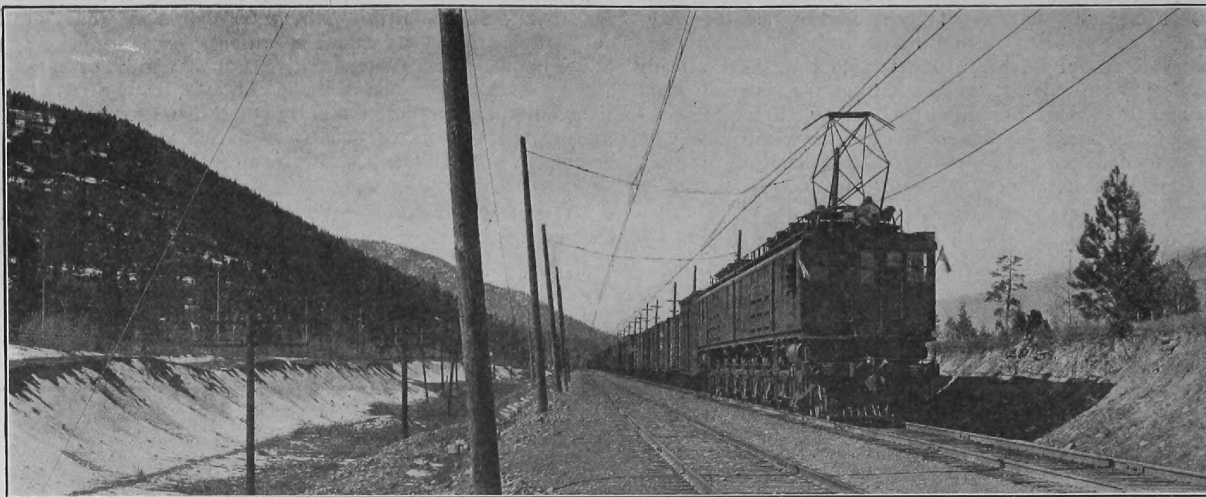


A 100-Car, 5,000-Ton Freight Train, East-Bound at Thelma on the St. Paul.

A Comparison of Electric and Steam Motive Power*

From Which It Would Appear That the Steam Locomotive Has About Outlived Its Usefulness.

By A. H. Armstrong
Railway and Traction Engineering Department, General Electric Company.

During the year 1920 the people of the United States will pay out for automobiles, not commercial trucks or farm tractors, but pleasure vehicles, a sum of money considerably greater than the estimated requirements of our steam railways for that year. The railways, however, may find it very difficult and perhaps impossible to secure the large sums needed without government aid, notwithstanding the fact that the continued operation and expansion of our roads is of vital necessity to the welfare and prosperity of the country and all its industries. The will of the American public has always been constructive and undoubtedly in due time its voice will be heard and properly interpreted by its representatives in Washington with the resulting enactment of such laws as will permit our railways to again offer an attractive field for the investment of private capital.

The purpose of this paper is not to discuss the politics of the situation nor any necessary increase in freight rates that may be required to make our roads self sustaining, but rather to offer certain suggestions as to the best manner of spending the sums that must ultimately be provided for new construction and replacements.

During the war period many lessons have been most clearly brought home to us and not the least of these is that there is something inherently wrong with our steam railroads. During the three generations of its development, we have become accustomed to look upon the steam engine as properly belonging to the railway picture with little thought given to its wastefulness and limitations, but around which railway practice of today has gradually crystallized.

During the winter of 1917-18 our railways fell down badly when the need was the greatest in their history. It is true that the cold weather conditions were unprecedented and the volume of traffic abnormal, but the weaknesses of steam engine haulage were disclosed in a most startling and disastrous manner. Delayed passenger trains in cold weather can be endured by the traveling public in suffering silence or voluble expression, according to temperament, but blocking our tracks with frozen engines and trains, serious reduction of tonnage in cold weather and the prohibitive delay in transportation of freight in times of great stress is quite another thing and plainly indicates the inability of the steam engine to meet overloads and adverse climatic conditions.

In marked contrast to the adjoining steam engine divisions, the 440 miles of electrified section of the Chicago, Milwaukee & St. Paul continued to do business as usual all through that trying winter of 1917-18. The electric locomotives brought both freight and passenger trains over the electrified tracks on schedule time or better; in fact, it was quite customary to make up on the 440-mile electric run fully two hours of the time lost by passenger trains on adjoining steam engine divisions. While the results obtained upon the Chicago, Milwaukee & St. Paul were perhaps more spectacular due to the greater mileage electrifically equipped, other electrified roads contributed similarly attractive records. The reliability and permanency of the comparison between steam and electric locomotive haulage is sufficiently guaranteed therefore by the results of several years' operation, to justify drawing certain conclusions regarding the merits of the two types of motive power. The following analysis of the railway situation is therefore offered for the purpose of exposing the fact that railroading today is in reality steam engine railroading and the general introduction of the electric locomotive will permit fundamental and far-reaching changes being made in the method and cost of hauling freight and passenger trains.

The writer is not proposing the immediate electrification of all the railways in the United States, as many roads of lean tonnage would render no adequate return upon the large

*Abstract of an address delivered before the Schenectady section of the American Institute of Electrical Engineers.

capital investment required, but offers the following table of total operating statistics simply as a measure of the magnitude of the problem confronting us in the future. In this country it should be noted, however, that we have already installed electric power stations during the past 30 years equal to twice the estimated capacity required for the electrical operation of every mile of track in the country today.

The tonnage passing over the tracks of our railways may be subdivided in a most interesting manner as shown in Table I.

TABLE I

TOTAL TON-MILE MOVEMENT

All Railways in United States Year 1918.

	Per cent	Ton miles
1. Misc. frt. cars and contents	42.3	515,000,000,000
2. Revenue coal cars and contents	16.23	197,000,000,000
3. Loco. revenue driver wt. only	10.90	132,300,000,000
4. Passenger cars all classes	16.13	196,000,000,000
Total revenue frt. and passenger	85.56	1,040,300,000,000
5. Railway coal	5.00	60,600,000,000
6. Tenders all classes	6.50	78,800,000,000
7. Locomotive railway coal	.39	4,700,000,000
8. Locomotive non-driving wt.	2.55	31,000,000,000
Total non-revenue	14.44	175,100,000,000
Grand total—all classes	100.00	1,215,400,000,000

The first four items, representing 85.56 per cent of the total ton miles made during the year 1918 may be regarded as fundamentally common to both steam and electric operation. The last four items, however, are seriously affected by introducing the electric locomotive to the extent of completely eliminating items 6 and 7, reducing item 5 by possibly 80 per cent and item 8 by one half. Of the total of 14.64 per cent affected, therefore, it may be assumed for purposes of comparison that approximately 12 per cent or 146,000,000,000 ton miles at present hauled by steam engines over our roads will be totally eliminated with electric locomotive haulage. This ton mileage eliminated is equal to over 20 per cent of items 1 and 2 representing the revenue producing freight traffic on our railways. In other words, if all our railways were completely electrified they could carry one-fifth more revenue producing freight tonnage with no change in present operating expenses or track congestion.

It is evident that the greater part of the tonnage reduction effected by electrification is included in items 5 and 6 representing the railway coal movement in cars and engine tenders. The steam engine tender will, of course, entirely disappear while the railway coal haulage will be largely curtailed by utilization of water as a source of power and the establishment of steam power houses as near the coal mines as an abundant supply of good condensing water and load demand will permit. While water power should be utilized to the fullest economical extent, the greater portion of the railway power must undoubtedly be supplied by coal, due to the unequal geographical distribution of water power available.

Two-Thirds of the Coal Wasted

Even with coal as a source of power, it may not be fully appreciated just how enormous is the saving made by burning fuel in large modern power stations under the most efficient conditions possible, instead of under the boilers of 36,000 engines, which by necessity must be designed and operated for service rather than for fuel economy. During the year 1918 the fuel used by railways is reported as shown in Table II:

TABLE II

Railway Fuel 1918

Total coal production—all grades	678,211,000 tons
Used by steam railways	163,000,000 tons
Percentage of total	24 per cent
Total oil marketed U. S.	355,927,000 bbls.
Used by steam railways	45,700,000 bbls.
Percentage of total	5.8 per cent
Coal equivalent of oil at 3½ bbls	13,000,000 tons
Total equivalent railway coal	176,000,000 tons

A quarter of all the coal mined in the United States is consumed on our railways and the following analysis will point out some features of this extreme wastefulness which are inseparable from steam engine operation.

During the year 1910, exhaustive tests were made upon the Rocky Mountain division of the C., M. & St. P. to determine the relation existing between horse power hours work done in moving trains and coal and water consumed on the steam engines in service. The summary, Table III, gives the result of these tests.

TABLE III

C. M. & ST. P.—ROCKY MOUNTAIN DIVISION

Coal and Water Used

	Water per hp.	Water per lb. coal	Coal per hp. hr.
Three Forks-Piedmont	39.6	5.08	7.75
Piedmont-Donald	35.4	4.70	7.54
Deer Lodge-Butte	39.7	4.85	8.31
Butte-Donald	40.4	4.86	8.74
Harlowton-Jenny	38.0	4.09	8.90
Jenny-Summit	44.2	4.65	9.48
Three Forks-Piedmont	41.4	6.51	6.37
Piedmont-Donald	40.2	5.63	5.78
Average of 8 tests	39.86	5.04	7.86

The above records were obtained during the portion of the runs that the engines were doing useful work in overcoming train and grade resistance, that is, all stand-by losses were excluded. The through run, however, included such losses in the following magnitude.

Adding standby losses to the average of 7.86 lb. per hp. obtained in the preceding eight tests, the total actual coal consumed under the engine boiler in 24 hours divided by the actual work performed by the engine was found to be 10.18 lb. per hp. at the driver rims.

TABLE IV

STANDBY LOSSES

	Coal per hour
Fire banked in roundhouse	150 lb.
Cleaning fires for starting	800 lb.
Coasting down grade	950 lb.
Standing on passing track	500 lb.

As the result of this particular series of tests it was determined that standby losses raised the coal consumed while doing useful work by 30 per cent. It should be appreciated in this connection, moreover, that this value was obtained on through runs with no yard switching service or adverse climatic conditions. It may be concluded therefore that under all conditions of service fully one-third the coal burned on our steam engines today is absolutely wasted in standby losses of the general nature indicated above.

Supplementing these tests, a thirty-day record was kept of all coal used on the entire Rocky Mountain division and the total engine, tender and train movement reduced to horsepower hours, resulting in a value of 10.53 lb. coal consumed per hp. at the driver rims. Both the above values were based upon constants of 6 lb. per ton train resistance at all speeds and seven-tenths lb. per ton per degree of curvature as determined in part by dynamometer car tests and representative of general railway operation. Reducing the average coal values of test runs and 30-day record per hp. hour to electrical constants we arrive at the results shown in Table V.

TABLE V

COAL EQUIVALENT PER KW. HR.—STEAM OPERATION

Coal per hp. hr. at driver rims	10.27 lb.
Coal per kw. hr. at driver rims	13.75 lb.
Coal per kw. hr. at power supply on basis 55 per cent efficiency	7.56 lb.

It is this last figure of 7.56 lb. of coal burned on steam engines to get the equivalent tonnage movement of 1 kw. hr. delivered from an electric power station that is of special interest to this discussion. Comparing coal and electrical records on the Butte, Anaconda & Pacific before and after electrification results in arriving at a value of 7.17 lb. of coal previously burned on the steam engines to equal the same service now performed by one kilowatt hour input at the substations, a figure comparing favorably with 7.56 lb. above arrived at by an entirely different method.

Making due allowance for the fact that Roundup coal is somewhat low in heat units, it is nevertheless within the limits of reasonable accuracy to assume that the steam engines operating over all our railways are consuming coal at a rate closely approximating 12.75 lb. of coal per kilowatt hour of useful work done, as measured at the driver rims or 7 lb. per kilowatt hour as measured at a power station and including for convenience of comparison the transmission and conversion losses inherent to electrical operation.

Analysis of Roundup Coal Used

Fixed carbon	49.26 per cent
Volatile carbon	38.12 per cent
Ash	7.74 per cent
Moisture	4.88 per cent
B. t. u.'s	11,899

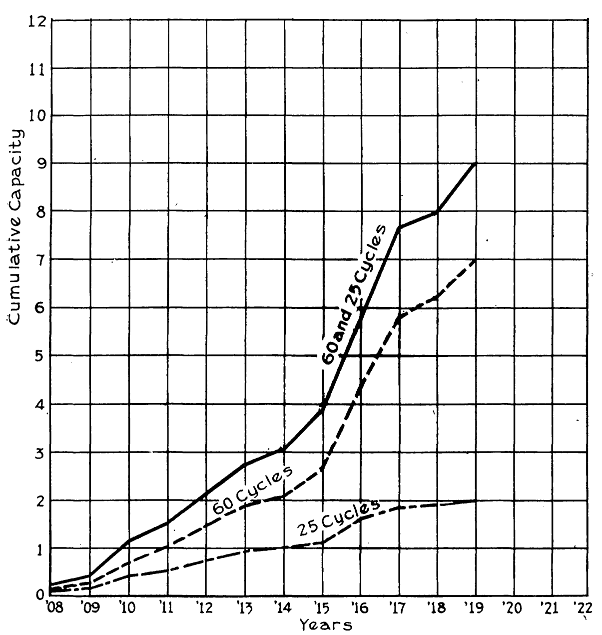
An electric kilowatt can be produced for so much less coal expenditure than 7 lb. that we are now in position finally to forecast the approximate extent of the coal economy that would result from electrification.

Table VI

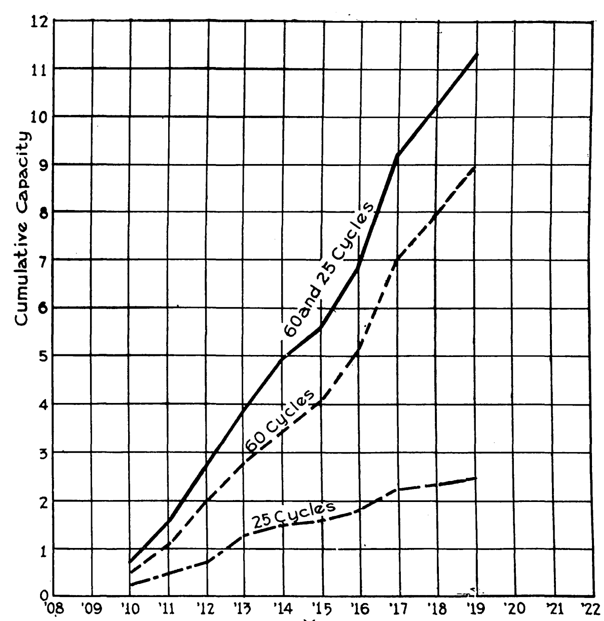
Relation between kw. hr. and ton miles
C. M. & St. P. Avery-Harlowton, Year 1918

	Passenger	Freight
Average weight locomotive	300 tons	284 tons
Locomotive miles 1918	651,000	1,431,500
Loco. ton miles	195,000,000	407,000,000
Trailing ton miles	434,406,000	2,903,099,000
Total ton miles	629,406,000	3,310,049,000
Kilowatt hours	24,890,000	105,287,000
Watt hrs. per ton mile	39.6	31.9
Ratio loco. to total	31%	12.3%
Watt hrs. per ton mile combined movement	33.2	
Ratio loco. to total combined movement	15.25%	

All power values (Table VI) are given at the point of supply from the Montana Power Company at 100,000 volts, and include deductions made for the return of power due to regenerative braking of the electric locomotives on down grades and amounting to approximately 14 per cent of the total. Owing to the excessive rise and fall of the profile of the electrified zone of the C., M. & St. P., its operation is materially benefited by regenerative electric braking and the value of 33.2 watt hours per ton mile for combined and passenger movement should possibly be raised to the round figure of 40 to make it apply more nearly to conditions universally obtaining on more regular profiles.



Comparative Sales of 60 and 25 Cycle Turbines



Comparative Sales of 60 and 25 Cycle Transformers

Hence referring again to the ton mile values of Table I:

Total ton miles 1918	1,215,400,000,000
Watt hrs. ton mile	40
Kw. hrs. total movement	48,700,000,000
Coal required at 7 lb. per kw. hr	170,000,000 tons

The actual equivalent coal consumed on our steam railways for the year 1918 is given as 176,000,000 tons, closely approximating the figure of 170,000,000 tons estimated above from the operating results obtained on the C., M. & St. P. electrified zone. These several values check so closely as to justify the completion of the fuel analysis of the railways, Table VII.

Table VII

Coal saving by electrification

Total ton miles steam	1,215,400,000,000
Reduction by electrification	146,000,000,000
Total ton miles electric	1,069,400,000,000
Kw. hrs. electric at 40 watts	42,776,000,000
Coal on basis 2½ lb. per kw. hr	53,500,000 tons
Equivalent railway coal 1918	176,000,000 tons
Saving by electrification	122,500,000 tons

The startling conclusion arrived at is that approximately 122,500,000 tons of coal or more than two-thirds the coal now burned on our 63,000 steam engines would have been saved during the year 1918, had the railways of the United States been completely electrified along lines fully tried out and proved successful today. This vast amount of coal is 50 per cent greater than the pre-war exports of England, and twice the total amount consumed in France for all its railways and industries. Moreover, the estimate is probably too conservative, as no allowance has been made for the extensive utilization of water power which can be developed to produce power more cheaply than by coal in many favored localities.

From figures given, the following conclusion is arrived at in the matter of power station capacity required for complete electrification of the railways in the United States.

Railway Power Required

Kw. hr. electric operation 1918	42,776,000,000 kw. hr.
Average load 100 per cent load factor	4,875,000 kw.
Power station capacity at 50 per cent load factor	9,750,000 kw.

It appears therefore that approximately 10,000,000 kw. power station capacity would have been sufficient to run all the railroads for the year 1918, or one-half the station capacity which has been constructed during the past thirty years.

In order of magnitude, therefore, it is not such a formidable problem to consider the matter of power supply for our electrified railways, and it becomes evident also that the railway power demand will be secondary to industrial and miscellaneous requirements.

Such being the case, the question of frequency of electric power supply becomes of great importance, if full benefit is to be obtained from extensive interconnected generating and transmission systems, covering the entire country. Indeed, with the full development of interconnected power systems supplying both railway and industrial load from the same transmission wires, the above assumption of 50 per cent load factor for the railway load can be materially bettered.

TABLE VIII

ESTIMATED POWER STATION CAPACITY UNITED STATES YEAR 1918

Central stations	9,000,000 kw.
Electric railways	3,000,000 kw.
Isolated plants	8,000,000 kw.
Total	20,000,000 kw.

In this connection a method of limiting the troublesome peak load hitherto considered inherent to railway power supply has been in successful operation on the electrified C., M. & St. P. zone for the past year. With unrestrained peaks, the load factor was approximately 40 per cent, but this low value has been raised to nearly 60 per cent by the installation of this inexpensive and most satisfactory device, known as the power limiting and indicating apparatus.

TABLE IX.

LOAD FACTOR RECORDS, C. M. & ST. P., 1919.

	Duration of peak, per cent	Load factor, per cent
April	6.4	59.3
May	4.6	56.1
June	1.6	56.5
July	0.7	55.6
August	4.1	54.7
September	9.5	58.8

The above readings cover the performance on the 220 miles of the Rocky Mountain division supplied by seven substations controlled as a unit. A load factor of nearly 60 per cent brings the electric railway within the list of desirable customers and makes it possible for power companies to quote attractively low rates for power.

Returning again to the question of power supply, it is instructive to note the general trend toward a higher frequency as evidenced by the turbine and transformer sales of the General Electric Company during the past decade.

It is quite evident that 60 cycles is rapidly becoming the standard frequency in America and many instances are of record where it has replaced lower frequencies, principally 25 cycles. This fact in no manner handicaps the future development of electric railways, as entirely satisfactory power can be obtained from 60 cycle transmission lines through rotary converters or synchronous motor generator sets, depending upon the direct current trolley voltage desired. Indeed, a growing appreciation of the declining importance of 25 cycle power generation in this country contributed largely to the demise of the single phase system as its chief claim for recognition is wiped out with the introduction of the motor generator substations required with 60-cycle supply.

From the power station standpoint, the electrification of our railroads admits but one conclusion. We have some 63,000 engines now in operation and their average combined load amounts to approximately four million horsepower at the driver rims, or only an insignificant total of 65 hp. for each engine owned. It is true that owing to shopping and for one cause or another a large proportion of these engines are not in active service at all times, still the average 24-hour output of each engine is less than 10 per cent of its rating. In the case of the C., M. & St. P. electrification, the average load of each individual electric locomotive is only 15 per cent of its continuous rating, but by supplying power to 45 electric locomotives from one transmission system, the average combined load factor is raised to nearly 60 per cent, a figure which could even be surpassed on roads of more regular profile. Furthermore, when the railway load is merged with the lighting and industrial power of the district and the whole diversified load supplied from the same 60 cycle transmission and generating system, it is quite evident that all the conditions are most favorable for the efficient production of power. In this country such an achievement will probably be governed by the laws of economic return upon the capital required, because our vast natural fuel resources are popularly regarded as inexhaustible, but in Europe there is the compelling spur of stern necessity behind the movement to economically utilize the water powers they possess in place of the coal they cannot get.

While the much discussed subject of power generation and transmission is a very vital part of the railway electrification project, chief interest centers in the electric locomotive itself. Few realize what a truly wonderful development has taken place in this connection in a comparatively few years and how peculiarly fitted this type of motive power is to meet the requirements of rail transportation. Free from the limitations of the steam boiler and possessing in the electric motor, the most efficient and flexible known means of transmitting power to the driving axles, the electric locomotive gives promise of revolutionizing present steam railway practice when its capabilities become fully recognized. The only limits placed upon the speed and hauling capacity of a single locomotive are those imposed by track alinement and standard draft rigging. Only questions of cost and expediency control the size of the locomotive that can be built and operated by one man, as there are no mechanical or electrical limitations that have not been brushed aside by careful development. Just what this means in advancing the art of railroading is as yet but faintly grasped any more than the boldest prophet of 20 years ago could have fully pictured the change that has taken place at the Grand Central terminal, as the result of replacing steam by electricity.

Progress in utilizing the capabilities of the electric locomotive has been slow. It is hard to break away from lifelong railway traditions established by costly experience in many cases. In consequence, the electric locomotive has thus far simply replaced the steam engine in nearly similar operation. Even under such conditions of only partial fulfillment of its possibilities, the electric locomotive has scored such a signal operating success as to justify giving it the fullest consideration in future railway improvement plans.

On the C., M. & St. P., 42 locomotives have replaced 112 steam engines and are hauling a greater tonnage with reserve capacity for still more. On this and other roads, it has set a new standard for reliability and low cost of operation. In fact, although no official figures have yet been published, it is an open secret that the reduction in previous steam operating expenses on the C., M. & St. P. are sufficient to show an attractive return upon the twelve and a half millions expended for the 440 miles of electrification, without deducting the value of the 112 steam engines released for service elsewhere. As the electric locomotive is destined to leave its deep impression upon the development history of our railways, it is fitting that the remainder of this address should be devoted to its consideration.

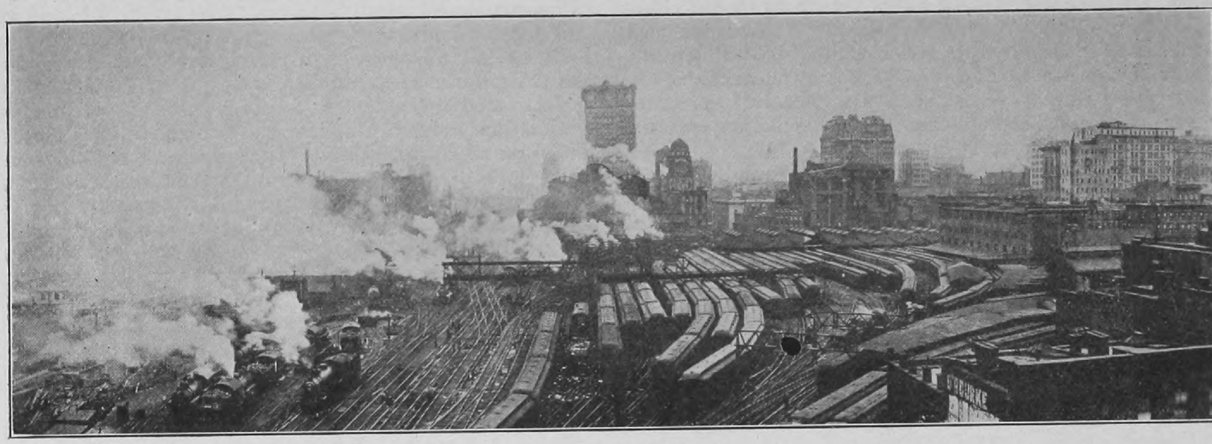
Our steam engine construction is unsymmetrical in wheel arrangement, and further handicapped with the addition of a tender to haul its fuel and water supply, must run single ended. The result has been much congestion at terminals and the necessary roundhouses, always with the inevitable turntable, ash pits and coal and water facilities, have occupied much valuable land and in addition steam operation has greatly depreciated the value of neighboring real estate. The contrast offered by the two large electric terminals in New

York City is too apparent to need more than passing comment and similar results may be expected on the fulfillment of plans for electrifying the Chicago terminals.

While it has been a simple matter to design electric locomotives to run double ended at the moderate speeds required in freight service, the problem of higher speed attainment exceeding 60 miles per hour, has presented greater difficulties. The electric motor is, however, so adaptable to the needs of running gear design that electric locomotives are now in operation which can meet all the requirements of high speed passenger train running. These results also are obtained with less than 40,000 lb. total weight and 9,500 lb. non-spring borne or "dead" weight on each driving axle, and finally, but not least, with both front and rear trucks riding equally well, a success never before achieved in locomotives of such large capacity.

There is as yet no general acceptance of a standard design of electric locomotive. Geared side rod construction for heavy freight service and twin motors geared to a quill for passenger locomotives appear to find favor with the Westinghouse-Baldwin engineers, while the General Electric Company goes in for the simple arrangement of geared axle motors for freight and gearless motors for passenger locomotives. In both Switzerland and Italy the side rod locomotive enjoys an almost exclusive field. How much of this preference for side rod construction is due to the restrictions imposed by the use of alternating current motors is hard to determine, but the facts available indicate the uniformly higher cost of repairs of this more complicated form of mechanical drive both in this country and abroad.

The electric railway situation in Italy is further complicated by the employment of three phase induction motors with all the attendant handicaps of double overhead trolleys, low power factor, constant speeds and overheating of motors resulting from operation on ruling gradients with motors in cascade connection. In many respects the non-flexible three-phase induction motor is poorly adapted to meet the varied requirements of universal electrification, and in consequence Italian engineers are still struggling with the vexing question of system which may, however, be in a fair way of settlement through the adoption of a standard of 50 cycles as the frequency of a nation wide interconnected power supply, thus throwing the preponderance of advantages to high voltage direct current.



The Grand Central Terminal, New York, as It Appeared in 1906

The Grand Central Terminal, New York, as It Appears Since It Was Electrified

Low Cost of Maintenance

The extreme simplicity of the gearless motor locomotive appeals to many as does its enviable record of low maintenance cost, reliability and high operating efficiency, as exemplified by its unvarying performance in the electrified zone of the New York Central for the past twelve years.

TABLE X

MAINTENANCE COSTS, NEW YORK CENTRAL

	1913	1914	1915	1916	1917	1918
Number locomotives owned..........	48	62	63	63	73	73
Average weight, tons	118	118	118	118	118	118
Cost repairs per locomotive mile (cents)	4.32	4.03	4.45	3.78	4.01	6.26

The high cost of living did not appear to have reached this favored locomotive until the year 1918.

The records on the C., M. & St. P. locomotive are equally remarkable when considering their greater weight and more severe character of the service.

TABLE XI

LOCOMOTIVE MAINTENANCE COSTS, C. M. & ST. P.

	1916	1917	1918
Number locomotives owned	20	44	45
Average weight, tons	290	290	290
Cost repairs per locomotive mile (cents)	8.21	9.62	10.87

In both these instances the cost of repairs approaches closely to 3c per 100 tons of locomotive weight. Giving due credit to the excellent repair shop service rendered in each case, it is instructive to note that 3c per 100 tons maintenance costs of these direct current locomotives is less than half the figures given for any of the alternating current locomotives operating in the United States or in Europe.

Compared with the cost of repairs of equivalent steam engines, the above figures for electric locomotives are so very favorable as to justify the general statement that electric motive power can be maintained for approximately one-third the cost of steam engines for the same train tonnage handled. As locomotive maintenance is a measure of reliability in service and in a way expresses the number of engine failures, it is quite in keeping with the records available to state also that the electric locomotive has introduced a new standard of reliability that effects material savings in engine and train crew expense as well.

Electrification and Operating Costs

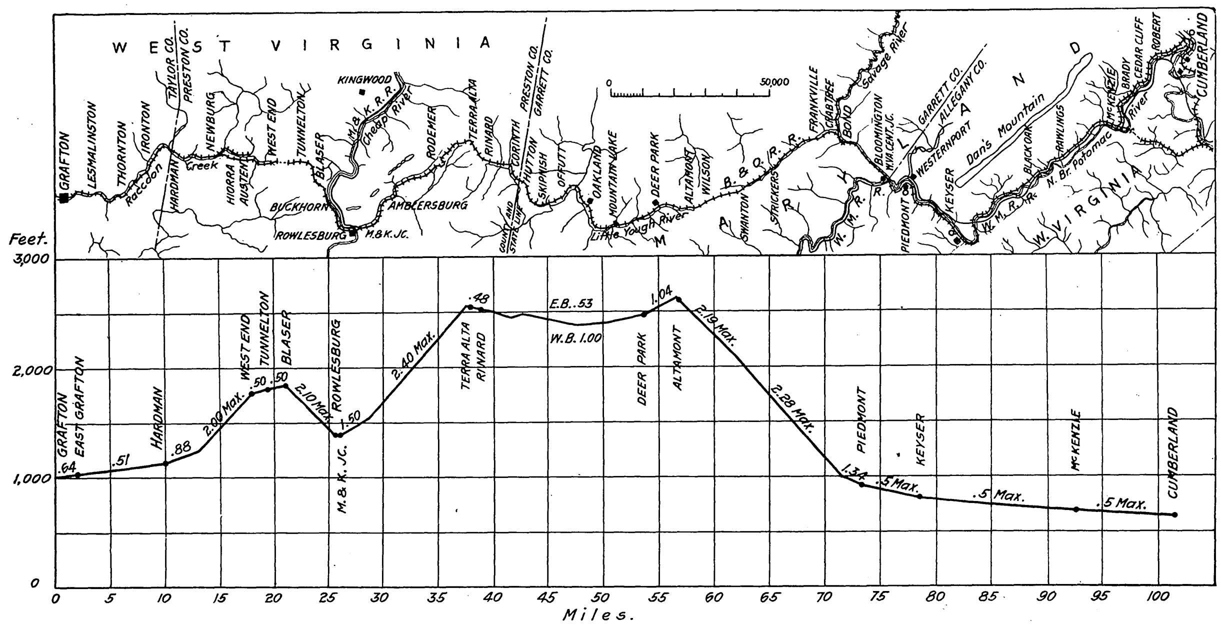
While the first cost of electrification is admittedly high, it may in certain instances be the cheapest way to increase the tonnage carrying capacity of a single track, especially in mountain districts where construction is most expensive and steam engine operation most severely handicapped. In this connection a comparison of steam and electric operation on the C., M. & St. P. may be summarized as follows:

For the same freight tonnage handled over the Rocky Mountain division, electric operation has effected a reduction of 22½ per cent in the number of trains, 24.5 per cent in the average time per train and has improved the operating conditions so that nearly 30 per cent more tonnage can be handled by electric operation in about 80 per cent of the time it formerly took to handle the lesser tonnage by steam engines. This means a material increase in capacity of this single track line which may be conservatively estimated in the order of at least 50 per cent and probably more. In other words, on this particular road, electrification has effected economies which sufficiently justify the capital expenditure incurred and furthermore has postponed for an indefinite period any necessity for constructing a second track through this difficult mountainous country.

A careful study of the seriously congested tracks of the Baltimore & Ohio, between Grafton and Cumberland, disclosed vitally interesting facts. Company coal movement in coal cars and engine tenders constituted over 11 per cent of the total ton miles passing over the tracks. In other words, due to the very broken profile of this division, the equivalent of one train in every nine is required to haul the coal burned on the engines. Taking advantage of this fact and the higher speed and hauling capacity of the electric locomotive and its freedom from delays due to taking on water and fuel, it is estimated that the three tracks now badly congested with present steam engine tonnage, could carry 80 per cent more freight with electric locomotive operation. The coal output of the Fairmont district is largely restricted by the congestion of this division and it is probable that equal relief with continued steam engine operation could not be secured without the expenditure of a much larger sum for additional track facilities than would be needed to put electric locomotives upon the present tracks.

Further instances could be cited where the benefits of electrification are badly needed and many of these are coal carrying roads, among which the Virginian Railway stands out conspicuously as a good opportunity to make both a necessary improvement and a sound investment.

Reviewing the progress made in a short twenty years, we have seen the steam turbine and electric generator drive the reciprocating engine from the stationary power field. The same replacement is now taking place on our ships, big and small, notwithstanding the fact that the marine reciprocating engine is a very good engine, indeed, and operates under the



Map and Profile of the Cumberland Division of the Baltimore & Ohio ideal conditions of a steady load and constant speed. And now the steam locomotive must in turn give way to the electric motor for the same good reasons that the reciprocating steam locomotive has become obsolete and fails to respond to our advancing needs. Electrification affords a cheaper and better means of securing increased track capacity and improved service than by laying more rails and continuing the operation of still more steam engines in the same old wasteful way.

To conclude the startling picture of our present railway inefficiency, we are today wasting enough fuel on our steam engines to pay interest charges on the cost of completely electrifying all the railways in the United States, fuel that Europe stands in sad need of and which England and Germany, the pre-war coal exporting countries, cannot now supply. With operating expenses mounting to 82 per cent of revenue, in addition to constructive legislation and real co-operation on the part of the government in the matter of rates and safe guarding invested capital, is wise direction in the expenditure of the large sums that must speedily be found and used to bring our railways abreast of the times. Accord full honor to the reciprocating steam engine for the great part it has played in the development of our railways and industries, but complete the work by replacing it with the electric motor and enter upon a new era of real railroading.

Winter Railroading in the East and Canada

The railroads and Old Boreas are having unusual combats in all quarters this year. The Reid-Newfoundland Railway (narrow gage), 546 miles long, reported last week an "express" train as reaching destination three weeks late. Some of the snow drifts required days of shoveling and the passengers reported that rations ran short; at times fish was about all they had to eat. At St. John, New Brunswick, 1,100 freight cars in the yards of the Canadian National Railways were so buried in snow and ice that only by hand-shoveling and picking by large gangs of men for many days were they extricated.

From the central part of Canada, which has large forces of experienced snow fighters, we have no unusual reports; but out in Alberta a trainload of passengers who arrived in Edmonton on Sunday, January 25, six days behind schedule, had such a serious time that they gave the newspapers long and detailed accounts of their sufferings supported by affidavits. This was on the Edmonton, Dunvegan & British Columbia, a line which extends from Edmonton about 400 miles up toward the North Pole. That region is so thinly populated that the one passenger train of this railroad runs only twice a week. Passengers in stations suffered from cold, and then, on boarding the trains, complained of lack of drinking water. The thermometer went to 60 below zero, Fahrenheit, and, according to a mechanical engineer who was on the train, the locomotives were all leaky or otherwise out of order, and five of them together failed to keep the passenger cars warm. At McLennan, the junction of the Peace river and the Spirit river lines, passengers waiting for the connecting train had to go to dwellings some distance away to get warm. One local newspaper prints the names of 67 passengers who signed a statement setting forth their discomforts. This road is also in difficulties in regard to freight, grain dealers complaining to the Canadian government that wheat to the amount of a million bushels is liable to be spoiled by moisture because of lack of freight cars unless relief is forthcoming without delay.

On Monday, February 16, northern New York and a large part of New England were visited by a heavy snowstorm, accompanied by high wind and low temperatures, and freight traffic was almost paralyzed before it had fully recovered from the difficulties of the storm of 10 days previous. On some branches and minor lines all traffic, both passenger and freight, was suspended for 12 to 24 hours or more. At Syracuse, N. Y., the thermometer registered 10 degrees below zero, and all railroad lines north of that city were reported on Monday as having no trains moving. Scores of trains were stalled in drifts, and some small villages had most of their food supplies eaten up by passengers. The main line of the New York Central was kept open only by the most heroic efforts all the way from Albany, N. Y., westward to Ashtabula, Ohio. High-class freight was kept moving with a considerable degree of success, but the heavy freight trains were motionless. Buffalo reported six inches of snow and a high wind, with trains many hours late from the south, east and west by all roads. Auburn, N. Y., reported no passenger trains in or out on Monday. This storm followed a thaw, and consequently switches were frozen at innumerable places.

On Tuesday there was a decided rise in temperature, and conditions were much improved.

In the storm of February 4-5 the difficulties in New England were worst in southeastern Massachusetts and in Rhode Island; but on the 16th trains were badly delayed in western Massachusetts and in Vermont and New Hampshire. From Concord, N. H., it was reported that the Boston & Maine was experiencing its worst tie-up in years. There, as in New York, the weather had been mild on Sunday, and on Monday switches and side tracks were frozen solid.

The New York, New Haven & Hartford had hard work not only in eastern Massachusetts but also on its line west of the Hudson river (the Central New England). Prior to the storm of February 4 the depth of snow on the ground was about 12 inches. Snow, sleet, rain and warm weather alternated for ten days and on February 15 a quick drop in temperature froze ice over the rails in many places throughout the company's lines. Some through passenger trains reached their destinations 24 hours behind time. As noted last week, many less important runs had to be omitted altogether.

In New England, as well as along the lines of the New York Central, the demands of cities for men in cleaning streets, and the general high wages paid to laborers, made very difficult the task of securing help. The New Haven road took about 1,300 men out of freight houses to handle shovels and picks, and about 1,700 were furnished by industries adjacent to the railroad, these latter being used largely to help in clearing freight yards and tracks other than the important main tracks. Altogether, the New Haven had nearly 8,000 men engaged in shoveling and picking. Train crews did a good deal of shoveling, and officers ran engines and snowplows.

Where the ice was thick the snowplows and flangers were almost useless and pneumatic tie-tampers were fitted with prone picks and used with considerable success in clearing switches. Three heavy Jordan spreaders were fitted with steel teeth on their nose-pieces and were successfully used in clearing the rails. These special expedients for dealing with ice were used mainly in and around Providence, R. I., where the ice formation was the worst. A statement credited to the Regional Director says that, in face of the adverse conditions, the New Haven road did wonderfully efficient work toward recovery.

On Tuesday, the 17th, the southern part of Michigan was reported as in the grip of the winter's worst storm, many trains being stalled in snowdrifts on the Pere Marquette and the Grand Rapids & Indiana.

In the region of New York City delays to trains because of obstructed tracks were less serious than farther north; but large numbers of freight cars had to be held many hours, and even days, because of difficulties of delivering in the