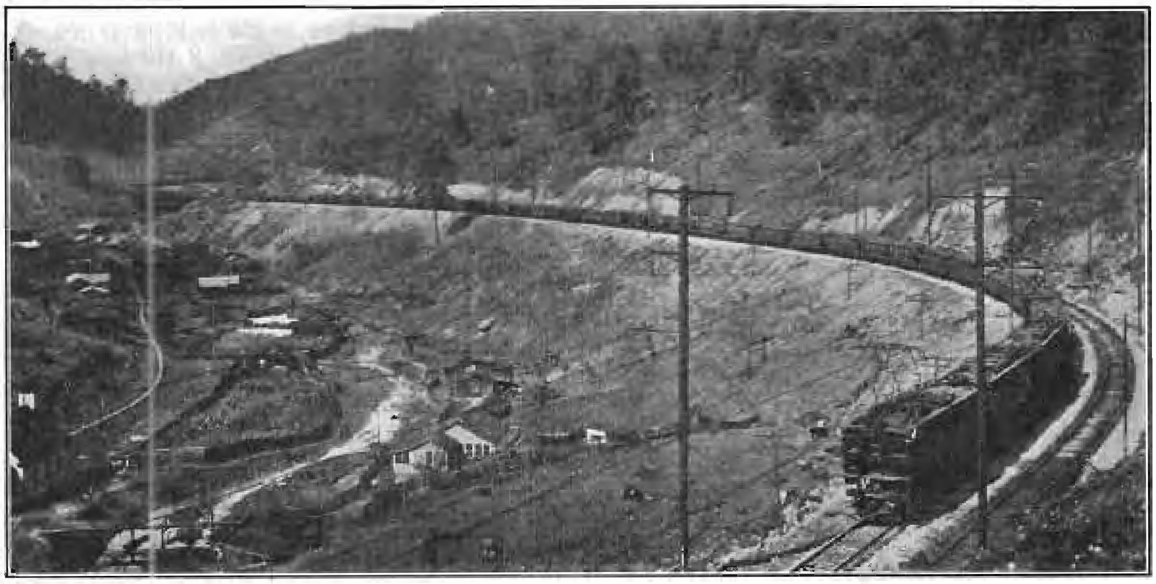


FIG. 5—Virginian Railway—9000 Ton Coal Train Pulled by 7125 H.P. Electric Locomotive.

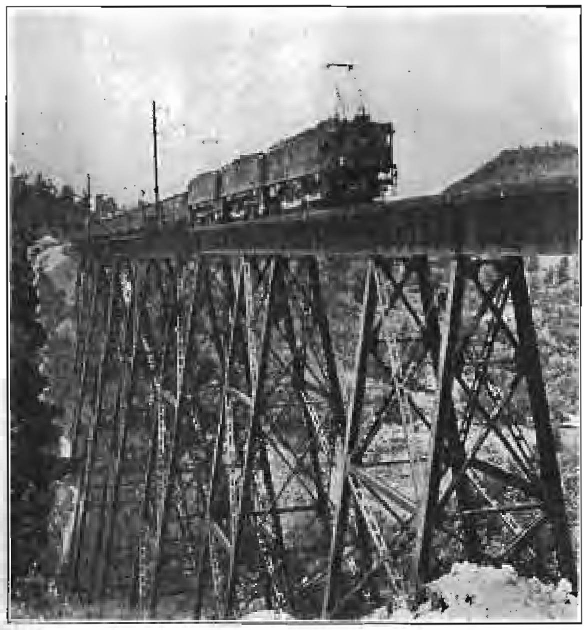


FIG. 6—Virginian Railway—Many High Bridges Are Found on Electrified Division.

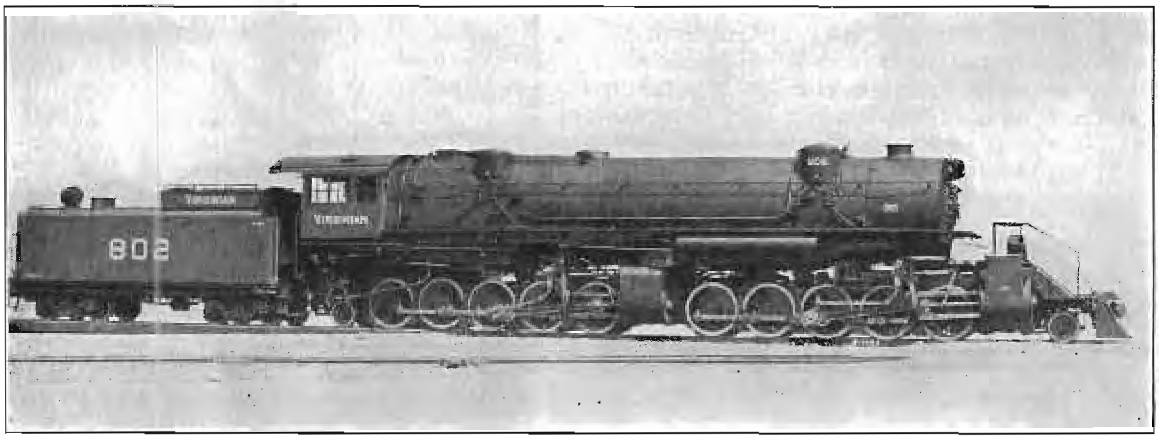


FIG. 7—Virginian Railway—2-10-10-2 Type Steam Locomotive Used as Pusher on Clarks Gap Hill Before Electrification. Now Hauling 12,000 Ton Trains, Roanoke to Victoria.

FIG. 8—VIRGINIAN RAILWAY—FRONT VIEW OF STEAM LOCOMOTIVE USED ON CLARKS GAP HILL PRIOR TO ELECTRIFICATION. TOTAL WEIGHT OF ENGINE AND TENDER 898,300 LB.

without cutting engine off of train. Between Roanoke and Victoria, we met one passenger train, one local freight train, and one westbound through freight train, consisting largely of empty coal cars, but in all cases these trains were on the passing track. Fortunately for the operation of the through freight trains, there is little local business, and the local freight trains are able to keep out of the way of through freight trains. As an example of this, the eastbound local freight train left Roanoke about one hour and fifteen minutes ahead of the through freight train and went into Victoria Yard ahead of it.

Coal Delivery to Ships

A very considerable portion of the coal handled by the Virginian Railway is delivered to vessels for either bunker or cargo at Sewalls Point. The Virginian Railway has two piers for delivering coal to vessels. The operation to the point of dumping into vessels is practically the same at both piers. At Pier No. 1 the coal is dumped into pockets and thence through a chute to the bunker or hold of the vessel; and, where delivered to the hold, it is necessary to use trimmers. At Pier No. 2 the coal is dumped into a traveling pocket and thence through a leg to the bunker or hold; and, when to the latter, is trimmed automatically by the leg, which has a specially designed, electrically operated conveyor for this purpose. At both piers, the method of transferring from the rail car to the electrically operated dumping car and to the coal pockets, or coal leg, is practically the same and is best understood by the accompanying cuts. It is possible to, and they do, handle two 55-ton or one 55-ton and one 70-ton cars, dumping them at one operation into the electric car that delivers to the hold or bunker. The capacity of the electric car which delivers the coal is 125 tons. It is stated that 20,000 tons have been delivered to vessels in three hours, and it is possible to deliver a total of 3,500,000 tons of coal per month to vessels.

Loaded cars are pulled onto the dumping cradle by an electric car puller, clamped into position, hoisted and rolled over, the coal falling onto an apron which directs it to the waiting electric dump-

FIG. 9—VIRGINIAN RAILWAY—FRONT VIEW OF 3-UNIT ELECTRIC LOCOMOTIVE WEIGHING 1,282,380 LB.

FIG. 10—Virginian Railway—Double Tracking Would Be Exceedingly Expensive on Account of the Topography of the Country.

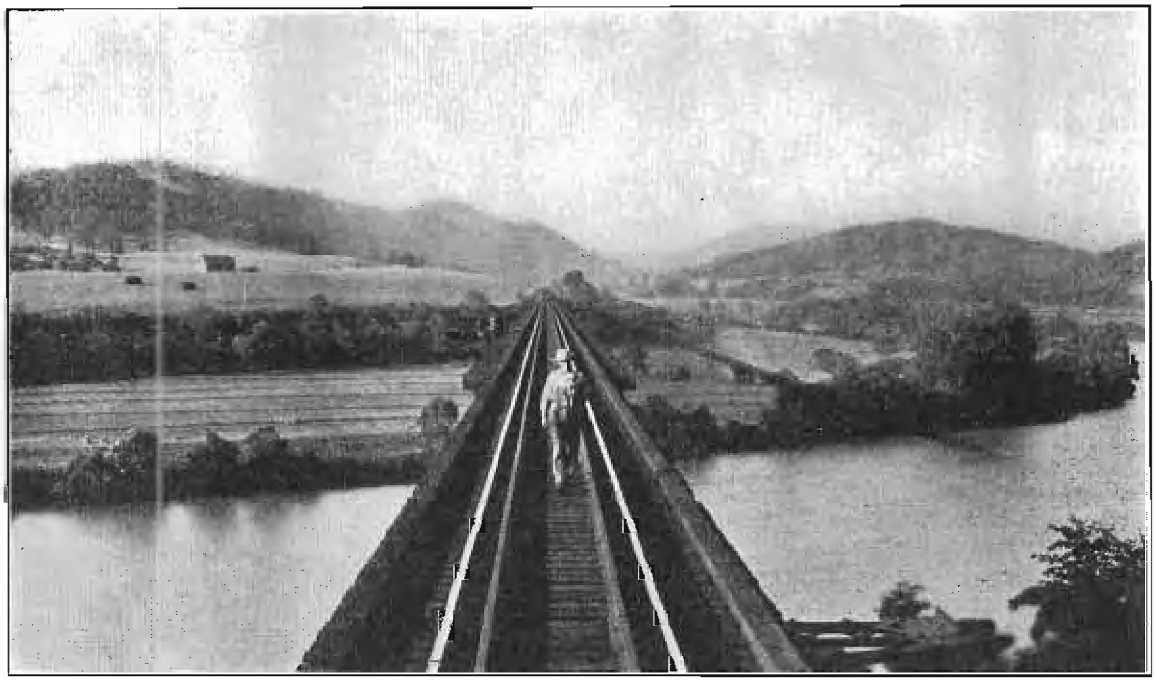


FIG. 11—Virginian Railway—The Track and Permanent Way Is Heavily Constructed and Well Maintained to Safely Carry the Heavy Locomotives and 120 Ton Capacity Coal Cars.

FIG. 12—VIRGINIAN RAILWAY—TYPICAL SCENE ON MOUNTAIN GRADE WITH TWO STEAM LOCOMOTIVE PUSHERS ON REAR OF TRAIN.

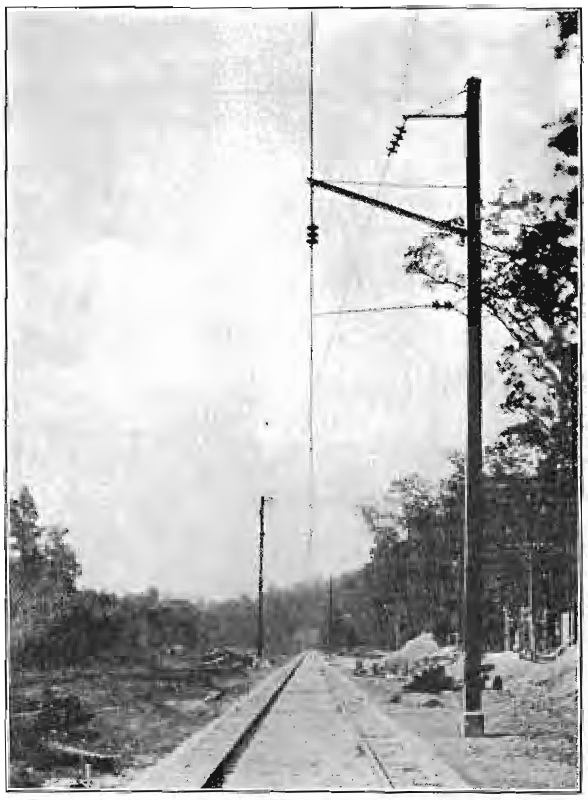


FIG. 13—VIRGINIAN RAILWAY—SIMPLE BUT STRONG OVERHEAD CONSTRUCTION WAS EMPLOYED FOR ELECTRIFICATION.

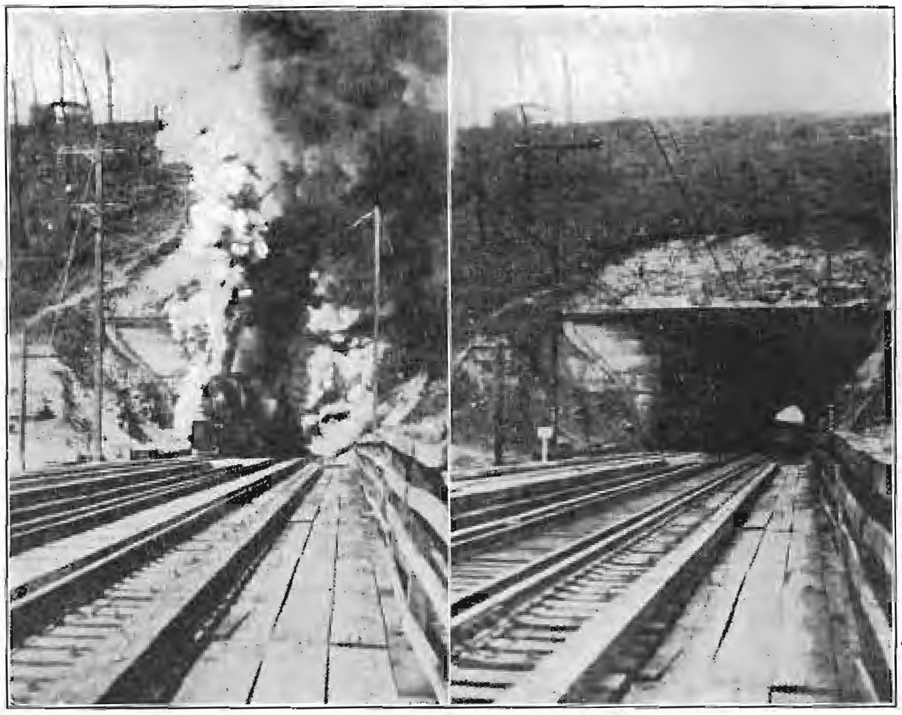


FIG. 14—VIRGINIAN RAILWAY—STEAM TRAIN AND ELECTRIC TRAIN LEAVING THE SAME TUNNEL.

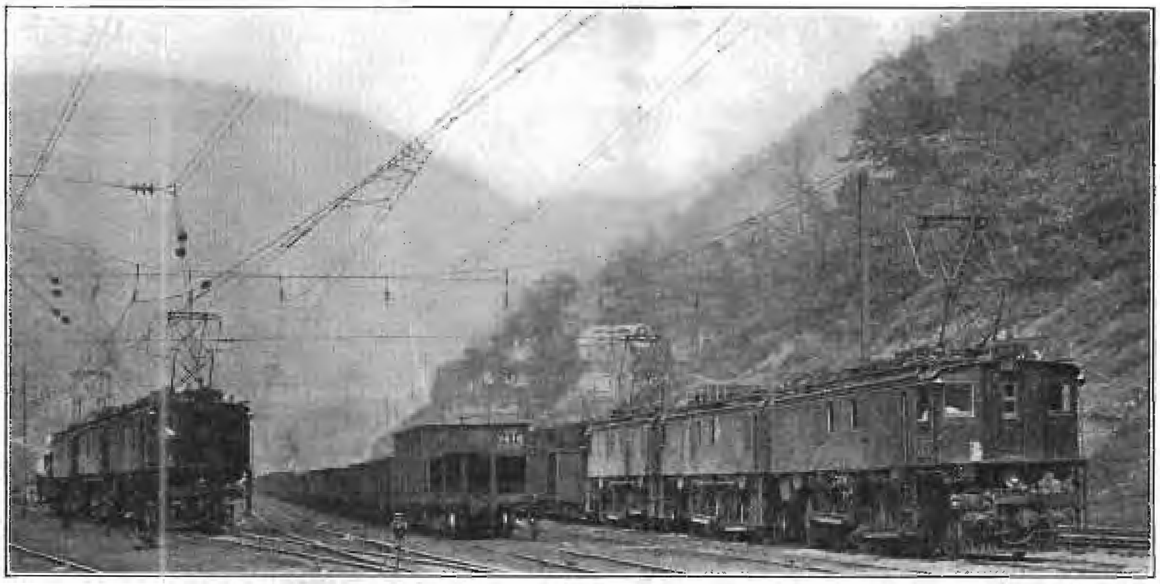


FIG. 15—VIRGINIAN RAILWAY—EAST END ELMORE YARD, W. VA.

FIG. 16—VIRGINIAN RAILWAY—WEST END ELMORE YARD, W. VA.

FIG. 17—VIRGINIAN RAILWAY—PRINCETON YARD, W. VA.

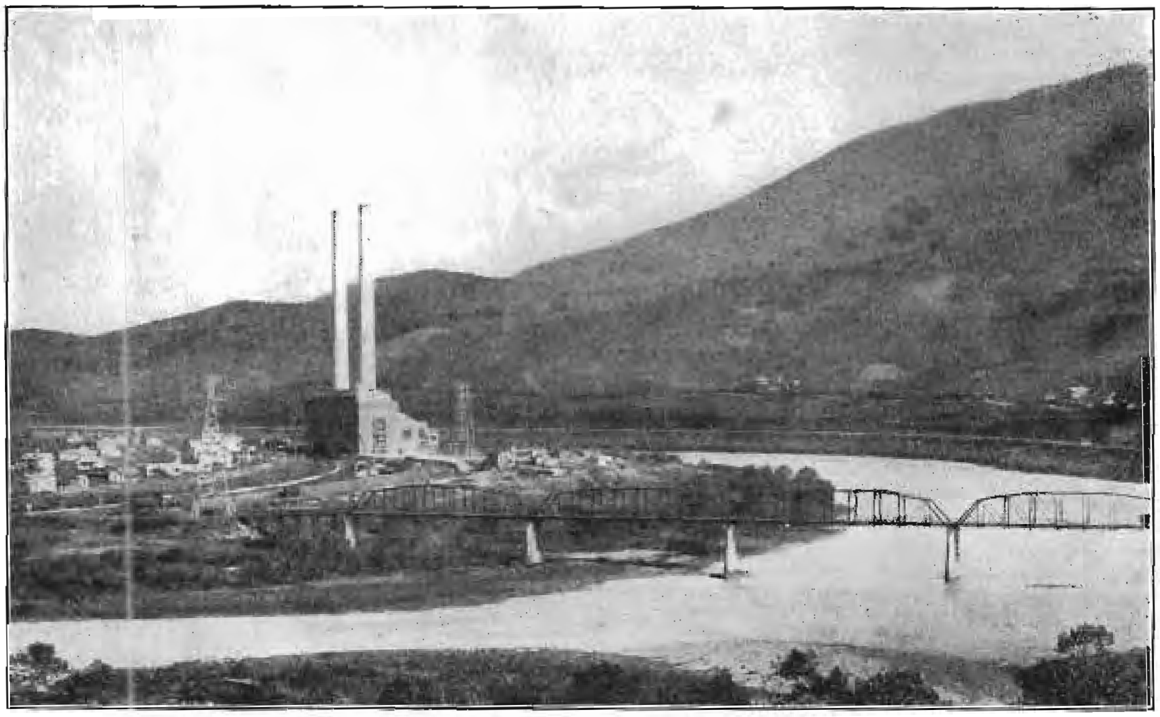


FIG. 18—VIRGINIAN RAILWAY—POWER PLANT AT NARROWS, VA.

ing or delivery car. These delivery cars are a complete operating unit, equipped with motors, air, and motorman's cab. There are two main tracks, one on each side, with center passing track, on top of pier, and double crossovers at each end so that cars can move promptly and without interference. Empty coal cars, when released from the dumping cradle, move to the empty yard by gravity.

Benefits of Electrification

Some of the benefits obtained by the Virginian Railway by electrification of its line from Mullens to Roanoke are:

1. A marked increase in train load from Mullens to Norfolk.
2. Elimination of turn arounds between Mullens and Princeton.
3. Saving of one hour or more on each eastbound train between Mullens and Clarks Gap, thus increasing its capacity to handle business.
4. Being able to move from 12 to 15 trains eastbound out of Mullens each 24 hours with an increased tonnage per train, as against 7 or 8 trains each 24 hours prior to electrification.
5. Being able to handle what is now normal business between Mullens and Merrimac without congestion or delay (there is but little question that, with the business handled in 1927 there would have been congestion in this territory under steam operation. It is a well known fact that congestion causes an increase in operating costs out of proportion to the increase in business).
6. Decreased cost of maintenance of equipment—reduced accidents and derailments.
7. Elimination of pusher out of Princeton and discontinuance of nine mile helper district from Whitethorne to Merrimac, with marked reduction in road overtime.

While the cost to electrify the section between Mullens and Roanoke was approximately $15,000,000 if electrification had not been undertaken it would have been necessary to spend large sums for additional heavy motive power and for additional second track in a territory where construction costs are very high, due to physical conditions necessitating heavy fills, deep rock cuts, and tunneling through mountains.

The results of electrification, as a whole, are best understood by a glance at the following figures:

In 1924 (the last full year previous to electrification) the Virginian Railway Company's cost of conducting transportation was 16.94 cents per hundred net ton miles, with total operating cost of 40.24 cents, while in 1927 (the first full year subsequent to electrification) the cost of conducting transportation was 13.63 cents, with total operating cost of 35.74 cents. This shows a decrease in operating cost of 4.50 cents per hundred net ton miles, or 11.2 per cent. The net tons moved one mile by the Virginian

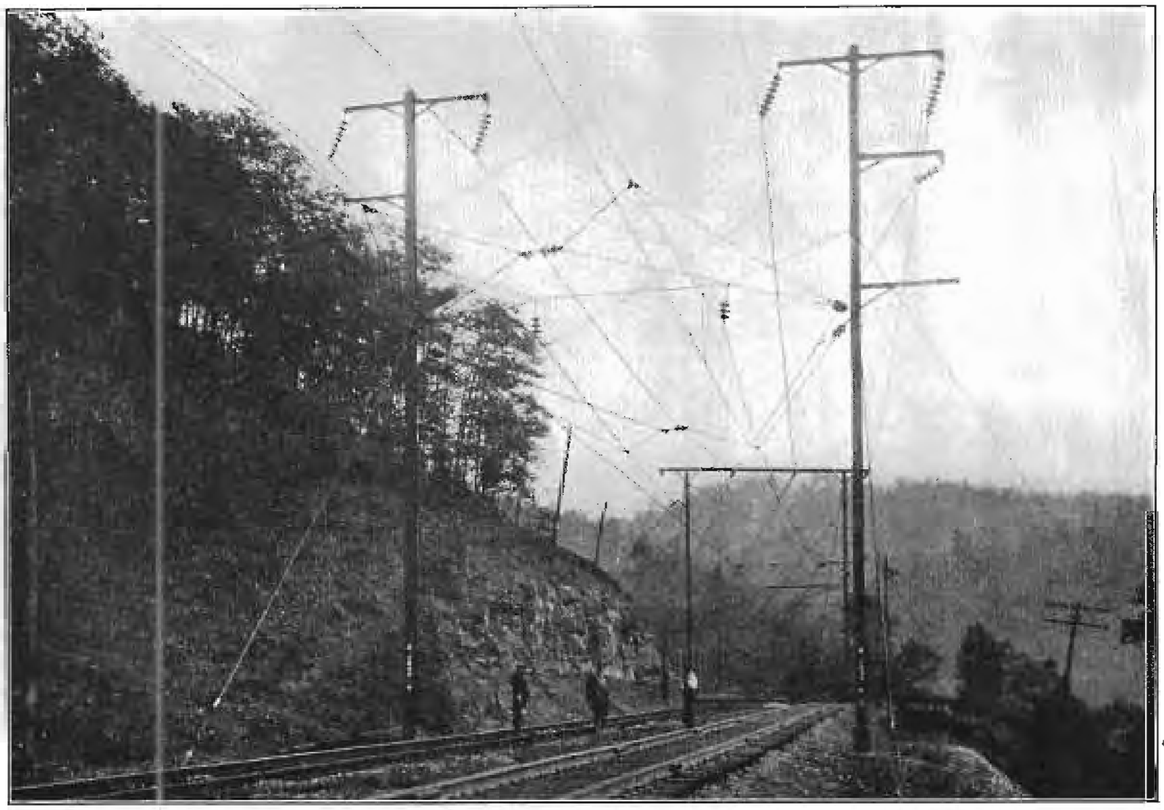


FIG. 19—VIRGINIAN RAILWAY—TYPICAL OVERHEAD CONSTRUCTION ON CURVES, ELECTRIFIED DIVISION.

Railway in 1924 was 3,034,366,000, while in 1927 the net tons moved one mile was 3,246,964,000. Applying the difference in operating cost of 4.50 cents per hundred net ton miles to the tonnage moved in 1927 indicates a saving of $1,461,133.80.

The figures quoted above represent the saving in total operating costs as between the years 1924 and 1927. I am unable to determine what part of this saving can be attributed directly to electrification and what part is due to other operating economies not associated with electrification.

In my opinion, there are few, if any, railroads with normal conditions as to class, direction, and density of traffic that would be warranted in electrification on a scale comparable with that which the Virginian Railway has accomplished. I question if any railroad having normal grades and operating conditions and handling a general business, such as is handled by the average railroad, in all kinds and classes of equipment, would be warranted in incurring the expenditure made by the Virginian Railway. It was apparently economical for the Virginian Railway, in view of its special operating conditions, class and trend of traffic, to do so.

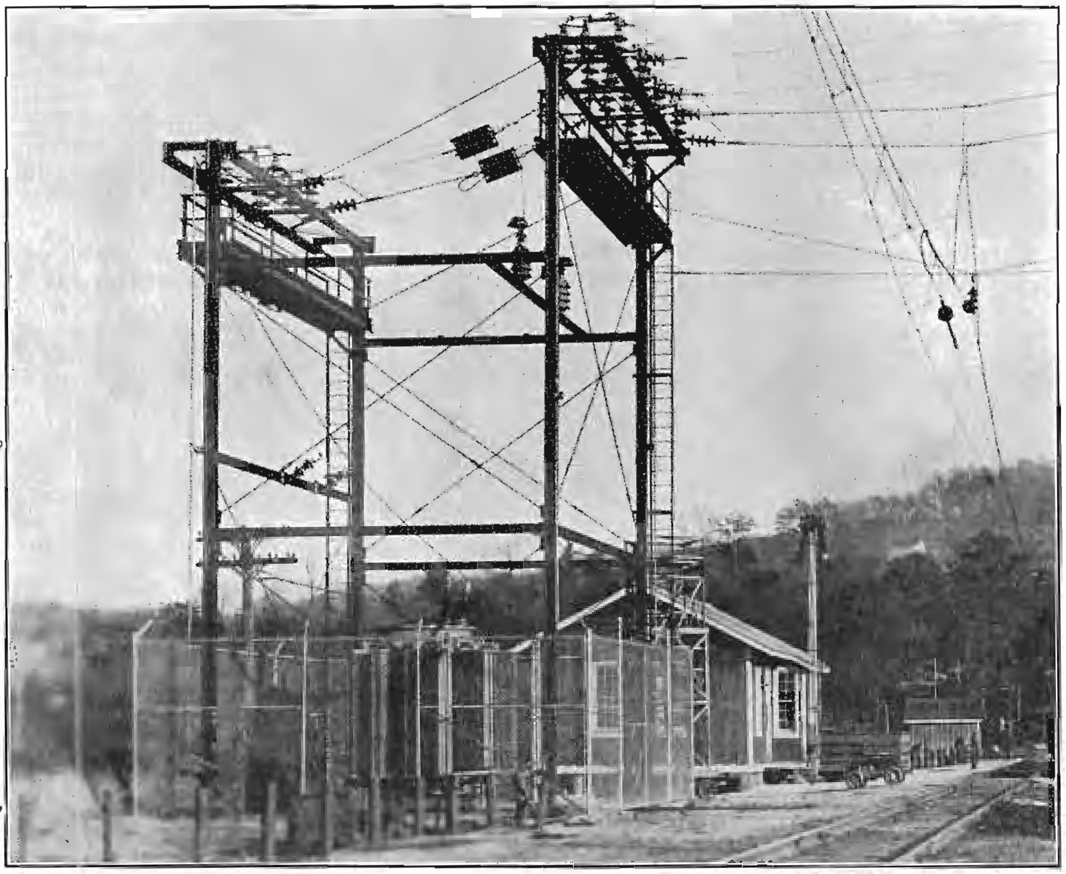


FIG. 20—VIRGINIAN RAILWAY—BALANCER STATION, ROCK, W. VA.

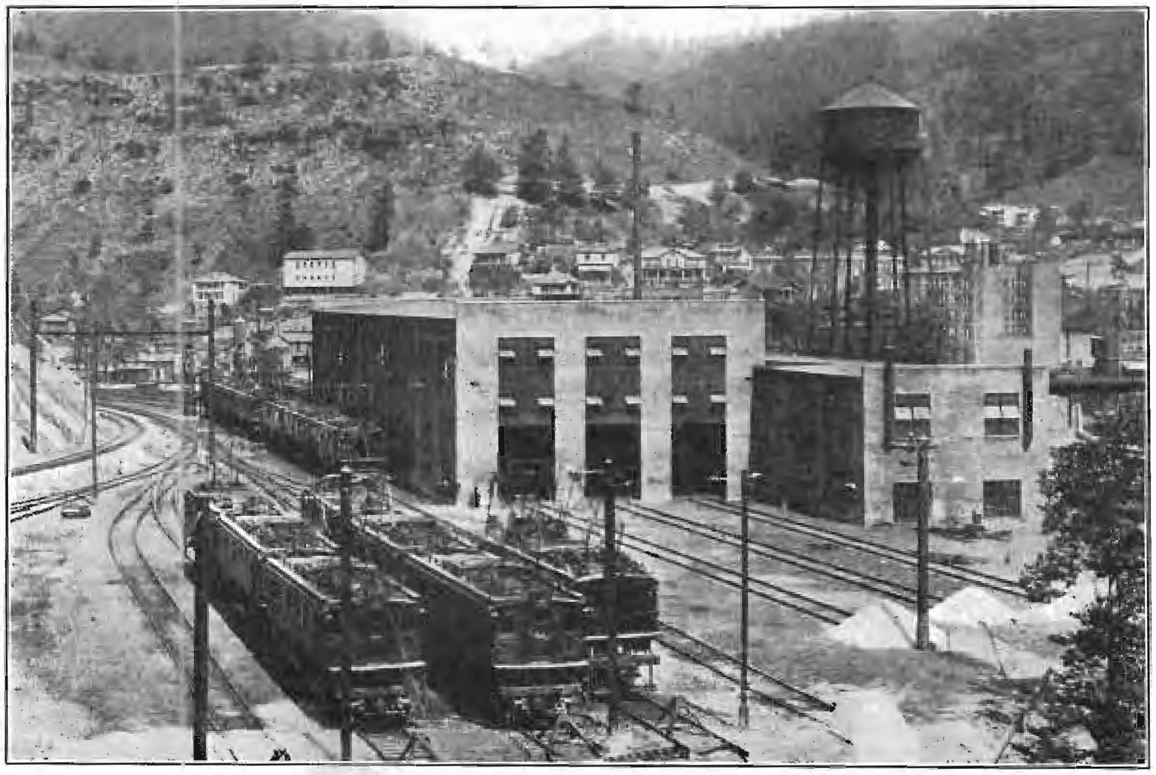


FIG. 21—Virginian Railway—Electric Locomotive Maintenance Shops at Mullens, W. Va.

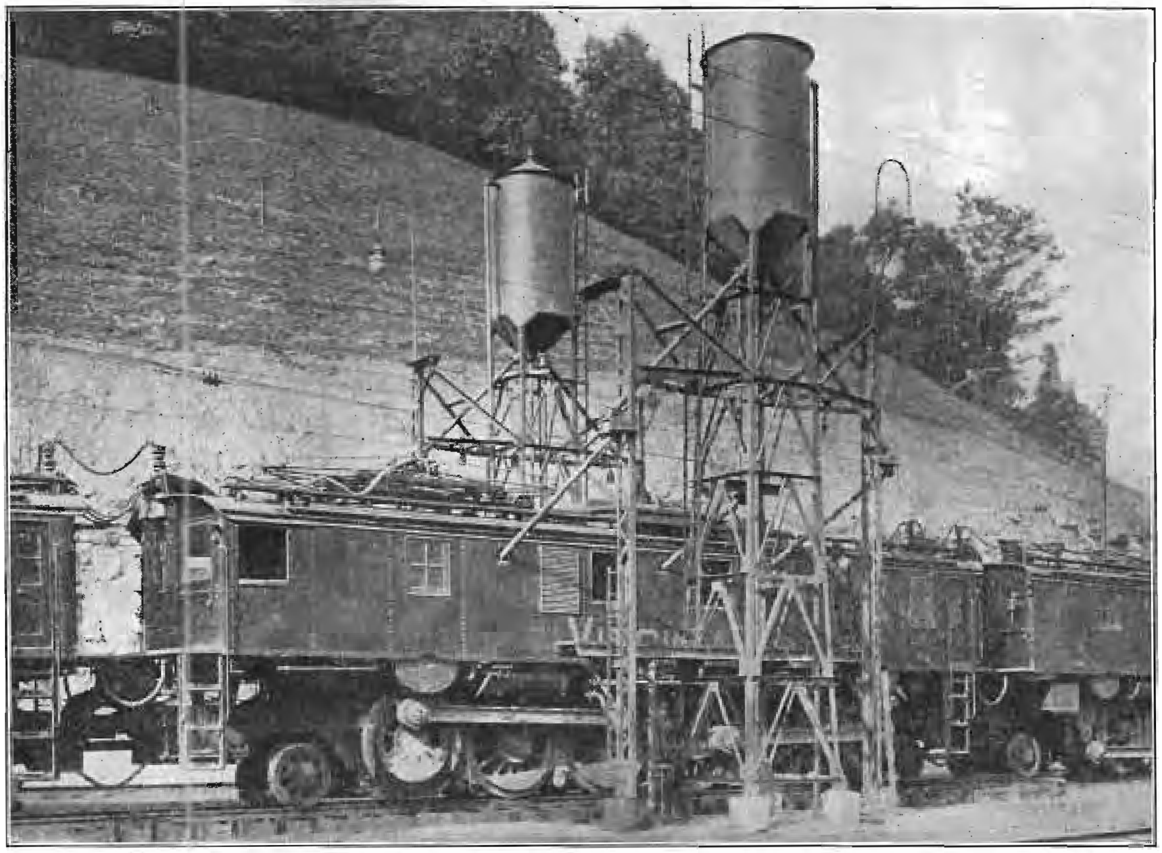


FIG. 22—Virginian Railway—Sanding Electric Locomotive at Mullens Shops.

FIG. 23—VIRGINIAN RAILWAY—GONDOLA CAR WITH CAPACITY OF 120 TONS.

FIG. 24—VIRGINIAN RAILWAY—CAR DUMPERS AT SEWALLS POINT, VA.

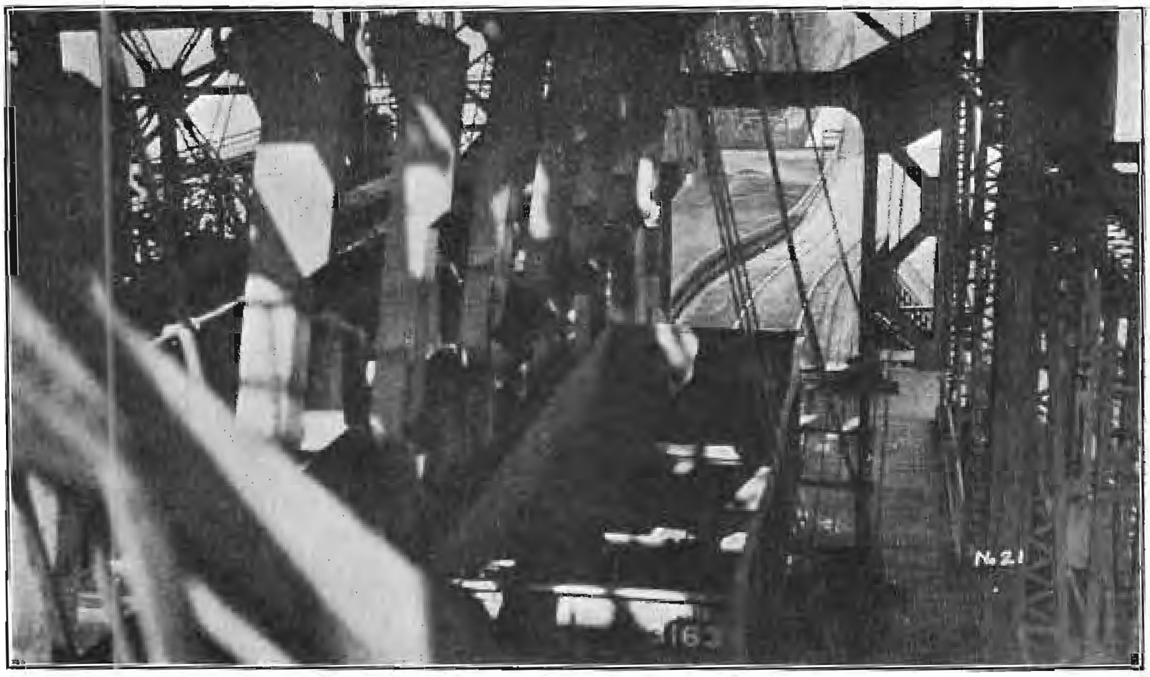


FIG. 25—VIRGINIAN RAILWAY—CARS ARE PULLED ONTO THE DUMPING CRADLE BY ELECTRIC CAR PULLER AND RETURNED TO STORAGE TRACKS BY GRAVITY.

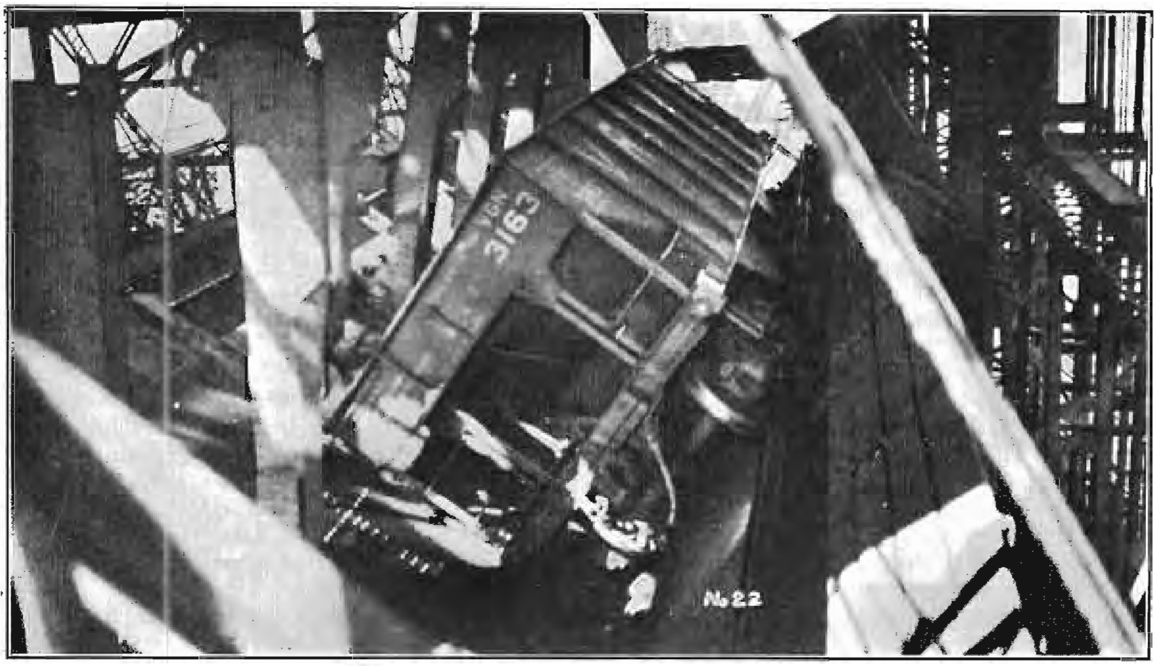


FIG. 26—VIRGINIAN RAILWAY—CARS ARE CLAMPED INTO POSITION ON DUMPING CRADLE, HOISTED AND ROLLED OVER.

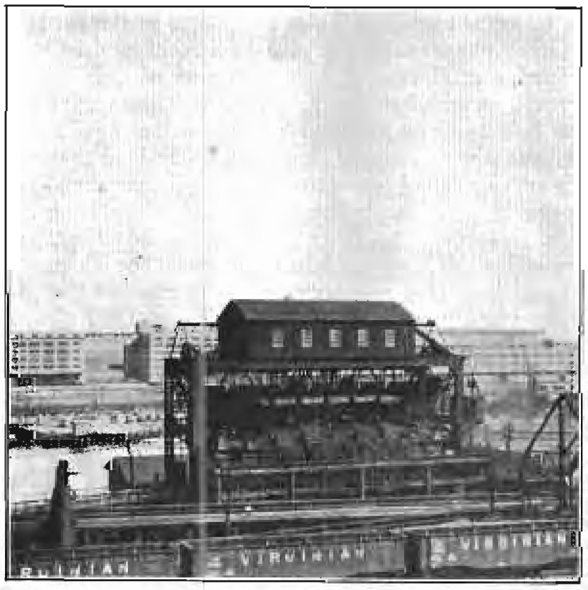


FIG. 27—VIRGINIAN RAILWAY—UPON LEAVING COAL CAR THE COAL FALLS UPON AN APRON WHICH DIRECTS IT INTO ELECTRIC DUMPING OR DELIVERY CARS.

FIG. 28—VIRGINIAN RAILWAY—DELIVERING COAL TO A BARGE BY MEANS OF ELECTRICALLY OPERATED, SELF-TRIMMING LEG.

APPENDIX II

THE ELECTRIFICATION OF THE ILLINOIS CENTRAL

BY LAWRENCE A. DOWNS, *President*
Illinois Central Railroad Company

An Address Delivered at the Fifty-first Convention of the National Electric Light Association

Electricity is nothing new in American railway operation. Three-quarters of a century ago, when the construction of my own railroad was just being undertaken, the first use of electricity in the operation of American railroads was begun. That was in 1851, when the first telegraph was installed to control the movement of trains. At that time there were only about 11,000 miles of railroad in the United States, compared with the quarter of a million miles we have today, and then there was not a single mile of railroad west of the Mississippi River.

I make these historical references because we are accustomed to think of electricity as a new factor in railway transportation, which it most certainly is not. New uses are constantly being found for electricity, however, and it is of one of these that I desire to speak. This fairly recent development, the use of electricity for railway motive power, had its inception in 1895 and has since grown to such proportions that nineteen American railroads now have approximately 4000 miles of electrified trackage in fifteen states of the Union and several railway electrification projects are now under way or in prospect.

The problems which have led to the adoption of electrification as a solution are many. In some cases, electrification has been adopted as a method of solving a combination of problems. The latter was the situation which led to the electrification of the Chicago terminal of the Illinois Central System. Because of the importance of this piece of work, you may be interested in hearing why it was undertaken, how it has been carried out to date, what it has accomplished and what is still expected of it.

In order to get the proper setting for the Illinois Central's Chicago terminal problem, we must go back to 1850, when Chicago had a population of approximately 30,000. South Michigan Avenue was then the principal residential street of Chicago, bordered on one side by stately homes and on the other by the shore line of the lake. Recurrent storms made it necessary for the city to incur considerable expense in protecting the avenue from the ravages of the lake, an expense to which residents of other parts of the city strenuously objected. This was the situation when the Illinois Central Railroad sought an entrance to Chicago. Plans were made to bring the railroad into the city along the south branch of the Chicago River, some distance from the lakefront, and these plans were submitted to the city council for approval. Just at the time, however, a fresh storm on the lake centered public attention upon the expense of lakeshore protection, and the harassed aldermen decided to force the Illinois Central to build its line into Chicago along the lakefront and to assume the responsibility and expense of lakeshore protection. This was done, and the Illinois Central came into Chicago by what might be called the front door.

Later, as Chicago grew from a frontier trading center to a great metropolis, there developed among its people a civic consciousness which found expression in the construction of many beautiful parks, boulevards and public buildings. Michigan Avenue became a magnificent boulevard, flanked by palatial hotels and clubs and towering office buildings, and a plan was worked out for the beautification of the lakefront by the construction of a succession of islands, lagoons and bridges to form a great new park extending from Jackson Park on the south to Lincoln Park on the north, and traversed for its entire length by two main boulevards. The negotiations growing out of the monumental plan for the beautification of the lakefront necessarily involved the Illinois Central. Certain riparian rights which had been acquired by the railroad when it was forced to assume the responsibility and expense of lakeshore protection had to be recovered and property boundaries had to be agreed upon. Meanwhile, the abatement of smoke had become a live issue. All the Chicago railroads put together contributed only a small part of the total visible smoke of the city and still less of the atmospheric pollution, but the prominent location of the Illinois Central on the lakefront made it a special target in the crusade.

Other elements in the situation combined to point toward electrification as a solution of the Illinois Central terminal problem. Suburban passenger service had been established in 1856 between Chicago and the then outlying village of Hyde Park, and this service had grown to immense proportions with the residential development of the Greater South Side. Despite its large patronage, however, this service had been a constant drain upon the income of the railroad, and no conceivable increase in commutation rates would place it on a self-supporting basis. Furthermore, the service was approaching a point where it would be necessary to retire its old equipment and to make extensive increases in its operation.

The Need for Electrification

Physical difficulties were encountered, too, in the operation of freight and through passenger service. The Illinois Central through passenger terminal, which had been one of the largest and most beautiful passenger terminals in the world when it was opened in 1893, the year of the Columbian Exposition at Chicago, had been outgrown. Freight operations were also approaching the point of congestion, and increased capacity had to be provided.

Faced with this multitude of problems, the Illinois Central participated in a series of negotiations with local governmental bodies, beginning in 1911, which resulted in an agreement taking effect in 1920, and the electrification of the terminal was an important part of that agreement.

In carrying out the electrification project in a manner to provide for the inevitable future growth of Illinois Central freight, passenger and suburban business at Chicago and assure the maximum efficiency in terminal operations, the Illinois Central is practically reconstructing its entire Chicago terminal. The electrification itself is being undertaken by stages. First is the electrification of the suburban service; that stage was completed in August, 1926, six months ahead of the time agreed upon. Next will come the electrification of freight operations, and later the electrification of through passenger operation.

When the electrification is completed, it will cover 420 miles of freight, passenger and suburban tracks. In addition to the electrification itself, the whole Chicago terminal improvement project includes: the elimination of both highway and railway grade crossings on the main line for a distance of thirty-eight miles south of the Chicago River; relocation of nearly all tracks in the Chicago terminal area; the movement of approximately ten million cubic yards of earth; construction of an immense gravity freight classification yard on the outskirts of the city; construction of extensive shop facilities; relocation and construction of freight and passenger car yards; construction of bridges, tunnels and subways; erection and reconstruction of suburban stations and platforms; erection of a through passenger terminal at the south end of Grant Park; construction of 250 miles of new trackage; construction of several miles of retaining walls and the reconstruction of the signal and interlocking system.

Some of these improvements were not essential to the electrification and could have been deferred until later, but it would have been more difficult and costlier to carry them out after electrification. The elevation and depression of tracks for the elimination of grade crossings, for example, was far more economical under steam operation than it would have been after the overhead supports were erected and transmission wires were in place on fixed bridges. A permanent track plan was worked out which will reduce to the minimum the possibility of having to shift tracks after electrification.

The electric suburban service covers a zone embracing 37.8 route miles and 127 miles of trackage. In the electrification of this service it was necessary to erect more than 900 catenary structures and to string approximately 293 miles of transmission wires and 470 miles of messenger and contact wires. The 1500-volt d-c. system with overhead contacts is used.

The electric service was begun with new equipment throughout. The cars, specially-designed for this service, are of all-metal vestibule construction, each having a seating capacity of eighty-four. Spaciousness, cleanliness, good ventilation, uniform heating and ample lighting are among their notable features. The trains are operated in multiple units of two cars—a motor car and a trailer semi-permanently connected—and four-car and six-car trains are most numerous, although station facilities have been designed to accommodate eight- and ten-car trains where required. At present 260 cars, having an aggregate seating capacity of approximately 22,000 persons at one time, are in use, and these cars are carrying approximately 120,000 passengers every week day.

Purchasing Power

Aside from equipment the most important factor entering into the electrification of the suburban service of the Illinois Central System was the choice of power supply. The practicability of constructing an independent power system, including generating plants, transmission lines and substations, for the sole use of the railroad was carefully considered, but the decision was against doing so and in favor of purchasing all electrical energy, under contract, from the Commonwealth Edison Company. Under this arrangement, the Commonwealth Edison Company erected its own substations at designated points on the right-of-way, and it now supplies direct current to the traction system and a-c. of suitable characteristics, for signal, light and other auxiliary uses.

I believe you will be interested in an outline of the reasons which led us to adopt this plan. The erection of an independent power system would have involved a heavy investment on the part of the Illinois Central, and the high cost of generation in such a plant, by reason of the necessity for a relatively high percentage of reserve generating capacity and on account of the comparatively small peak load demand, would have made the operation inherently less economical than the purchase of energy from a large and highly-organized power system. Furthermore, the ownershp and operation of such a plant would have carried the railroad out of its sphere into the highly-specialized field of power production, a field in which it might have been difficult for the railroad to keep itself up-to-date. Moreover, uninterrupted service must be maintained. Any breakdown of electric supply in such a busy terminal would be highly disastrous. The purchase of energy from a large power system having an ample generating reserve and duplicate transmission lines assures the Illinois Central of a dependable, uninterrupted supply of energy.

In its physical characteristics, the electric suburban service represents a vast improvement over the steam service which it replaced. The widespread public approval that has been given this service is evidenced by the fact that the present volume of suburban patronage is already more than one-third greater than immediately prior to electrification in 1926. The increase in patronage has been so much greater than was anticipated that we have already found it necessary to place orders for twenty additional cars for early delivery. Because the running time of trains has been reduced between 11 and 28 per cent, electrification has increased the desirability of outlying communities by bringing them all within closer reach of the central business district.

Losses Wiped Out

I have already referred to the fact that under steam operation the Illinois Central suburban service was an unprofitable enterprise. It not only was failing to pay a return upon the investment in suburban facilities and equipment, but the revenues were not sufficient to meet out-of-pocket expenses. By reason of the greater economy of operation and the increased patronage which followed electrification, in addition to an increase in rates which shortly preceded it, these out-of-pocket losses have been entirely wiped out, and the service is now producing considerably more than enough revenue to pay operating expenses and taxes. Although the present net income is still substantially short of a fair return on merely the outright cost of the suburban electrification itself, including the $10,000,000 worth of equipment purchased, there is ground for hope that with the continued growth of patronage the time will eventually come when the suburban service will be fully self-supporting, including a moderate return upon the whole investment.

One of the potential by-products of railway electrification in the larger cities is the development of air rights. The development of such rights at New York demonstrates the possibilities in this direction at Chicago. The Illinois Central owns sixty-five acres of valuable property adjacent to the Loop business district in Chicago which will be available for air rights development as a result of the electrification of the terminal. It will be some time before these air rights can be fully developed, but they will be of large importance in estimating the eventual results of electrification.

Because of the prominence of our electrification program—the publicity it has received and the discussion it has caused—I am often asked for an opinion concerning the future of railway electrification. I am not given to prophecies, but I think there is no doubt that utilization of electric energy will continue to increase as special problems in railway capacity and operation are encountered.

As I see it, there are two elements which will have important influences upon the future development of railway electrification. The first of these is the development in the art of applying electricity to the problems of railway operation. Thus far it can hardly be said that railway electrification has passed out of the experimental stage. It has not been standardized to the extent of steam railway design. Each project that is undertaken is a new experiment in that it deals with a special problem, all phases of which have not been developed heretofore. I regard our own electrification as such a project. I have faith that the results we shall finally accomplish will fully compensate us for the expense we incurred, but when costly undertakings are being considered without the necessity which forced the Illinois Central into its electrification program it takes more than faith to justify the large expenditure involved. Engineers must know in advance that the results will be sufficient to pay a full return upon the investment, and they must be able to marshal the facts with which to support that knowledge.

If you are desirous of hastening the utilization of electricity in the solution of railway problems, there is scarcely any service you can render of greater importance than that which looks toward the development and standardization of the art of producing electrical energy and its application to steam railway operation. I do not mean that all types of electrification should be alike, for there are many different problems to solve, but I do mean that the art shall be reduced to such generally applicable terms that a railway engineer can know that under certain definite conditions certain definite results will be produced.

The other important element influencing the future development of railway electrification is the financial element. After it is proved that money can be saved by spending money for electrification, there is still the problem of where to get the money to spend. Every railroad in the country has plans for large engineering projects of demonstrable money-saving value that must be deferred from year to year because the money is not readily available with which to carry them through.

Fair Treatment for Roads

Here, too, but in another way, you can make a real contribution not only to the progress of railway electrification but also to the continued improvement of railway service and the increased economy of railway operation. That is by using the great weight of your influence in behalf of that character of treatment of the railroads that will maintain rate levels against the onslaughts constantly being made to beat them down.

The law under which railway rates are now regulated has been in existence since 1920. That law provides that rates shall be made so the railroads as a whole, under honest, efficient and economical management, will be able to realize a fair return upon the value of their property. The honesty of railway management in this period has been above question. The efficiency and economy of railway operation are matters of record. The railroads have fulfilled their part of the agreement. But, notwithstanding the demonstrated efficiency and economy of railway operation, and in spite of the record-breaking traffic that has been moved, there has not been a single year in all this period when the railroads of the country as a whole have earned the 5¾ per cent on the value of their properties which the Interstate Commerce Commission has held to be the fair return contemplated under the law of 1920, and pressure has been constantly brought to bear upon the railroads and the Interstate Commerce Commission for lower rates.

A simple illustration will show the results of the constant pressure for reduced rates. On the Illinois Central System our average revenue for hauling a ton of freight one mile was reduced from 9.66 mills in 1921 to 8.86 mills in 1927. Now, this reduction of eight-tenths of 1 mill per ton mile may seem to be a small item, but when it is applied to the 16⅓ billion ton miles of revenue freight handled by the Illinois Central System last year, it amounts to more than $13,000,000—and $13,000,000 is 6 per cent on approximately $216,000,000. I am not going to say that this missing $216,000,000 worth of potential investment would have been made in electrification if we had had it at our command, but you can see for yourselves how much better disposed toward electrification a railroad with $216,000,000 extra of investment power would be than a railroad that lacked such an amount.

The constant downward adjustment of rates threatens to undermine railway credit. Credit is dependent upon adequate rates. If the railroads are to improve their properties and increase the capacity of their plants in keeping with the ever-increasing demands which are being made upon them, they must be allowed to earn returns that will attract the needed capital. As persons interested in railway electrification, you will appreciate the importance of that point.

The electrical industries and the railroads have much in common. Both are engaged in providing for the masses of our population services of the most essential nature which have contributed greatly to the effectiveness of human endeavor. Both face large and important problems arising out of their common necessity for increased production, greater economy and equitable regulation. Finally, the buyer-and-seller relationship between them has grown to large proportions as the railroads have come to make greater use of electricity for light and power and the expanding electrical industries have made greater use of the transportation service which is the product of railway operation.

Both industries have felt the blighting effect of misguided public opinion in the past. Both have been the targets for hostile legislation and restrictive regulation. Both have consciously and earnestly sought to improve their relations with the public. There is no question in my mind that a great deal has been accomplished in this direction in the last decade. This accomplishment is reflected in the friendly attitude that now prevails generally in the public mind toward these industries, and in the increased tendency on the part of law-making and regulating bodies to give them both a square deal.

I have been impressed by the excellent work which the National Electric Light Association and the various electrical companies have been doing in recent years toward bringing about a better public understanding of their problems. There is no question that the whole electrical industry has been vastly benefited by this work. I believe it has had a beneficial effect upon corporations generally. On the other hand, the efforts of the railroads along similar lines have probably benefited your industry in like manner. Such efforts are cumulative in their effect. Their full benefits will not be felt for years to come. It takes time to efface the long-standing prejudices of the past and to bring the public mind, long given to mistrust of corporations, into a sympathetic understanding of their problems.

Confidence and cooperation cannot be built on any other basis than that of mutual understanding and such understanding can be obtained only with the constant interchange of trustworthy information and intelligent discussion. The public is fair when it knows the facts and understands them. To me it is unthinkable that the frank, open, straightforward course which has increasingly marked the conduct of business affairs in recent years shall be abandoned. And if we continue in that course, earnestly striving not merely to win but to merit public good-will, I am confident of the outcome.