II. The Evolution of Steam Railroad Electrification*

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III. Development of Electrification in the United States

STEAM railroad electrification in the United States had its origin when the Baltimore and Ohio Railroad electrified its Baltimore tunnel to eliminate the menace of operation under smoke hazards. This occurred in 1895. About the same time, the New Haven installed electric traction on a small portion of its Nantasket Beach branch. Both electrifications were experimental and crude when compared with the standards set by modern electric installations. It must be remembered that these two electrifications were completed only a few years after the first commercial application of electricity to railroad transportation. In 1888 F. J. Sprague had introduced the electric trolley system in Richmond, Virginia, and in 1894 the City of Chicago granted the Northwestern Elevated Railway Company a franchise to operate an electric railway.[7] Thus, as might be expected, early steam railroad electrifications were not looked upon as introducing a new era in motive power for transportation.

Railroad electrification in the United States may be divided into three periods: the first, from the Baltimore tunnel installation to the initiation of electric operation on the Milwaukee in 1915; the second, from 1915 to 1919; and the third, from 1920 to the present. While the characteristics which help to set off these periods overlap, it is possible to make a general summary if this overlapping is kept in mind (Table IV).

The Period 1895-1915. The two 1895 electrifications were followed within a few years by the installation of electric traction on a portion of the New Haven then characterized by relatively dense passenger traffic. Third-rail collection of D. C. power was employed then, as in practically all electrifications prior to 1907, at which time the Erie used overhead collection of alternating current in its Rochester-Mt. Morris installation. Manson, in his *Railroad Electrification and Electric Locomotive* (p. 127), adds that the latter installation "bears the distinction of being the first case where a single-phase alternating-current system has been placed in commercial operation on a steam railroad."

Up to 1905, electrifications were largely the result of so-called voluntary factors. However, in 1905 the Long Island Railroad was forced by legislation of the City of New York to electrify its tunnels in the terminal area included within the city limits. Considering tunnel electrification alone somewhat less economical than electric installation on an entire division, the Long Island electrified nearly 40 miles of its Flatbush-Rockaway Division.

* The previous installment of this article analyzed the reasons for electrification of steam railroads, and traced its development in Europe from its beginning in 1893 together with a description of the various types of installations in use there. Footnotes and tables in this article are numbered consecutively with the first installment.

[7] H. S. Haines, *Efficient Railway Operation* (New York: Macmillan Co., 1919).

In 1906 the New York Central electrified its tunnel and terminal approaches in the New York area. Electrification was extended to White Plains,

TABLE IV. STEAM RAILROAD ELECTRIFICATIONS IN THE UNITED STATES, AS OF JUNE 30, 1930*

Railroad	Mileage Electrified			Date	System Installed	Type of Service	Reasons Assigned for Electrification
	Route	Track	Percentage of Route to Track Miles				
Baltimore and Ohio (Baltimore Tunnel)	3.60	7.96	45.2%	1895	650-D. C. Third-rail	Freight and passenger	Tunnel smoke
Boston and Maine (Hoosac Tunnel)	7.92	21.38	37.0	1911	11,000-A. C. Overhead	Freight and passenger	Increase capacity; eliminate tunnel smoke
Butte, Anaconda and Pac. (Butte-Rocker, Mont.)	37.38	122.75	30.5	1913	2,400-D. C. Overhead	Freight and passenger	Increase capacity; general economy
Chicago, Milwaukee, St. Paul and Pac. (Montana-Idaho-Washington)	658.77	878.47	75.0	1915–27	3,000-D. C. Overhead	Freight and passenger	General economy; heavy grades; tunnels; increase capacity
Delaware, Lackawana and Western (New Jersey Suburban)	78.70	173.00	45.4	1930	3,000-D. C. Overhead	Suburban	Increase facilities; petition from communities to be served; rates guaranteed
Detroit, Toledo and Ironton (Fordson-Flat Rock, Mich.)	16.58	50.05	33.1	1926	22,000-A. C. Overhead	Freight	City ordinance; increase capacity; smoke elimination
Erie (Rochester-Mt. Morris, N. Y.)	33.76	36.23	93.2	1907	11,000-A. C. Overhead	Freight and passenger	Increase facilities
Great Northern (Cascade Tunnel)	25.50	31.70	80.4	1909–28	11,000-A. C. Overhead	Passenger and freight	Smoke elimination; increase capacity
Illinois Central (Chicago-Richton, Ill.)	37.80	127.10	29.7	1926	1,500-D. C. Overhead	Suburban	City agreement; smoke elimination; increase facilities
Long Island (Long Island)	138.08	424.40	32.5	1905–26	650-D. C. Third-rail	Suburban, passenger and freight	City ordinance; tunnels; cooperation in terminal operation
Michigan Central (Detroit-Windsor, Can.)	4.60	28.55	16.1	1910	650-D. C. Third-rail	Freight and passenger	Smoke in tunnel
New Haven (Mass.-R. I.-New York)	42.73	113.82	37.5	1895–1907	650-D. C. 3R Overhead	Suburban passenger	City ordinance; increase facilities; tunnel smoke
(Conn.-New York)	92.14	545.46	16.9	1908–27	11,000-A. C. Overhead	Passenger and freight	Increase capacity; general economy
New York Central (New York-White Plains)	63.10	326.64	19.3	1906–26	650-D. C. Third-rail	Suburban passenger	Tunnel smoke and safety; increase facilities.
Norfolk and Western (West Virginia)	63.70	209.54	30.4	1915–25	11,000-A. C. Overhead	Heavy freight	Heavy grades; tunnel smoke; increase traffic
Pennsylvania (New York-New Jersey)	88.41	260.46	33.9	1906–10	650-75-D. C. Third-rail	Passenger	City ordinance; terminal improvement; increase capacity
(Philadelphia)	36.16	124.65		1914–18	11,000-A. C. Overhead	Freight and passenger	Increase terminal capacity
Virginian (Mullen-Roanoke)	134.00	231.00		1926	11,000-A. C. Overhead	Heavy freight	Grades; tunnels; heavy freight

*Many of the data presented in the above table have been taken from annual statistical reports on steam railroad electrification published by the American Railway Association, American Electric Railway Association, and National Electric Light Association. In addition, certain information on recent electrification has been furnished by the Westinghouse Electric Company and the General Electric Company.

a few miles from the New York terminal. Shortly after the court order which had forced the New York Central electrification, the Pennsylvania and the New Haven made certain terminal electric installations. The latter engaged in electrification largely because of the necessity of coordinating its operations with those of the New York Central over whose lines it had trackage rights. In the case of both the New Haven and the Pennsylvania third-rail feed was used.

The remaining years of the first period witnessed few initial electrifications; most of the installations made were additions to route mileage already electrified.

The Period 1915-1919. The second period of electrification, including the war years, is chiefly of interest because of the main line installations of the Chicago, Milwaukee, St. Paul and Pacific (then the Chicago, Milwaukee and St. Paul), and the Norfolk and Western.

Before considering these two major projects mention should be made of the New Haven road which in 1914-15 initiated its first A. C., overhead collection in one of its denser traffic areas. If one excepts the Erie's 1907 installation, which was of minor importance as far as traffic was concerned, the New Haven venture can be considered the first major A. C. electrification in the United States. Incidentally, the New Haven project embodied a plan to generate rather than purchase the greater part of the energy used. The decision to install high-voltage, A. C. feed on the New Haven main line was somewhat unexpected. The New York Central was at the time using D. C., third-rail feed as were most of the other United States electrifications. Mr. W. S. Murray, in charge of the New Haven project, suggests that the so-called "battle of the systems" originated with the Erie's 1907 electrification and received its major stimulus from the 1914 New Haven move.[8] Without doubt the influence of the latter has been great. The electrification itself was one of the most carefully considered and carefully worked out installations in American railroad history. Approximately 550 track miles were electrified, including 324 miles of mainline track and 226 miles of secondary and other track. It will be pointed out later that the decision of the New Haven has had an important effect on later electrifications, such as those of the Reading, and the Pennsylvania.

The Norfolk and Western Railway installed electric traction service on a large part of its heavy-grade, rough-profile, West Virginia territory between 1915 and 1917. The desire to increase the capacity of its facilities to meet increased coal traffic demands was the prime motivating factor. Power to supply the needs of the 11,000-volt, A. C. system is generated in the railroad's plants.

The major electrification of this second period, however, was that of the Milwaukee. Certain traffic and transportation problems similar in part to those of the Norfolk and Western motivated the Milwaukee to install 3,000-volt, D. C. service on two of its western divisions.[9] However, in addition to operating problems the Milwaukee was forced to meet rail and to some degree water competition. The decision to use direct current was a little unusual, especially as the New Haven and the Norfolk and Western

[8] W. S. Murray, *Superpower—Its Genesis and Future* (New York: McGraw-Hill, Inc., 1925). Mr. Murray's chapter on "Railroad Electrification" is one of the best of recent studies of the problem.

[9] The profile, i. e. topography, of the Milwaukee, while not as continuously rough as that of the Norfolk and Western, is much rougher in certain sections than that of the latter road. In addition, grades are steeper.

had definitely determined upon A. C., high-voltage collection. However, the Milwaukee's problem was solved by the construction of the necessary substations, a certain amount of transmission line—in addition to that of the power companies already available—and the erection of transmission equipment. Power was purchased. The Milwaukee has been criticized rather severely because of its electrification venture, which was entirely voluntary, since the traffic needs of the time could have been handled by steam motive power. Another criticism has been directed at the power contracts made by the Milwaukee with the Montana Power Company. The guarantee of a 60% load factor was part of the criticism. The road's load factor has rarely exceeded 30%.

The Period 1920 to Date. The third period of electrification is significant in that electric installations made in the past six or seven years have been preceded by exceedingly careful study of the economic advantages to be gained, particularly those broader economies relating to territorial development, and a careful weighing of the relative advantages of steam and electric power. To cite an example: the Illinois Central Railroad, in making a study of the advantages to be gained by electrification of the Chicago suburban area served by that road, employed engineers advocating both types of electric traction systems, D. C. low-voltage and A. C. high-voltage, overhead contact. A study was made of the New Haven and New York Central installations and the results applied as far as possible to the Chicago problem.

A desire to build for the future has characterized the last period and the one through which we are now passing. To what extent this is the result of increasing competition of other railroads and other types of transportation is subject to some question. That it is more than an attempt to meet present operating and traffic problems alone is evident. The Pennsylvania has recently announced that it intends to electrify its Pittsburgh area. It has already started work on the electrification of the Philadelphia-Wilmington main line. It has been frequently rumored that the New York Central is giving some consideration to the possibility and feasibility of electrifying the Harmon to Buffalo section of its eastern territory. At present a large part of this mileage is served by a six-track system. To some extent competition is forcing such consideration. Moreover, the existing trackage is hardly adequate for heavier traffic than is now handled, especially as this portion of the system must carry the movements of the New York Central, Big Four, Michigan Central, and to some extent the Pittsburgh and Lake Erie.

While the third electrification period has included a number of important installations, probably the outstanding of these have been the Chicago suburban electrification of the Illinois Central and the Virginian's mountain freight installation. In addition to these, at least three other electrifications are in various stages of construction. The Delaware, Lackawanna and Western recently completed work on a large section of its New Jersey suburban area. The Reading is engaged in electrifying certain of its suburban territory. One of the most important of the electrifications in progress is that already noted, the Philadelphia-Wilmington section of the Pennsylvania's eastern railroad network. When this is completed the Pennsylvania will have the nation's largest electrification, both from the standpoint of route miles electrified and with respect to track miles of electric traction.

The only major suburban electrification west of the Alleghenies is that of the Illinois Central, already referred to. In 1926 the first electric unit and trailer began operation on some 37 miles of suburban route south of Chicago. Within a few months the electrification was operating smoothly and efficiently. At first no thought was given to the electrification of through passenger or freight service. Two years ago freight service was included[10] and it was expected that within a short time through passenger service would be electrified. At this writing this has not occurred. The Illinois Central project is important in that it represents a degree of cooperation between city and railroad not to be found prior to 1920. In this case the road, for many years at odds with the City of Chicago over lake front improvement, grade crossing elimination, and terminal improvement, was able in 1919 to present a plan of cooperative terminal and suburban improvement to the City. Two years later railroad and City commenced work on the cooperative projects outlined in the plan. The road commenced its survey of existing electrifications and within a few years was able to initiate work on the electrification.

The agitation for compulsory electrification of certain steam railroad mileage in terminal and suburban areas had its origin in the United States in 1905, at which time the New York City problem was presented. To a certain extent the New York experience, in which electrification has been forced on the railroads, has been used as a precedent in attempting to deal with the Chicago problem. As early as 1915 smoke abatement was discussed. At that time a committee appointed by the Chicago Association of Commerce published a voluminous report in which it included an exhaustive survey of existing steam railroads serving Chicago, the conclusions of the committee being that steam power would be sufficient to meet most traffic and transportation needs of at least the immediate future. The report pointed out that the railroads of Chicago were causing less than 8% of the smoke of the entire city.[11]

The agitation for compulsory electrification was abated but little by the report of the Chicago Association of Commerce, though the City ceased to bring pressure on the roads to electrify. After the war the question was again brought to the attention of the public as a result of the rapidly increasing suburban and terminal congestion and the unsatisfactory terminal facilities of the City. The Illinois Central, faced with operating problems of its own, decided to electrify its suburban service. The "Lake Front Ordinance," passed in 1919, was a three-party contract between the railroad, the South Park Commission, and the City of Chicago. In accordance with the terms of the ordinance the railroad electrified its suburban service, completing the installation six months ahead of schedule, in June, 1926.[12]

Probably the outstanding freight electrification of the United States is that of the Virginian, completed in 1926. The Virginian electrified about 134 route miles of its total mileage of 443, a little over 30% of its system. Traffic congestion, limited facilities, and the predominance of heavy, eastbound freight were instrumental in bringing about this the installation. Existing facilities were

[10] Electric freight operation only applies to the switching of freight.

[11] Since 1915 numerous improvements on the steam locomotive have still further reduced the amount of smoke emitted. Hence, from the standpoint of smoke nuisance, there appears to be little need for electrification at present.

[12] Freight switching service on the Illinois Central is now electrified.

inadequate. Trackage through the mountainous territory served could not be increased except at a much higher cost than that necessitated by the existing trackage at the time of construction. Following the example set by the only other major freight electrification in the United States, the Norfolk and Western, the Virginian employed high-voltage, alternating current. Largely because power stations were infrequent along the electrified right of way and for the most part unable to handle the somewhat irregular, and at times heavy, load of the railroad, it was decided to generate the energy used. The Virginian and the Norfolk and Western are the only major roads in the United States generating all energy used on their electrified sections.

A summary of the three periods of electrification in this country shows that: (1) from 1895 to 1914 most electric installations were voluntary and largely experimental, most of them being of tunnel, terminal, or suburban service with but one or two relatively unimportant main-line constructions; (2) the second period witnessed two major electrifications but largely as a result of the chaotic financial conditions of the war and its immediate aftermath, no other electric installations of importance; (3) the period from 1920 to the present has seen the installation of numerous well-planned and economically-justified electrifications, most of them voluntary in the sense that they were not the result of governmental coercion.

Extent of Electrification in the United States. Approximately 7/10 of 1% of the steam railroad mileage of the United States is at present electrified. With the exception of the Milwaukee Divisions, the greater part of this is in the East, particularly in the Atlantic seaboard area between Boston and Washington. Table IV shows that eight of the 16 roads having electrified service are in the East. In addition to these, the Virginian and Norfolk and Western installations serve a territory which is more a part of the eastern than of the western trunk-line area. Of the remaining six electrifications, only four are worthy of more than passing interest, the Milwaukee, the Butte, Anaconda and Pacific, the Illinois Central, and the Great Northern. The last is primarily a tunnel installation, and the second relatively insignificant as far as railroad traffic is concerned. The Illinois Central installation, one of the most important in the trans-Allegheny region, is the only mid-western electrification constructed after careful and to a certain degree exhaustive study of existing installations.

Even with the exclusion of the Milwaukee mileage, main-line electrification exceeds that of any other type in the United States. A little over 65% of the total route mileage electrified in this country is in main-line service. Approximately 20% is in suburban service, and the remaining 15% in tunnel electrification. It is, of course, exceedingly difficult to segregate the mileage of steam and electric operation where both are employed jointly; for example, the Illinois Central electrified trackage is jointly used by the South Shore, the trackage being used by both types of traction on the part of the Illinois Central. The completion of the Reading, Pennsylvania, and proposed New York Central projects will materially increase the percentage of main-line electrified route mileage in the United States and slightly increase the degree of suburban electrification.

Standardization of Equipment. The prospect for standardization of electric traction motive power and of transmission and distribution lines seems to be slight. Until very recent years, "the battle of the systems," begun in 1907, has shown little signs of abatement. Electric equipment companies have developed rapidly their own standardized systems, bidding against each other for the electrification of each project. Thus one of these, the General Electric Company, has specialized in the installation of electric traction systems employing direct current, with either third-rail or overhead collection. Among the important electrifications engineered by this Company have been those of the Milwaukee, Illinois Central, Butte, Anaconda and Pacific, Lackawanna, and the suburban electrifications of the Pennsylvania, New Haven, and the New York Central.[13] With the growing need of higher powered installations, because of increasing size, weight, and speed of motive power equipment and cars, the old type of third-rail feed was seen to be inadequate. The electric equipment manufacturer then swung over to the advocacy of relatively high, direct-current voltage with overhead collection, rather than high voltage with alternating current similar to the type of system advocated by the Company's chief competitor. Hence, even among those railroads employing direct current, a lack of uniformity of both power and collection has existed. The writer has been informed that the major electric equipment companies are at present modifying somewhat their stands, but even in view of such changes much unnecessary waste has occurred.

While it is true that such factors as substation cost, including original investment, transmission and distribution costs, and track congestion have an important bearing on the type of electrification installed, little justification is apparent for the installation of different systems of electrification for the same service and often in the same operating area. A recent example comes to mind. The New York Central, New Haven, and Pennsylvania, and to some extent the Long Island, employ direct current in their New York suburban service. The New Haven, however, is using alternating current of high voltage on its main line. The Pennsylvania has installed the same type of feed and power in its Philadelphia service. Interconnection of the New York Central and Pennsylvania is virtually impossible without duplication of motive power units unless steam power is used (motive power units capable of handling either type of current and feed are available at a relatively high price). Neither can the Pennsylvania, which contemplates extending its Philadelphia system to New York, interchange either passenger or freight equipment with the Long Island, which employs a different type of electric traction system. Likewise, the Delaware, Lackawanna and Western, now erecting a 3,000-volt D. C., overhead feed for its suburban service, will find it difficult to interchange with the Pennsylvania in case the former decides to increase its electrified service to include main-line traffic.

Aside from the difficulties of interconnection and interchange of traffic, the economic waste of having two different systems with numerous variations and combinations in each is not easily condoned. Such costs are, of course, indirectly effective in maintaining, if not actually increasing, the level of rates, which is but one evil attending unjustified equipment expenditure. Electrical engineers, many of them in charge of past or of present electric installations, admit that there is little or no

[13] The three suburban electrifications employ both alternating and direct current; i. e., the roads named have electrified two or more divisions of their systems, using different power and collection systems.

justification for the different systems of electrification in the United States. Perhaps this lack of standardization is felt most keenly in the case of electric motive power. At present more than 75 different types of electric locomotives are on the market, whereas the varieties of steam motive power units are less than ⅓ this number. With the initial investment in electric locomotives from two to three and a half times that of steam units, it can readily be seen that this cost is one of the chief barriers to electrification. In addition, the equipment companies are constantly developing new types of electric locomotives to meet the ever changing systems of installation.

Generated v. Purchased Current. Quite as difficult to locate and evaluate as were the reasons for electrifications are the choices of the separate roads between generated and purchased current for their electrified lines. Here again local conditions weigh heavily in the decision. Table V suggests the prevailing reasons, although the presence and effect of other factors should be borne in mind.

Table V also indicates that, where the load for the electrification is small, purchase rather than generation of power is the more economical plan. Again, where the load is uneven and is capable of being met with existing central station facilities, purchase of power may be expected. There are exceptions to these observations. For example, the Virginian has what is probably the most uneven load of all steam railroad electrifications, daily increasing from nearly zero at 6 p. m. to 40,000 kilowatts some 40 minutes later. However, the Virginian was faced with the

TABLE V. POWER SUPPLY DATA OF STEAM RAILROAD ELECTRIFICATIONS IN THE UNITED STATES AS OF DECEMBER, 1930*

Road	Source	Power Companies Selling Energy	Reasons for Generation or Purchase
Baltimore & Ohio	Pchsd.	Consolidated Gas	Load too small
Boston & Maine	Pchsd.	New England Power	Load too small
Chicago, Milwaukee & St. Paul	Pchsd.	Montana Power	Cheap hydro
	Pchsd.	Washington Water Power	Small load
	Pchsd.	Puget Sound, R., El., Lt. & Power	Small load
Delaware, Lackawanna & Western	Pchsd.	Public Service Co.	Irregular load
Erie	Pchsd.	Niagara, Lockport & Ontario Power	Small load
Grand Trunk	Pchsd.	Detroit Edison	Small load
Great Northern	Gen.	Own plants	Cheap hydro
	Pchsd.	....	Small load
Illinois Central	Pchsd.	Commonwealth Edison	Large, uneven load
Long Island	Pchsd.	Pennsylvania R. R.	Uneven load
		Long Island Power	Uneven load
Michigan Central	Pchsd.	Detroit Edison	Small load
New York Central	Gen.	Own plants	Large load†
New Haven	Gen.	Own plants	Cheap hydro
	Pchsd.	New York Central	Cheap steam
Norfolk and Western	Gen.	Own plants	Low fuel costs
Reading	Pchsd.	....	Irregular load
Pennsylvania	Gen.	Own plants	Large load
	Pchsd.	Philadelphia Electric	Steady load
Virginian	Gen.	Own plants	Low fuel costs

*A. J. Manson, *op. cit.*, p. 316.
†Sells a small amount of power to the New Haven for suburban service in the New York City area.

problem of obtaining sufficient energy and power to meet its demands with only small stations from which to draw. In other words, the power companies serving the mountainous territory traversed by the Virginian's line could hardly be expected to meet the load necessitated by the freight traffic. The road was thus forced to consider seriously the problem of generation. Low fuel costs enable the road to minimize its generation costs.

Of the six roads generating all or part of the energy necessary for their electrified service, three are serving suburban and terminal service, two are mountain freight electrifications, and the last is generating the energy used in an electrified tunnel operation. Two of the three suburban-terminal electrifications have large loads, somewhat more uniform than other similar services, as main-line traffic uses the energy of the electrified portion of the line.

The majority of the recent electric installations have employed central station power. However, despite the fact that these furnish large and, to a certain extent, fairly regular loads, purchase rather than generation of energy has been decided upon. It is still too early to conclude that the railroads have determined upon a policy of purchasing rather than generating energy and power requirements for their electrifications from central stations. Probably the greater number of suburban electrifications of the future will purchase their power. Strategic location of central stations and substations will, of course, have an important bearing on this point.

Summary

It is impossible in a paper of this length to go into the various phases of all important electrifications of the United States. The following paragraphs give a bird's-eye view of steam railroad electrifications of the present and a few comments as to certain possible trends of the future. These comments are intended to be prophetic only to the extent that they are based on observations of past and present electrification procedure.

1. Tunnel and Terminal Service. The number of unelectrified tunnels of more than five miles in length in terminal areas will be few in the near future. Most of the tunnels of the eastern seaboard, especially where four or more tracks are utilized, are at present electrified. Of course, unless traffic is of sufficient volume to warrant the added capital cost of electrification, the tunnel installation is less likely to be voluntary and more likely to result from city ordinance. With the rapid growth of terminal electrifications, as in the New York City area, all tunnels included in the electrified area may be expected to be electrically operated. Traffic congestion and legislation will go far in bringing about these installations. The desire of the carriers to stimulate traffic by improved service is an important factor which must not be neglected. With the rapidly increasing congestion of population in the industrial areas of the country a material decrease cannot be expected in traffic congestion.

2. Suburban Service. Agitation for suburban electrification of certain metropolitan areas has been increasing rapidly. The entire terminal and suburban problem of Chicago has been gone into thoroughly by the railroads and by civic bodies interested in terminal improvements. The Association of Commerce report of 1915, concluding that electrification of the metropolitan area of Chicago was unnecessary and too expensive at that time, postponed this agitation very effectively until the post-war period. In 1923 and again in 1926 the railroads were brought into conflict with the City on electrification measures. In both cases the roads presented evidence of the high costs involved and the relatively small traffic increase which might be expected from such a move. At present the World's Fair year of 1933 may find the City with inadequate terminal and suburban facilities. To a certain extent, terminal consolidation may effect the desired improvement. However, as consolidation of facilities and the necessary relocation of trackage involved therein are a costly process, electrification of existing facilities appears more likely to be adopted by the railroads. In view of the failure of New York to force electrification of its terminal areas it is doubtful whether Chicago will be successful in a similar venture.

Although prices of electric traction equipment may be expected to fall in line with general, lower price trends, present conditions in both the traffic field and the money market make it improbable that the roads could meet the cost of electrification.[14] Terminal electric traction installation alone will hardly pay. Eventually, tunnel, terminal, and suburban installation will take place. Suburban electrification will not necessarily develop interchange complications. However, terminal electrification, especially where belt-line operation is involved, will call for a certain degree of standardization of equipment. The trend of recent suburban and terminal installations is away from the low-voltage, third-rail feed, D. C. type and toward the relatively high-voltage, overhead collection of direct current.

3. Main-line Electrification. Gradual extension of suburban and terminal electrification to include portions of the main line seems to be the process of evolution of railroad electrification. Obviously, some attempt will be made to see that the type of system installed will be the same as that on the other electrified mileage. Aside from an occasional freight or main-line installation in rough-profile territory, probably electric traction will not make much headway in the West or Midwest, at least in the near future. The Sante Fe Railroad made a careful study of the possibilities of electrifying a section of its heavy-grade territory. The decision was that revenues added to the total would hardly meet the increased cost of the investment. Steam power will be able to meet operating conditions in three-fourths of the United States for many years to come.[15]

[14] One road, the Chicago and Northwestern, has estimated that the interest charges alone on complete suburban electrification would be more than the total present revenue from suburban traffic. While this statement should be taken with the proverbial "grain of salt," it is true that suburban traffic is in many cases unable to bear its share of operating expenses.

[15] Gasoline-electric motive power may be expected to supplant steam service where there are fewer than two or three movements of traffic each way per day.