The Electric Locomotive, Pro and Con

At Sectional Meeting of A. S. M. E. and A. I. E. E. Held in New York City on Oct. 22 Experts Discussed the Respective Merits of the Two Types of Motive Power Available for Heavy Traction

A GATHERING which overtaxed the large capacity of the auditorium of the United Engineering Society's Building in New York City was held on Oct. 22 to discuss the respective characteristics of the steam and the electric locomotive with respect to modern transportation conditions. The meeting was the first to be held under the joint auspices of the railroad section of the American Society of Mechanical Engineers, the metropolitan section of the same organization and the New York section of the American Institute of Electrical Engineers. The meeting was well advertised and the enormous attendance indicates the lively interest which is taken by engineers in the subject of heavy electric traction.

The principal papers read were abstracted in the issue of the ELECTRIC RAILWAY JOURNAL for Oct. 23. One of the advantages of the steam locomotive was presented by John E. Muhlfeld, Railway & Industrial Engineers, Inc., while the cause of the electric locomotive was championed by F. H. Shepard and A. H. Armstrong, respectively connected with the Westinghouse Electric & Manufacturing Company and the General Electric Company. The program was presented under the direction of E. B. Katté, chairman of the railroad section of the A. S. M. E.; H. W. Buck, chairman of the New York section of the A. I. E. E., and W. S. Finlay, Jr., chairman of the metropolitan section of the A. S. M. E.

In opening the meeting Mr. Katté said that not only was it the first to be held under the auspices already mentioned, but the occasion was the first on which mechanical and electrical engineers had come together for the discussion of the electrification of steam railroads. It was fitting, he said, that at this meeting attention should be directed to the electric locomotive. He then introduced first Mr. Buck and later Mr. Finlay, who spoke briefly of the importance of the subject and the interest of their respective organizations in it. Next Frank J. Sprague was called upon for introductory remarks, and he responded for the "purpose of 'dressing the window,'" as he expressed it. The chairman referred to him as the "father of electric traction."

Demand for Increased Track Capacity Will Bring Electrification

At the outset Mr. Sprague said that he would not attempt a history of the development of the electric railway, but would refer briefly to some facts incident to his own association with it. He quoted from the *Sun* of a certain day in August, 1887, as follows: "They tried an electric car on Fourth Avenue yesterday. It created an amount of surprise and consternation from Thirty-second to 117th Street that was something like that caused by the first steamboat on the Hudson. Small boys yelled 'dynamite' and 'rats,' and made similarly appropriate remarks until they were hoarse. Newly appointed policemen debated arresting it, but went no further. The car horses which were met on the other track kicked without exception, as was natural, over an invention which threatens to relegate them to a sausage factory." Soon afterward the famous Richmond road, which is fairly called the forerunner of the modern trolley, was equipped, and in three years there were in operation or under construction, here and abroad, something like 350 electric trolley roads, and a quarter of the street tramway mileage of the United States had already been converted to the new power. The reason for this astounding growth was simply that the electric car could do what was impossible to its predecessor.

A result of this success was that wild prophecies were made by imaginative enthusiasts of the coming debacle of the steam railway, so that Mr. Sprague found it necesssary, as the incoming president of the A. I. E. E., in June, 1892, to sound a warning in his inaugural address, cautioning against undue optimism.

MULTIPLE-UNIT IDEA WAS FUNDAMENTAL

Mr. Sprague said further that the solution of the trunk line transportation problem had to be preceded by another and more pressing development which signalized the growth of a new idea, one essential to urban rapid transit, namely, the multiple-unit system. This, now the fundamental of electric rapid transit the world over, for a long time met only with contemptuous regard, despite an existing willingness to put it to a conclusive test on the elevated railroads at his personal risk. Then came the larger developments in the broad field of trunk-line operation for which it has supplied a vital essential.

Looking ahead Mr. Sprague said that he wished again to record his unchanging belief in the coming supremacy of electric power for transportation. This faith was based, not upon a vast disparity between the best which can be built in a steam or electric locomotive, nor upon any overwhelming claims of superior fuel economy when both are dependent upon coal supply, nor upon any material saving in operating expense sufficient to pay the charges incident to the increased capital cost when considered on existing traffic density and methods of operation, but rather upon the broad ground of the overwhelmingly vital demand for increased capacity, a demand which ultimately can be met only by the electric system, because of characteristics individual to it.

He admitted that there are inherent differences between the steam locomotive and its rival. The former is a moving power plant, limited both as to its maximum and its continuous rate of power development by the capacity of its boiler and portable fuel supply. It has, it may be granted, a certain apparent advantage because of its independent entity, but that very independence limits its capacity, not materially in maximum tractive effort, for any locomotive can slip its wheels, but in the amount of energy, that is, the product of speed and drawbar pull, which is possible. The electric locomotive, on the other hand, is but the user and transformer of electric energy created at distant power stations and transmitted to it by stationary conductors, and, thanks to the multiple-unit system, any desired concentration or distribution of power units, under a common control, can be had, and any number of power plants, taking their energy from the centuries-old and diminishing supplies, or the annually renewed frozen white coal of the mountains, may be joined together in common supply.

Mr. Sprague attributed the need for the great concentration of power to the insistent demand for increased capacity. There will come a time when duplication of tracks and increases in bridges, tunnels and terminals and the power of individual units will reach practical limits, when physical facts will rebel against engineering dictum or operative demands, and then the way, and the only way, to meet the demand for increased capacity is by increase of speed, which can only be obtained when unlimited power is at the command of the operator.

Already, said he, the electrification of railway terminals is an essential, suburban service has long been in operation, and through-operation of freight and passenger trains on mountain and other main-line roads satisfactorily negotiated. The same kind of service which characterizes suburban operation can be as readily applied to the longer local runs, such as those between New York and Philadelphia, and one's watch will be the time-table. Where, then, is the limit of the use of electricity? Mr. Sprague fails to see any. All the while the demand for a someday maximum of capacity will persist, as well as the present-day demand for vastly increased expedition in freight movement.

As these demands increase it will become more and more necessary to eliminate as far as possible non-essential rail transportation, and among such will be that coal which can be better burned at or near its source of supply and have its energy transmitted by wire. Unless those responsible for and in control of the country's transportation are sufficiently broad and far seeing to visualize the country's future requirements, and to realize how the welfare of every man, woman and child is bound up in the question of transportation, we shall have a hardening of the arteries and fatal blood clots in the circular system of transportation which will tend toward apoplexy.

In conclusion, Mr. Sprague said that the general electrification of trunk-line railroads is not a matter of immediate possibility of accomplishment. It will only come, as it is coming, progressively and with the accelerating power of example. It will be governed very largely by financial conditions, however justified under a sufficiently enlightened public policy railroads might be, if given sufficient encouragement, to assume the large added burdens incident to electrification. But the test of wisdom of railway officials, financiers and national and state governments is the ability to anticipate and plan against the inevitable before the slowing down and paralysis of traffic, such, for example, as is illustrated by the rapid transit situation in New York City, where congestion affects the daily life and well-being of the whole community.

Mr. Sprague referred to a recent article by President Underwood of the Erie Railroad in which the statement is made that the motive power of a railroad represent but 8 per cent of the capital invested, and that the remaining 92 per cent is wholly dependent upon its earning capacity. Considering the business as a manufacturing proposition only, the making and selling of transportation, Mr. Sprague asked, what would be the verdict with regard to any other manufacturing property in which the tool equipment represented but a twelfth of the invested capital. One would naturally suggest an increase of the investment in tools, and so it should be with transportation. There will come the time when the great increase of capacity available because of the use of electricity, plus the fact of its already successful use in many portions of the railway field, will compel the enormous increase in motive power investment inseparable from the adoption of electricity, large as it may prove, a fact which will be justified by the need existing and the results obtainable.

After the reading of the papers by the authors the chairman called in succession upon a number of speakers, each of whom spoke particularly with reference to one or the other type of motive power. In the following report the contributions are grouped, the speakers for the steam locomotive being listed first.

Advantages of the Steam Locomotive

The first advocate of the steam locomotive was F. J. Cole, chief consulting engineer Locomotive Superheater Company, his paper being read by H. B. Oatley, chief engineer of the same company. Mr. Cole said in part: In the twenty-seven years which have elapsed since the first electric locomotive was built for the operation of the tunnel into Baltimore slow progress has been made in this country toward superseding the steam locomotive. In all the papers and reports of the electrical installations we find much about their advantages and much of what has been accomplished, but we search in vain for a complete financial statement showing at what cost in dollars and cents all this is accomplished. Many electrical installations are necessary for special needs such as are mentioned elsewhere in this paper, but it has yet to be proved that there is any great demand for the wholesale electrification of railroads in this country. In the motor trucks and automobiles on the highway, carrying much of the passenger and freight business, we can appreciate something of the value of self-contained, independent power units, which have extreme flexibility and lend themselves readily to some of the transportation needs of this country. While a steam locomotive is limited in its movements to the track on which it runs, yet because it is a self-contained unit it serves well and economically many of our transportation requirements.

In the case of electricity, the entire cost of changing over from steam operation must be taken into account. For electrification it is customary to supply power station capacity in boilers, engines, turbines and generating apparatus largely in excess of the normal demand, located in more than one station so that there may be no interruption in the supply of current. Presumably railroads are now in possession of the necessary appliances for steam operation, and electrification means that much of such equipment must be diverted into other channels or discarded.

The electrification of terminals, tunnels and certain mountain divisions where water power is available is now recognized as desirable installation. Some of this is absolutely necessary, regardless of cost. There may also be a few zones in this country which by reason of density of traffic and co-ordination with the electrified terminals could be changed from steam to electric power with profit and the quicker despatch of business. It is a question, however, whether the best interests of electrical development are served by sweeping generalities and propaganda which has the object of relegating the steam locomotives to the scrap heap, and instilling into the mind of the public how unprofitable, how wasteful and how unsatisfactory is the transportation business when operated by steam locomotives, and recommending as a remedy for some of the ills from which we have been suffering in transportation matters the electrification of the principal roads in this country.

Admittedly, there should be a considerable decrease in fuel consumption for electric operation, but it is doubtful whether it will save anything like the enormous amount which we have recently been told could be saved if all the railroads in this country were electrified. And I think consideration of all the factors entering into the cost of both methods of transportation will show that one is very much exploited at the expense of the other.

THE gist of the presentation of the steam locomotive side of the electrification question seems to be this: Electrical engineers have been somewhat over-optimistic in their expectation of early replacement of steam by electric locomotives. The latter have been greatly improved of late and they have certain inherent virtues which are highly regarded by operators. Moreover, where is the money for electrification to come from, anyway ?

In the paper read by A. H. Armstrong* in Schenectady, Feb. 20, 1920, it is claimed that 122,500,000 tons of coal can be saved by electrification of railroads. These figures are based on tests which assume that locomotives used 7.86 lb. coal per horsepower-hour, or 10.23 lb. per kilowatt-hour at the driver rims. In regard to two points raised in this paper: (a) Not all of the coal consumed by railroads is used by locomotives. Shops, power stations, passenger and freight depots, offices and sometimes floating equipment have to be supplied; therefore, deduction must be made from the total amount charged to railroad use. Actual figures from one large railroad show that when winter and summer months are considered, 88.6 per cent of the coal consumed is used by locomotives and 11.4 per cent for other purposes. (b) The amount of coal per horsepower-hour of the steam locomotive given in the paper is entirely too high.

Much of the argument is dependent upon the high assumed rate of coal consumption, 7.86 lb. coal per horsepower-hour. For electric locomotives the estimated input required is 40 watt-hours per ton-mile. For coal the estimated amount is 2½ lb. per kilowatt-hour. Now the grand total for all regions (229,057 miles) reported in 1918 for steam locomotives is 190.7 lb. coal, hence the following values per 1,000 gross ton-miles: Electric locomotives 100 lb., steam locomotives 190.7 lb. If all of the engines were new and of modern design, a much better showing could be made. In 1918 the average cost of coal used by locomotives was $3.49 per ton. At 190.7 lb. per 1,000 gross ton-miles the cost of fuel was 33.4 cents per 1,000 gross ton-miles for steam locomotives over the entire United States. On the Virginian Railroad, where the power is comparatively modern, 163.3 lb. coal in 1917 and 160.6 in 1918 was used in steam locomotives per 1,000 gross ton-miles. The cost of fuel for the same railroad in 1917, 1918 and part of 1919 was from 18.7 cents to 25.9 cents per 1,000 gross ton-miles with coal at $2.38 to $2.74 per ton. On the Norfolk & Western for 1918 (five months) and the second quarter of 1919 the cost of fuel was 23.3 cents and 26.6 cents per 1,000 gross ton-miles with coal at $2.51 and $2.65 per ton.

These figures compare very favorably with 28.8 cents for water power given on page 730 of the *General Electric Review*, September, 1920. The cost of electric power for the Baltimore tunnel, 1910 to 1914, was from $1.049 to $1.435, average $1.199 per 1,000 gross ton-miles.

The increasing cost of coal permits the economical use of many fuel-saving devices on locomotives. A few years ago there was not much interest shown in such appliances; therefore, many locomotives are now running which are not so economical as modern engines. A Mallet compound locomotive, if in good condition and using superheated steam, in road tests will average 3.14 lb. dry coal per developed horsepower-hour at moderate speeds mostly on ascending grade. At an average of 3.10 lb. coal per horsepower-hour useful work can be done for 39.5 per cent of the figure given by Mr. Armstrong. Adding standby losses, taken at 17.5 per cent, the consumption is 3.75 lb. coal per developed horsepower-hour. In electrical units this is 5.05 lb. of coal per kilowatt-hour. If a kilowatt-hour can be produced at driver rims for 2½ lb. by electrification and by steam locomotives for 5.05 lb., the total amount of coal required by the roads of the United States if all were electrified will not show the great saving claimed.

The relative merits of steam versus electric locomotives are largely matters of cost. If a correct estimate of energy required to replace a steam engine is taken, in the first instance, it is possible then to estimate with some degree of accuracy the cost of electrification. Then the number of electric locomotives required, the number of power stations, the overhead construction, or third rail, changes in signaling system, shops and appliances to take care of the electric locomotives and power stations and the hundred and one items which go to make up a complete transformation from steam to electrification must be considered. A balance can be struck between the present cost of steam (which is known with a great deal of accuracy) and the computed cost of operation electrically with interest on capital expenditures at the present high rates. After this is done the operating costs can be correctly determined.

There are, admittedly, many attractive characteristics of electric power, but when it comes to a wholesale replacement of steam locomotives, especially on roads not peculiarly adapted to electrification, those responsible for the financial returns to the owners and to the public may well hesitate and ask to be shown the cost, not only of the installation under consideration, but of those now in operation, and the probable return on the investment for the large expenditure they are asked to approve.

After the presentation of the above paper by Mr. Cole the steam railroad standpoint was further explained by A. W. Gibbs, chief mechanical engineer Pennsylvania System. His paper will be abstracted in a later issue of the ELECTRIC RAILWAY JOURNAL.

*See issue of this paper for Feb. 21, 1920, page 878.

Remarks of Chief of M. P., New York Central

A paper written by F. H. Hardin, chief engineer of motive power and rolling stock New York Central Railroad, was read by R. M. Brown, engineer of motive power of the same road. Mr. Hardin wrote in part:

In comparing the cost of maintenance or operation of electric and steam locomotives it must be remembered that in the steam locomotive a complete power plant must be maintained and operated, whereas in the electric locomotive there is merely the tractor. However, in computing comparative costs, from either the maintenance or the operating standpoint, it seems absolutely necessary to consider the proper proportion of the cost of operating the central power plant in electric service and also the cost of power. One phase of the question is whether the matter of cost is to be based upon existing conditions or the situation fifteen or twenty years hence. The railroad today must pay 7 per cent interest on money, and capital expenditure involved in the construction of power plants, substations and electric transmission lines would be enormous.

Referring to Mr. Armstrong's suggestions as to certain things which the train dispatcher might be able to accomplish with electric locomotives, Mr. Hardin said that if the present steam locomotives could be removed from the rails and replaced with electric locomotives of equal capacity, the question would be how often the electric locomotive could "deliver the goods" at the other end of the line without delay or failure as compared with what the steam locomotive now does. If the electric locomotive can be made to run 1,000 miles without change and without breakdown or diminished power the dispatcher might accomplish a great deal even with present cars, track facilities, etc., but there is more involved than merely replacing a Mikado or Mallet locomotive with an electric locomotive of equal capacity.

Maintenance Costs Not Unreasonable

As to the statement that there is no need of the back shop for electric locomotives unless turning tires or painting may be considered heavy repairs, Mr. Hardin said that shops will be required, as electric locomotives must be heavy, so that drop pits, cranes and other shop facilities will be needed even for running repairs. Ability quickly to substitute repair parts would be an advantage, but no one can tell how many kinds of parts would be required for the different kinds and types of electric locomotives which would exist after fifteen or twenty years of electric operation. Furthermore, the spare parts or repairs would have to be made in shops maintained either by the railroad or outside concerns. As to the quoted maintenance cost of 60 cents per mile for a steam Mallet as compared with 14.65 cents for the St. Paul electric, costs on a New York Central division which used Mallets for most of its heavy freight trains in 1918 and 1919 amounted to from 21 cents to 25 cents per mile. These figures included some simple locomotives in operation on the same division. Some further figures covering back shop repairs of Mallet locomotives on two different divisions for the year 1919 showed averages from 12 to 19 cents per mile. Engine house maintenance cost is not readily obtainable, but may be assumed at not more than the shop cost per mile. Therefore, the total cost for the Mallet locomotive, including shop and engine house repairs, would be from 24 cents to 37 cents per mile.

Referring to costs, Mr. Hardin said that electric locomotives had been stated to cost possibly 50 per cent more than steam for equal driver weight, etc. In 1917 five modern 4-8-2-type freight locomotives cost about $205,000, about the same as one St. Paul electric locomotive. The five steam locomotives had total maximum tractive effort of about 250,000 lb., whereas the one electric had only 115,000 lb.

Taking up some points in Mr. Shepard's paper he said that the solution of the railroad problem lies in obtaining the money to build, more than electrification or any other factor. As to present standards of train make-up, classification and terminal handling, as to which Mr. Shepard thought that electrification would double the capacity of any railroad and, as methods are improved, double it again, he felt that electrification is only one factor in the solution of the problem and perhaps not the greatest one involved in accomplishing what Mr. Shepard sees in the future. As to the practicability of greatly increasing the speed of freight trains almost to that of superior trains, this undoubtedly means that improvements in freight car design must be made.

Mr. Hardin concluded by reference to Mr. Armstrong's statement that the Mikado locomotive burns 158 lb. of coal per 1,000 ton-miles. Some recent figures on one of the New York Central principal main-line divisions show a fuel consumption varying from 125 to 130 lb. per 1,000 gross ton-miles in freight service. In passenger service the consumption is from 12 to 17 lb. per passenger car-mile.

Coal Consumption on Steam Locomotives

In the absence of W. F. Kiesel, Jr., mechanical engineer Pennsylvania Railroad, some comment which he had prepared was read by title. His contribution in abstract follows:

Mr. Shepard expresses his belief that electrification is bound to be the most potent factor in the relief of the transportation problem. For electric locomotives he claims greater power, speed, flexibility and mobility; intimates that under electric operation divisions can be made much longer, and electric locomotives can be built to take any train which will hold together over any profile, at any desired speed, limited only by condition of track and car equipment. The same claim can truthfully be made for the steam locomotive.

For either kind of operation the length of divisions and location of terminals are governed by other than locomotive limitations, or, at least, there is no valid reason why any features of either electric or steam locomotives should affect the location of, or distance between, terminals.

In power, speed, flexibility and mobility either type can furnish all that track and car equipment will permit. To illustrate this, attention is directed to three recent locomotives: One was built by the General Electric Company, for the Chicago, Milwaukee & St. Paul Railway. According to a General Electric Bulletin* it has a starting drawbar pull of 115,000 lb., and a drawbar pull of 56,500 lb. at 25 m.p.h. on a 2 per cent grade. The two others were built by the Pennsylvania System. One is an electric locomotive having two synchronous speeds (10 and 20 m.p.h.), and the other a steam locomotive with four simple cylinders.

Both Pennsylvania locomotives have a drawbar pull, in starting on level tangent, of 135,000 lb. On grade

*No. 44,102.

the effect of truck and tender weight of the steam locomotive shows its influence, and the net drawbar pull, at 20 m.p.h. at rear drawbar (calculated) of these locomotives is as follows:

	Electric	Steam
On level, lb.	81,000	83,375
½ per cent grade, lb.	78,000	80,250
1 per cent grade, lb.	76,000	77,125
1½ per cent grade, lb.	73,500	74,000
2 per cent grade, lb.	71,000	70,875

Furthermore, the steam locomotive can deliver more net drawbar pull than the Milwaukee electric locomotive at any speed up to 50 m.p.h., and on any grade that it would have to encounter.

The strongest coupler in use today (American Railroad Association Type "D") has an elastic limit of about 200,000 lb. On present equipment there are several million couplers of a strength inferior to this. Therefore, it would scarcely be advisable to build locomotives of greater pulling capacity than two-thirds of the elastic limit of the strongest coupler, or 135,000 lb.

Mr. Shepard mentions retirement of weaker car equipments, which no doubt is advisable but will require time. His sentence, "Every other industry that has been electrified has experienced a revolution in methods and service, due to electrification," invites the most careful thought of those contemplating a change in operation.

Will electric service produce greater returns? Can the revolution in methods and service be accomplished without serious handicap during the transition period?

The capital investment for electric service will be more than five times as much as for steam service. The cost of an electric locomotive is about twice as much as that of a steam locomotive of the same power. The electric locomotives have shown some saving in repairs over steam locomotives, but after ten or twelve years' service they require rebuilding, especially in the electrical equipment, which runs the total cost of repairs beyond that of the steam locomotives. Possibly this can be improved.

From the report of the commission which investigated the advisability of substituting electricity for steam, in Chicago, it appears that the maintenance cost for wages and material would be 30 per cent more for electric operation than for steam. This is offset, at least partially, by electric traction advantages of regeneration, no reforking of ballast to remove smokestack cinders, less wheel and brakeshoe wear, etc.

With the exception of three factors, capital investment, coal per drawbar-horsepower and standby losses, there is too little difference between the two, for operation in open country, for further consideration.

Mr. Shepard speaks of one locomotive as a generator of power, and the other as a transformer of power coming from central stations with many refinements and high thermal efficiency. He credits the best steam locomotive with an average coal consumption of twice that of electric operation, for the same work performed.

Fine Coal Consumption Record on Pennsylvania

The Pennsylvania System steam locomotive referred to has the same steam distribution system as that of a 2-10-0 locomotive, which has been fully tested on the locomotive test plant* and will burn no more coal per drawbar-horsepower. The average coal consumption per drawbar-horsepower of the locomotive tested on the plant was 2.7 lb. for all firing rates up to 100 lb. per square foot of grate per hour and 3.27 lb. for all firing rates from 100 lb. to 160 lb. per square foot of grate per hour. Locomotives seldom have to burn more than 100 lb. per square foot of grate per hour. These steam locomotives had no feed-water heaters, the use of which, as proved by other tests, would reduce the amount of coal per drawbar-horsepower appreciably.

Inquiries were sent to various electrified roads, not including those with only short transmission terminal operation, requesting the average cost in coal per kilowatt-hour at the power plant, the average efficiency of the transmission line from power plant to the locomotive and the average efficiency of the locomotive.

One road, which has been electrically operated a number of years, and records each month's operation, has a power-plant "cost" of coal per kilowatt-hour of 2⅝ lb. as the minimum when the plant output is maximum. Taking this as 100 per cent load factor, the cost is per kilowatt-hour 3.2 lb. of coal for a load factor of 50 per cent, and 3.53 lb. for a load factor of 40 per cent. Most of the monthly record figures lie between 35 and 50 per cent load factors, and the average of coal per kilowatt-hour is above 3¼ lb. These figures necessarily reflect both the daily and monthly variations in load factor, and are, therefore, high.

Another road reports 40,000 to 44,000 B.t.u. per kilowatt-hour at switchboard for coal varying between 13,000 and 14,200 B.t.u. per pound.

Mr. Beeuwkes Quoted

The coal used in the test of the 2-10-0 steam locomotive given above averaged 13,429 B.t.u. per pound.

Replies as to the line efficiency appeared inconsistent, therefore the data given by Reinier Beeuwkes in his paper before the Pacific Coast section, A. I. E. E.,* are cited. These show an average ratio of net input at locomotive to actual system input for locomotive of 66.3 per cent for the Missouri division, and of 68.3 per cent for the Rocky Mountain division. Replies as to locomotive efficiency indicate that this is less than 75 per cent in all cases.

Apparently the fluctuations in load factor present a greater menace to coal economy than steam locomotive standby losses. The average load factor may be taken at 50 per cent. Neither line efficiency nor locomotive efficiency is likely to average as high as 75 per cent.

Existing installations may be taken as approaching, but not yet reaching, 3 lb. of 13,500-B.t.u. coal per kilowatt-hour at the power plant, a line efficiency of 75 per cent and a locomotive efficiency of 75 per cent, resulting in a consumption of 4 lb. of coal per drawbar-horsepower-hour. Therefore, the standby and other losses of the steam locomotive can be 32.5 per cent to equal the probable best average performance of present-day electric traction in coal consumption, and that much loss would be a sorry reflection on operating methods.

Possibly improvements may change this situation, but until the electric locomotive is ready to do the work as cheaply as the steam locomotive it is illogical to tear up the old operation by the roots and substitute a much more costly plant whose habits are not so well known.

Mr. Armstrong also dwells on greater power, speed, flexibility and efficiency, and speaks of running a thou-

*See Pennsylvania System Test Bulletin 31.

*See ELECTRIC RAILWAY JOURNAL, July 31, 1920, p. 227.

sand miles with no attention, except by crews. He describes ideal characteristics of a locomotive, none of which apply to the electric locomotive in any greater measure than to the steam locomotive. The "precedent and prejudice" to which he refers seem to be imaginary. As he uncovers step after step of his flights of imagination a gradually increasing desire for "facts" is felt.

In view of existing locomotives described in the foregoing, the table of comparisons between two steam locomotives, a Mikado at 14 m.p.h. and a Mallet at 9 m.p.h. (evidently not good specimens) and an imaginary electric locomotive at 16 m.p.h., is, to say the least, inconsistent, and the claim that a mountain division will have an increase of 50 per cent in daily tonnage over possible steam engine performance is not so "modest" as claimed.

In this statement the claim that "electric locomotives can be maintained for 20 to 25 per cent of the upkeep cost of steam locomotives" should be included.

Two statements in the fuel comparison deserve some analysis. The standby losses for steam locomotive are given as 9,042 lb. of coal. The regenerative braking on the electric locomotive is credited with a saving of 1,430 lb. of coal. About half, or 4,595 lb. of coal, of the standby losses are for making fire and drifting, which is high. The coal used for making fire is not all loss.

As to regeneration returning 18 per cent of current used back into the line, that appears high, and leads to the suspicion that Mr. Armstrong uses a comparison between a very bad steam operating condition and a very good electric operating condition, which is not representative of averages.

At present steam locomotive standby losses are high, but when railroads get back to normal these losses will be materially reduced, and the average will no doubt be less than 15 per cent of the coal used. Regeneration may be a slight factor, but it will be nearly negligible in averages.

ELECTRIFICATION SOMETIMES HAS PRIORITY RIGHTS

For certain local conditions electric traction should be given priority rights, even if the cost is greater. They are: (1) In tunnel operation; (2) in large cities and their suburbs; (3) where sufficient water power is available; (4) where super-power plants can be built in juxtaposition to an adequate supply of culm, or other low-grade combustible not easily marketable.

In the open country, where smoke and gases from the stack are not seriously objectionable, existing installations do not yet indicate that electric traction can be carried on with as little coal consumption as modernized steam traction. Where steam locomotives are too small and inefficient, larger and more economical steam locomotive units to meet any power and speed requirements within the limitation of track and equipment can be substituted without in any way interfering with the continuity of traffic or educating the personnel to handle the new power. As tersely stated by Mr. Shepard, the substitution of electric traction will require a revolution in methods and service.

The answer to the problem is governed by whether there is a saving in coal with electric traction over that with steam traction, including standby losses, and whether this saving is sufficient to pay interest, depreciation, taxes, insurance, etc., on more than 400 per cent greater capital investment, and for the interruption of traffic and the revolutionizing of the organization during the transition period.

Maintenance of Electric Locomotives Affected by Overload

The fifth speaker for the steam locomotive was W. L. Bean, assistant general mechanical superintendent New Haven Railroad. Mr. Bean declared that while, broadly speaking, electrical operation requires less coal per unit of traffic handled than steam operation and the mileage per unit of electric equipment is ordinarily greater per unit of time, yet on one road the first cost of the electric engines per unit of capacity was 84 per cent greater than in the case of steam. Referring to the comparative flexibility of the two types he said that a certain modern passenger electric locomotive will handle a heavy train of Pullmans at high speed on a through run with few stops such as would require a modern Pacific type steam engine of about 43,000 lb. tractive effort, but because of heating caused by frequent starting in heavy local service, the maximum train which could be handled by the same electric locomotive is one which could be hauled by a steam engine of about 30,000 lb. tractive effort. There is also not much elaboration of the fact that an inconsiderate or overambitious yardmaster may overload the electric engine, and that machine, possibly in sympathetic endeavor to live up to the expectations of its sponsors, goes after its job like a spirited horse. A steam locomotive, on the other hand, being what might be termed more phlegmatic, will do about so much and no more, and either stalls or loafs over the road without injury to itself. The electric engine may not be subject to "creeping paralysis," but since it leads a strenuous life, it acquires a sort of hardening of the arteries in the way of accumulative depreciation of insulation which leads the way to heavy repairs.

Again, it is difficult to understand how railroads are to maintain electric locomotives without back shops, unless they job the work out to manufacturers of electrical equipment. Bearings wear, springs fail, axles and frames break on electrics as much as they do on steam engines. Switch groups, transformers, motors, both main and auxiliary, air compressors, blowers, control and collector apparatus, all require overhauling periodically. Officers in charge of maintenance of electrical equipment on one Eastern road are at present insisting that $350,000 be expended soon for an addition to the present back shop.

While the design of a steam locomotive is said to be utterly circumscribed by the necessity for tying it up to a steam boiler, the statement can also be made that some modern high-powered electric locomotives are so compact with apparatus, both inside the cabs and beneath, as well as on top, that additions to, or enlargements of details, even of a minor nature, are well-nigh impossible. When one comes to the problem of heating passenger trains, electrically drawn, the difficulty of finding room for the boiler, water and fuel oil storage, auxiliaries, etc., and keep within weight limitations, lead one to the conclusion that on electric passenger locomotives the boiler is circumscribed by electrical apparatus. Electrical engineers on one road have even advocated the construction of a tender for carrying the boiler, water tanks, etc. Imagine an electric locomotive requiring a tender!

The steam locomotive, except in a moderate way as to clearance and weight limits, has a wide range of application. Railroads loan steam power back and forth with advantage usually to both parties, but no case comes to mind where electrical equipment for heavy traction can be interchanged. It is to be hoped that the lines of development of electrical facilities will tend to converge along lines of common usage rather than diverge too widely. Some reasons for such desirability are: (a) Railroad managements will not be so fearful of becoming tied up with a heavy and inflexible type of investment, which may quickly become obsolete through not lending itself reasonably well to extension of modernization, and (b) the need for a broader field of design and manufacture of equipment and the furnishing of repair parts for the same.

Dependence largely on one manufacturing concern which must unload heavy overhead charges at surcharge rates, unheard of in the case of steam locomotives, is highly undesirable and is restrictive to the extension of electrification.

Virtues of the Electric Locomotive Extolled

The first speaker to reinforce the arguments of Messrs. Shepard and Armstrong in favor of the electric locomotive was C. H. Quinn, chief electrical engineer Norfolk & Western Railway. He said that if we are to maintain our standing in the commercial world our railroad facilities must go forward. Obviously the movement of freight traffic takes precedence over other transportation problems, hence interest and study should be concentrated on the freight locomotive. The following extracts indicate Mr. Quinn's line of thought:

If our knowledge of the development of freight car equipment is indicative of what our freight transportation motive power needs may be in the future, we should begin to look into the possibility of the steam locomotive being able to keep up with development of other transportation facilities. Freight cars for carrying coal within the past ten years have been increased in capacity from 50 to 100 tons per car for 100 per cent. Apparently the steam locomotive may be called upon indefinitely to meet the ever-growing demand for heavier trains which must be operated at higher speed and with minimum delay between terminals. During this same period the largest type of steam locomotive has added generally about 13 per cent to its weight and number of driving wheels. In 1909 the Mallet engine had up to a total weight of 700,000 lb., with 412,000 lb. on driving wheels (Santa Fé 2-8-8-2). In 1919 the engine of the same type had a total weight of 731,000 lb., with 478,000 lb. on driving axles. With the exception of a special design only permissible in restricted track districts these are characteristic figures for the representative steam locomotive development during this period. With vertical and side clearance limited to fixed values the engine can only be enlarged by adding to its length. Again the rigid wheelbase stops the expansion along the track.

Reference has been made to similarity in capacity of the 2-10-10-2 Mallet locomotive on the Virginian Railway and the electric freight locomotive on the Milwaukee. However, it was only by reason of the extremely wide side clearance existing on this one road that such an engine could be used. Furthermore, the engine could not be handled by its own power over any railroad but had to move over a special route from factory to point of delivery. If we are to provide for the use of these larger steam engines on all railroads the cost of bridge and tunnel work and possibly the rearrangement of clearances on some double-track railroads must be given consideration and the cost charged against the future increase in capacity of the steam locomotive.

Again, in the improvement in fuel economy in the steam locomotive for the past ten years we find that relatively little has been done to keep pace with the ever-increasing demand for fuel conservation.

The American Locomotive Company in 1911 issued a bulletin giving in detail the results of six dynamometer-car tests, made behind a 0-8-8-0 Mallet engine. This locomotive had a total weight of 523,500 lb., with 376,800 lb. on drivers. It operated on saturated steam and was hand-fired.

This particular engine, under special supervision of the testing crew, as an average of six tests delivered a drawbar-horsepower hour on 5.15 lb. of coal fired. In 1918 under similar operating conditions a practically new 2-8-8-2 Mallet engine, weighing 695,000 lb., with 472,000 lb. on the driving wheels, and equipped with superheaters, brick arch and stokers, as an average of six tests gave a drawbar-horsepower-hour on 4.33 lb. of coal.

30 PER CENT OF COAL SAVED ON N. & W.

The above figure of 4.33 lb. of coal may be compared with the performance of the electric locomotive on the Norfolk & Western, the operating conditions being very similar. Converted into electrical terms this is 5.77 lb. per kilowatt-hour at the drawbar. Adding to this 23 per cent, a nominal amount for standby losses, we have a total of 7.12 lb. During 1919 our Bluestone plant generated for traction purposes about 67,395,000 kw.-hr. and burned 103,034 tons of coal, which is equivalent to about 3 lb. of coal per kilowatt-hour at the switchboard. As a total loss between busbar and drawbar of 40 per cent is an average for electric locomotives of the size and weight of those on the Norfolk & Western the coal consumption is 5 lb. per drawbar kilowatt-hour, a saving of 2.12 lb., or 29.3 per cent in favor of the electric locomotive. During this twelve-month period we handled 4,714 eastbound trains and burned 103,034 tons of coal, or slightly under 22 tons per train. An average of three tests with hand-fired Mallet engines in the same service and using a sacked coal showed a total consumption per train of 35 tons, or an excess for the steam engine of 13 tons per train over the electric locomotive.

The suggestion has been made here this evening that we consider from twenty-five to fifty years as the useful life of a steam locomotive and that the steam locomotive designer and builder become active in the direction of superheating and compounding of steam locomotives for the purpose of increasing their capacity. Might we ask what has become of the four-cylinder and cross-compound engines of thirty years ago and likewise of the experience gained with compound engines during this period? If the benefits derived from compounding are not thoroughly understood after thirty years of experience how can we expect the next twenty-five years to develop such data as will materially improve the situation. It required fifty years to settle upon 4 ft. 8½ in. as the standard track gage. It is inconsistent to attack the electric locomotive because after a limited trial of fifteen years we still have two systems of power distribution in use.

Reference is made to the handling of heavy tonnage trains as reflecting in peak loads on power plants and the transmission system. On the Norfolk & Western we handle our entire electric operation without any instructions from train dispatchers and without any system of arbitrary train spacing. Our power plant and transmission system are fully able to take care of 100 per cent more tonnage in a given time than had ever been handled by steam power. The prospective user of the electric locomotive need not fear any failure or limitation from this source if the installation is laid out with the present degree of latitude in providing general facilities over the right of way and at terminals for steam power.

The electric locomotive is charged with imposing definite spread of traffic over a division, the inference being that this is necessary for economical and successful operation. In this connection I may say that the automatic block signals on the Norfolk & Western are the only devices used to guarantee a spread traffic in our electric zone, and so far they have been very successful.

Further reference is made to some uncertainty in the functioning of the regenerative control of the electric locomotive. Like all other systems of braking, the regenerative system is susceptible to man failure. On the Norfolk & Western we are moving in one direction an average of 4,000 trains per year. We have had the electric locomotives in service about five years and in that time have handled more than 20,000 trains, using only the regenerative apparatus to brake a 3,250-ton train down a 2.3 per cent grade.

So far we have not had a man failure and the regeneration still has 100 per cent operation to its credit.

If our freight-car carrying capacity can be increased 100 per cent in ten years are we to be satisfied in considering the freight locomotive as having reached its maximum development? Is the railroad operating world as a whole going to be satisfied with the freight revenue obtained by using 100 per cent larger cars and be forced to reduce the number of cars per train by the limitation of the steam locomotive? Do we expect our operating officials to be satisfied with the continued payment of premium overtime for freight train crews brought about by the slow movement of trains and the eight-hour day? The average engine and train crew is held 25 per cent of its time at terminals. If we are to eliminate the ever-growing labor expense of premium overtime and reduce the standby losses of our locomotives running time per 100 miles must be reduced to five hours instead of eight, now about the best we can expect from the steam locomotive.

If we are to aproach this problem with the purpose of providing such motive power at the head end of our freight trains as will develop not only the drawbar pull up to the maximum capacity of the heaviest gear now in use but such an engine as will sustain this pull at a speed that will permit train operation over a 100-mile division of varying profile within the time limit of the eight-hour day we fail to find a steam locomotive record that will answer this specification.

Following Mr. Quinn, the case for the electric locomotive was carried further by A. L. Ralston, mechanical superintendent New Haven Railroad. His paper will be abstracted in a later issue.

Mr. Beeuwkes Sends a Contribution

The Milwaukee Railway was represented in the discussion through a communication sent by Reinier Beeuwkes, electrical engineer of that road. Mr. Beeuwkes' paper, which was read by title, is abstracted below:

Mr. Beeuwkes said that as frequent references were made in the papers to the Chicago, Milwaukee & St. Paul electrification, he wished to correct mistaken impressions which might be derived from such references in Mr. Muhlfeld's paper. He quoted Mr. Muhlfeld's statement to the effect that "few if any existing steam roads can justify or stand the additional capital expenditure per mile of road for electrification, etc." The statement, he said, is supported by neither facts nor figures. It is not borne out in the case of the St. Paul electrification, and there are many roads with like conditions which might expect results similar to those which the St. Paul has obtained. The electrical operating experience of this road enables accurate determination to be made of what the results of electrification will be in any similar case, and there are few cases which will not profitably warrant at least consideration of electrification. In any event actual available operating data will permit of settling the matter one way or the other in the individual case. That Mr. Muhlfeld's opinion does not represent the foregone conclusion of steam men in general is evidenced by the serious attention they have more and more been giving the matter of electrification.

Mr. Beeuwkes also referred to the comparison made between a St. Paul electric articulated and a Virginian steam articulated locomotive. In this the assumption seems to be that the electric locomotive had been designed to secure the maximum capacity possible, and the purpose of the comparison seems to be to show that the steam locomotive can be built with still greater capacity. The St. Paul locomotive, he said, was actually designed for capacity sufficient to handle a 2,500-ton trailing load over any portion of the profile without helper on grades of 1 per cent or less, at a speed of approximately 16 m.p.h. It was designed for no greater capacity, because that specified was deemed by the railway to be sufficient. The tractive effort of this locomotive at 15 m.p.h. is about 88,000 lb. instead of 71,000 lb. as given in the tabulation. The figure of 71,000 lb. represents approximately the continuous tractive capacity, and the speed corresponding would be approximately 16 m.p.h.

The item of train speeds is important to consider in connection with the many cases in which the question of terminal capacity does not enter, but rather that of increasing existing track capacity or, in lieu thereof, providing additional tracks. While it might be practicable to secure any desired speed at any tractive effort in an electric locomotive, provided the necessary resistance were supplied, actual practice has demonstrated that ample flexibility is secured by providing two or three running speeds for any particular tractive effort. There was no particular difficulty involved, however, in securing as many as nine running speeds in the case of one of the new types of St. Paul passenger locomotives.

In connection with the comparison between a Pacific steam locomotive and the St. Paul passenger locomotive, Mr. Beeuwkes stated the facts to be: That the electric locomotive is designed to handle, and tests have shown it capable of handling, a trailing load of not less than 960 tons over the profile, including the 2.2 per cent grade at the Columbia River. This is equivalent on the average to a train made up of thirteen of the St. Paul steel cars, or of fourteen cars of the average weight of the cars in the train mentioned by Mr. Muhlfeld.

Referring to Mr. Muhlfeld's comments on fuel consumption, Mr. Beeuwkes said that fuel economy does not constitute the principal claim for electrification. This depends, in the individual case, upon the relative cost of delivering coal or electricity to the locomotive after all fixed and operating charges are considered. It may for such individual case develop that the savings from electrification will be those due to decreased cost of engine repairs, engine house expense, train and enginemen's wages, increased ton-mile capacity of locomotives, etc. In the case of the St. Paul the power contracts apply for 100-year terms, and a fixed price for energy is thus assured. The figure of 40 kw.-hr. per 1,000 ton-miles used by Mr. Armstrong represents an average for the whole year for trains of varying tonnages and under all weather and other affecting conditions. A corresponding figure based on special test runs as derived by Mr. Muhlfeld would obviously not be comparable. The comparable fuel figure for all trains and for the whole year for the district to which Mr. Muhlfeld refers could hardly be expected to run very high, as the average grade between the points mentioned is only about 0.06 per cent and the ruling grade only 0.8 per cent, as compared with the mountain grade conditions on the St. Paul. Mr. Beeuwkes also took up the reference made to the steam equipment which was replaced by the electric locomotives. This was stated to be antiquated or obsolete. The line of the St. Paul west of Mobridge has only been in operation since 1908 and most of the locomotives for it were purchased new. While most of the new locomotives were not of the most improved present-day type, they are probably representative of what is in general use by other roads.

> THE proponents of the electric locomotive contended that fuel economy does result from its use. But the greatest boon conferred by electrification is increase in track capacity. This results from the possibility of obtaining higher speed and greater tonnage per train. Regenerative braking also is a unique contribution to the art of railroading. Railroads which have electrified sections appear to be enthusiastic as to the future of electrification.

The list in Table I shows the types in operation on the Rocky Mountain Division in December, 1915 (excluding locomotives in shop), just before electrification. The coal per 1,000 ton-miles for October, November and December, 1915, averaged for freight service 276 lb. as against 39.4 kw.-hr. per 1,000 ton-miles for October, November and December, 1916, under electrical operation.*

TABLE I—C., M. & ST. P. STEAM LOCOMOTIVES IN FREIGHT SERVICE, ROCKY MOUNTAIN DIVISION

Number	Class	Weight on Drivers, Pounds	Rated Tractive Power, Pounds	Remarks
		Road Engines		
7	Prairie	152,000	33,300	Simple
3	Mikado	216,500	50,600	Simple, superheater
12	Mikado	201,000	46,630	Simple
7	Mallet	327,500	76,200	Comp., superheater
5	Mallet	323,500	76,200	Compound
		Helper Engines		
1	Mikado	213,500	50,000	Simple, superheater
2	Mikado	205,000	46,630	Simple
2	Mallet	323,500	76,200	Compound

Taking up the item of efficiency of locomotive operation, Mr. Beeuwkes said that allowance for transmission losses between power plant and railroad electric system depends on the conditions of the particular case, provided that the station coal consumption, in this case 2.5 lb. per kilowatt-hour, is not already sufficient to cover the transmission loss. If the power plant is located on the railroad adjacent to the railway transmission system, no additional loss allowance is necessary. If the plant is not so located a maximum allowance of 10 per cent of the power delivered would cover the transmission loss, even for a considerable distance, without expensive transmission construction. He also said that comment is superfluous regarding such indefinite remarks as: "When, on account of transportation conditions, a motor is required to carry an overload for periods of five or six hours it either breaks down due to heating, etc." An electric motor can exert abnormal tractive effort for considerable periods without injury, whereas the steam locomotive has a well-defined maximum tractive capacity, depending upon the steam pressure at which it is supplied.

By way of summary of Mr. Beeuwkes' comment on several other points in Mr. Muhlfeld's paper, the following points are of interest: (1) One of the marked economies effected by electrification is the reduction of train and enginemen's expense, on account of the increased ton-miles per train-mile and per engine-mile, and the reduction of equipment repair and roundhouse expense. (2) The spacing of trains to hold down the power demand on the St. Paul electrification has in combination with the action of the power-indicating and limiting system worked out very well. When the load factor was running 60 per cent or higher the automatic slowing up of trains involved an increased expenditure for freight train and enginemen's time of about 10 per cent. With a load factor of from 50 to 55 per cent, however, the limiting action takes place through only a small part of the day, and while there is a considerable reduction in the maximum demand there is little effect on the operation. (3) As to ease of starting trains, this feature of electrical operation is noticeable, conducing to increased comfort of passengers, an electrical operation asset whose value is not always recognized. As to starting each car successively, this does not apply in the case of a train on a mountain grade. (4) The performance, described by Mr. Muhlfeld, of a heavy steam freight train going down a 17-mile grade averaging 2.2 per cent, without stop to cool brakes, is unusual. His information as to the accident on the St. Paul is incorrect. There is nothing in the regeneration system which prevents the application of the air brake at any time, and if they are applied soon enough and properly, and are in good condition, the train will stop. At an investigation of the accident, testimony was introduced by some of the crews to indicate that the brakes were not in proper condition, but it was admitted that the brakes were tested before the train was started down the grade and the brake-inspection crew testified that the number of good brakes per car was above the requirement. The speed-recorder tape was not operating, so direct knowledge of the speed at which regeneration was attempted was not available. In any event the

*See issue of this paper for March 24, 1917, page 541.

overload relay or overvoltage relay on the locomotive operated and disconnected the motors from the line, and the engineer, whatever the reason, failed to bring the train to a stop by means of his air brake. The enginemen, trainmen and others connected with the electrical operation were unanimous in declaring that the accident was in no way an electrical failure. The electric locomotive in this case attained a maximum speed of about 50 m.p.h. and at this speed passed round a sharp curve at the foot of the grade without leaving the track or damaging it in any way. (6) Frequent references are made in the paper to improvements which are being or can be made in steam locomotives and steam operation which will make the average steam locomotive compare favorably in its performance with the electric locomotive. Steam locomotives have been used for a great many years and the electric locomotive is comparatively new. It is not too much to expect that the electric locomotive and electrical operation will also be progressing while the steam locomotive and steam operation are trying to catch up.

Mr. Katte Sums Up the Case for the Electric Locomotive

The chairman had prepared some comment for the close of the discussion, but owing to the lateness of the hour he omitted the reading of his notes. These were of a conservative tenor. The conservative engineer, he wrote, on considering the papers prepared for the meeting, would be apt to conclude that too much has been claimed for the steam locomotive as well as for the locomotive operated by electricity. Without doubt there are advantages peculiar to each, but it will always rest with the railroad engineer to determine and decide which type of locomotive will be best suited to the peculiar conditions surrounding the railroad which he serves.

Because of the different operating characteristics of steam and electric service it may be misleading to compare the time the locomotives are in use. For example, the electric locomotives of the New York Central Railroad operate only in a terminal zone, which makes the comparison with locomotives on steam-operated divisions hardly a direct one. However, the following comparison of per cent of "time ready for service," compiled from actual records for the first eight months of this year, will be of interest:

READINESS OF LOCOMOTIVES FOR SERVICE

Condition of Locomotive	Electric Locomotive	Steam Locomotive
Ready for service, waiting, per cent	56.2	24.3
In service, per cent	31.3	47.8
At terminals, per cent	4.0	4.6
At engine house, per cent	8.5	23.3
	100	100

The fact that the electric locomotives stood waiting for service 56 per cent of the time and were actually in use only 31 per cent of the time is due to the train schedule and the grouping of a large number of trains night and morning with comparative inactivity between these hours. This clearly illustrates the necessity of carefully studying local conditions before coming to the conclusion that electric operation will prove more economical than steam operation for a given railroad proposition.

Unfortunately, a direct comparison, applicable for all railroads, between the coal burned on the steam locomotive and the fuel consumed in the power house for supplying energy to the electric locomotive cannot be made with the same accuracy as, say, between a reciprocating engine and a steam turbine. This is because there are not a representative steam division and an electric division operated under anything like the same conditions. The following comparison of fuel consumption has been computed from the reasonably accurate records of three railroads operating both steam and electric locomotives under widely different conditions both as to equipment and service:

COMPARATIVE FUEL CONSUMPTION—STEAM AND ELECTRIC

Items	C., M. & St. P. R. R.	N. & W. R. R.	N. Y. C. R. R.
Kilowatt-hours per train-mile measured at alternating-current side of substation	29.1	361	34.5
Pounds of coal burned on steam locomotive per train-mile	188.	1400	112
Pounds of coal on steam locomotive equivalent to 1 kilowatt-hour measured at alternating current side of substation	6.46	3.88	3.25
Computed pounds coal at power station per kilowatt-hour referred to alternating current side of substation	2.44	2.44	2.44
Saving of coal in favor of the electric locomotive, per cent	62	37	25

This wide range of results and the apparent discrepancy in the relative fuel consumption are due to widely different conditions. Even a wider difference in power consumption will be found on trains in different service on the same division, as, for instance, on the New York Central Railroad, a multiple-unit train making stops every mile or so will consume 150 watt-hours per ton-mile, whereas the through trains making no intermediate stops in thirty miles or more will consume but twenty-six watt-hours per ton-mile.

Finally, too much reliance should not be placed on results obtained from test runs, even if they fairly well simulate actual conditions. To be of comparative value, service records should extend over several years, and the data should be carefully collected, correlated and averaged to give results that may be expected in everyday operation.

Closing Remarks by George Gibbs

The discussion of the evening was closed by George Gibbs, chief engineer electric traction Long Island Railroad. Mr. Gibbs spoke as a railroad man. He said that in discussing this subject it is presumably permissible to view it from the standpoint of either design or performance. It concerns the relative advantages of two kinds of power plants for conducting railway transportation. An abstract of Mr. Gibbs' remarks will appear in a later issue.

Electrolysis Committee Active

THE research sub-committee of the American Committee on Electrolysis is making an important series of investigations in Cleveland, with the financial support of the Cleveland Railway and the Cleveland Electric Illuminating Company. L. P. Crecelius, superintendent of power of the railway and American Electric Railway Association representative on the research sub-committee of the A. C. E., has been active in this work. Pipe drainage as a means for electrolysis prevention is being particularly studied, and the first work includes new installation. Problems of interchange of current between conductors, of joint electrolysis, etc., are being considered in connection with gas and water piping and power and railway cables.