OFFICIAL PROCEEDINGS

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The regular monthly meeting of the Western Railway Club was held at Hotel Sherman on Monday evening, December 15th, 1919, President Goodwin in the chair. The meeting was called to order at 8:15 P. M. Among those present the following registered:

*Albright, C. S.
Barnes, C. A.
Barnett, E. J.
Barr, L. S.
*Batchelder, W. O.
Beattys, W. H., Jr.
Bender, Geo. W.
Bergin, D. J.
Biddle, A. E.
Boyce, Geo. R.
Boynton, H. L.
Bunn, G. F.
Butters, H. M.
Caldwell, C. R.
*Childs, T. M.
Cizek, J. J.
Clokey, A. W.
Comee, J. F.
Cook, W. G.
Cooledge, F. J.
Cooper, J. H.
Court, C. W.
Cross, A. B.
Denham, T. B.
*Dodd, S. T.
*Donaldson, W. F.
Dorticos, C.
Ehrwald, O. E.
Evans, Walter H.
*Ewing, I. P.
Farrelly, A. J.
Fogg, J. W.
Forsyth, B. H.
*Freeman, C. M.
Gale, H. C.
*Ganzert, A. E.
*Gaskill, C. H.
*Goddard, G. T.
*Gould, E. F.
Griffin, H. G.
Grogan, W. J.
*Hale, J. H.
Hamilton, K. M.
Hauser, W. H.
Hayward, Oscar C.
Heacock, W. F.
*Heidel, Ed. H.
Heiser, W. F.
Hermansader, E. Z.
*Hershey, Quincey W.
Hohmyer, A. K.
Hull, Geo. A.
*Jansen, E. W.
*Jenks, A. P.
*Jennings, Henry L.
Johnson, B. S.
Johnson, H. A.
*Johnson, J. H.
Kass, P.
Kelly, W. T.
*Knapp, Chas. S.
Kucher, T. N.
Lammedee, John M.
Lamon, Judson A.
LaRue, Henry
Longman, Chas. H.
*MacKenzie, T. A.
McLellan, R. L.
*Meisel, B. W.
Mellor, C. L.
Milton, J. H.
Moody, Louis M.
Moore, W. H.
Morehead, L. B.
Motherwell, J. W.
Naylor, N. C.
*Nutter, C. E.
O'Donnell, Harry B.
*Otis, H. A.
Parkinson, H. W.
*Parker, A. J.
Parke, P.
*Parker, S. W.
*Peck, C. B.
Pennington, H. R.
Ponic, J. L.
Porterfield, R. R.

MR. E. W. PRATT: I would like to ask as a favor of the Club to make a motion relative to this resolution. Before I make the motion I should like to say just a word.

I have little doubt that you were all shocked greatly at the news that Mr. Barnum had gone beyond. To me, who had worked with him more particularly in the last three or four years on committee work, and in fact, we had been thrown together nearly a week at a time at various periods in Washington and at other points where the committee was meeting, it was almost a stab to the heart.

Mr. Barnum is well spoken of by the words of our past president and his committee, and I crave the honor, having been a past president of this Club, of making a motion that this committee be authorized to present in suitable form a copy of this beautiful memorial to the family of Mr. Barnum.

MR. H. LA RUE: Mr. President, I second the motion.

THE PRESIDENT: Moved and seconded that a copy of this memorial be prepared in suitable shape and sent to the family of Mr. Barnum.

MR. LA RUE: Also that the report be spread upon the minutes of this Club.

THE PRESIDENT: And that the report be spread upon the minutes of the Club. All in favor say "Aye." It is carried.

I think there are possibly some members that came in while the Reception Committee was not looking. Will you not pardon them, because they are new on the job and they missed you. Any that did not register, we will appreciate it if they will get cards and as you go out, leave your names.

MR. WRIGHT: May I not say that if there are any here that have not registered, if they will hold up their hands, we will pass the cards.

THE PRESIDENT: Gentlemen, if you will indicate in this manner, we will register you.

The paper of the evening is "The Increasing Necessity for Steam Railway Electrification." The author is Mr. Norman W. Storer, General Engineer, Westinghouse Electric & Manufacturing Company. It gives me pleasure to introduce to you Mr. Storer.

THE INCREASING NECESSITY FOR STEAM RAILWAY ELECTRIFICATION

BY NORMAN W. STORER, GENERAL ENGINEER, WESTINGHOUSE ELECTRIC & MFG. CO.

The question of Railway Electrification has been kept continually before the notice of Railway men for more than a score of years. It would seem that everything that could be said has been said over and over again. In spite of this I am emboldened to undertake another paper on the subject because Calvert Town-

ley, now President of the American Institute of Electrical Engineers, in discussing this subject at the Boston meeting of the Institute last March, declared that, "if at times we (Electrical Engineers) have injured the cause of Electrification by claiming too much, strange as it may sound, we have injured it still more by not claiming enough." That seems like a serious charge to make against us, especially when he practically says that no one has known enough about the subject to claim all the possible advantages, but the most serious thing about it is that it is true. I do not believe there is a man living with a broad enough vision to see *all* the advantages that would accrue to a Railroad if it were properly and completely electrified. Mr. Townley puts the reasons for his statement so plainly that I quote the paragraphs in full:

"Electrical Engineers not having always been railroad men, have been unable to study railroad problems as they should have been studied, that is to say with only real and not with any arbitrary limitations before them. It has been natural for the electrical man to ask the railroad man for a statement of the conditions he was expected to meet. It was equally natural for the railroad man to prescribe the conditions upon which his steam service was predicated. Under these circumstances the problem became largely one of replacing one sort of locomotive with another, and of balancing hoped-for economies in operation and maintenance on the one hand, against fixed charges for the additional investment required, on the other. Right there comes the mistake. A perfectly natural but yet a fundamental mistake, for which no individual or class should be censured but for which the unusual development of the art is responsible. We cannot blame railroad men for not being electrical engineers nor electrical engineers because they are not railroad men but the progress of electrification has had to lag until both should be able to see, each with the eyes of both. It is only by combining the railroad man's knowledge of the fundamental requirements of his service with the electrical man's skill in applying electricity to perform that service that all the possibilities of any specific problem may be developed.

"The electrification of a railroad is not simply the substitution of one kind of locomotive for another. It is far more than that. It is the adoption of a fundamentally different method of train propulsion. It is conservative to say that, within the bound of ordinary practice, electricity can furnish every train with all the pulling power that can be used. The limitations of the steam locomotive in this respect disappear and ruling grades rule no longer. A strictly limited motive power is replaced by one that is practically unlimited."

A great many have caught a part of the vision of what an electrified railway would be like, and many advantages have already been realized in various places, but to most people electrification means simply the substitution of a kind of motive power for steam

which removes the limit placed on the weight and speed of trains by the steam locomotive, and which also eliminates the danger, discomfort and expense due to smoke, steam and cinders.

Actually, electricity has been tried in practically every known kind of railway service from street railways to high-speed passenger locomotives, from mining locomotives to the heaviest freight locomotives for mountain grade and tunnel service, and from switching in the great classification yards to fast freight trains on Transcontinental lines. In every case electricity has shown its ability to do the work as well as, and in most cases it has done better than, the steam locomotive has done or would do it. Some advantages of electrification have been pretty thoroughly demonstrated, and are generally recognized.

1. Electrification increases the capacity of a railway track because the power is practically unlimited. This makes it possible to go to the limit with weights and speeds of trains. It is easy to double the speed of freight trains on mountain grades as has been done on the N. & W. and the C. M. & St. P. Railways. The weight of the train is governed by other considerations than power, such as strength of drawbars, length of sidings, etc.

2. Electricity increases the capacity of a terminal by decreasing the number of train movements, largely due to the use of multiple unit trains for suburban service. The Broad Street Terminal of the Pennsylvania Railroad at Philadelphia is a good example of this. The adoption of multiple unit trains for the Paoli and Chestnut Hill suburban service alone increased the capacity of the terminal about 24%. This is a stub end terminal and from four to six train or locomotive movements were necessary with steam for every train entering or leaving the station. Now a train runs in, unloads, loads and leaves on the next run, there being no idle train movements whatever.

3. It makes long tunnels possible and safe, and thus points the way to the elimination of the long grades, tortuous curves and snow sheds now necessary in crossing the mountains. The Italians and Swiss are now utilizing this to the fullest extent, and have electrified several long tunnels, one of them, the Simplon, being 13 miles long. Such a tunnel would, of course, have been impossible with the steam locomotive.

4. It increases the security of operation on existing heavy mountain grades by the use of regenerative braking which enables the locomotive to hold the train under control on the down grade without brakes, as easily as in ascending the hill. At the same time it is generating electricity which is returned to the line to be used by some other train. The best examples of this in the United States are the N. & W. Railway operating on the Elkhorn grade division with heavy coal trains, and the C. M. & St. P. Railway which crosses three mountain ranges in the 440 miles of one

electrified section and two ranges in another which is now about to begin operation.

5. It takes less than half the coal to furnish a given amount of transportation on an electrified railway than is required for steam locomotives. This was proven on the New Haven Railway several years ago.

6. It greatly increases the daily mileage of a locomotive, both by increasing the speed and because the electric locomotive requires so much less time out of service. This has been demonstrated on every road that has been electrified. Four hundred to five hundred miles per day for passenger service, and half that for freight service, are not at all difficult to secure with electric locomotives. It is chiefly a matter of arranging schedules rather than engine limitations that limits the mileage.

7. A corollary to the greater mileage of the electric locomotive is the possible length of the engine division which was formerly determined solely by engine limitations, and a great reduction in the number of shops at terminal division yard tracks. The C. M. & St. P. is the only road with a long enough line to demonstrate this advantage, but it has done so quite satisfactorily. The shops and general headquarters are at Deer Lodge, the middle of the 440 miles of electrified line. One passenger crew may take the train over the entire 220 miles on either side of Deer Lodge with one locomotive. A freight crew covers half the distance, but the locomotive covers the entire distance and can return immediately after a light inspection.

8. Under steam operation the line was divided up into engine divisions approximately 110 miles in length. At every division point there had to be a round-house, an inspection and maintenance force and a considerable number of tracks available for use with the engines and their trains. Electrification has thus eliminated any necessity for round-houses and shops at any of these points, except at Deer Lodge, the only work done on the engines at other points being a very light inspection.

9. The greater weight of trains, as well as higher speeds, increases the ton mileage of a crew, although the greater distance may not count on account of the mileage basis of payment.

10. It gives more reliable service; this is demonstrated in all cases.

11. It increases the comfort and pleasure of passengers. One has only to talk to passengers to find out their opinion of this.

12. It increases the value of real estate belonging to railways in cities, as well as the value of adjoining property, by the elimination of the smoke, cinders and steam of the steam locomotive. It permits the railway to cover its entire tracks with buildings of various kinds, thus taking full advantage of the aerial rights. Freight and express ware-houses, offices, hotels and post-offices, are among the buildings most suitable for such locations. These ad-

vantages have been only partly realized to date by the Pennsylvania and New York Central Railway in New York City. A great deal of study and planning will be necessary before the full possibilities of this can be realized.

The terminal in the large city forms one of the most serious difficulties in the whole transportation problem. How to get freight trains unloaded and the contents delivered in a reasonable time is the question. The congestion of freight at the sea-board in the memorable winter two years ago was responsible for a large part of the difficulty. Electric locomotives would have worked wonders to help them, as their capacity for work increases as the temperature decreases, unlike that of the steam locomotive, which does just the reverse.

It is probable that there is no place where the man of vision has a greater opportunity than in the development and improvement of railway teminals; in this work electricity will play a most important part.

When it comes to the consideration of reasons for electrification, the increased capacity of the road and, greater flexibility and reliability will probably appeal more to the transportation man than anything else in the foregoing, as those things are always in front of him and no one can deny their importance. To the general public, the higher class of service as noticed in the lack of smoke and cinders, the greater reliability, higher speeds and, in general, the greater comfort of traveling in trains propelled by electricity, seem to be of greatest importance; but there are other reasons for electrification which have been shown within the last two or three years to be of paramount importance. These are not reasons arising simply from the war, although it has brought them to the forefront probably years sooner than would otherwise have been done. To my mind, the greatest reasons for electrification of our steam railways are,—the conservation of fuel; the shortage of labor; and the congestion of railway terminals.

It seems unnecessary to discuss the relative efficiencies of the large power stations and the steam locomotive. The modern central power station has turbo generator units of larger capacity than the largest power station twenty years ago. Their efficiency has reached an extremely high figure, while the limitations of the steam locomotive in this respect are well known. However much the efficiency of the steam locomotive may be improved by the addition of superheaters and other accessories, and we know the improvement has been remarkable, it is still true that it must use a large amount of coal for standby losses, inefficient boilers and radiation, so that, at best, we can expect only one-third to one-half the transportation for a pound of coal burned under a steam locomotive, that is secured with the same coal burned under the boiler in a large central power station. Mr. E. W. Rice, the President of the A. I. E. E., in February, 1918, devoted his Presidential address to the

crying necessity for fuel conservation. He claimed that electrification would save two-thirds of the fuel used by the railways.

Statistics show that about 25% of the total coal produced in this country is used by the steam railways. In 1916 this amounted to 136,000,000 tons of bituminous and 6,735,026 tons of anthracite coal, about 1⅓ tons of coal per capita for the entire population of the country, or 1 ton per day for every mile of track, including yards and sidings, in the United States. It is, of course, absurd to talk about electrifying all of the railways; that will probably never be done; in any case not for a great many years; but it seems reasonable to assume that one-half of them will be eligible for electrification.

If one-half of the railways can be electrified and will use only one-third of the coal now used by the steam locomotives, a very substantial amount will be saved. The saving is due not simply to the higher efficiency of the electric installation, but in part to the reduction in non-revenue tonnage and by the utilization of water power.

The non-revenue freight in 1915 over the entire country was 13% of the revenue freight, or 11.5% of the total. Undoubtedly a large part of this was coal. When we consider that every steam locomotive carries a tender full of coal and water which is not counted as freight, and which in the case of passenger locomotives averages at least 10% of the train weight, we must agree that at least 10% of all the coal used on a railway is used simply to carry coal for the railway itself. If the railway were electrified, this non-revenue tonnage would scarcely be more than 3% of the revenue tonnage, and would probably not be that much, since the power stations would be located as close to the coal mines as possible.

A great many railways, notably in the western part of the country, would be operated entirely by water power, which would save all of the fuel that is now used, a great part of which is oil. The greatest incentive to this is in the increasing price of this oil, which should be conserved to the maximum extent for use in our Navy, or for motor vehicles. Altogether, it seems a very conservative estimate to say that if one-half of the railways could be electrified, it would save not less than 50,000,000 tons of coal, or its equivalent in fuel oil, per annum, based on the present rate of consumption.

At the time of writing this paper, the miners' strike is on and the railways have commandeered all the coal in sight, or at least have a first lien on it. With the production only 30% of normal, the country faces a very serious situation. At this time the possible saving of 50,000,000 tons of coal simply by more efficient use of it, looks wonderfully attractive, and, in fact, it seems to be in the class of economic crime to do anything else.

But even if there were no strike and no difficulty in getting all the coal needed, it would still be our duty, for the benefit of future

generations, to save every pound of coal we possibly can without increasing operating costs. Nature has blessed us wonderfully in the vast stores of coal, oil and gas she has provided, but all these stores are limited, and at the increasing rate of consumption, will be exhausted much sooner than now seems possible.

The incentive to the Railway Company for electrification on account of the fuel situation lies in its increasing cost, and the difficulty of securing it. These reasons, from present appearances, will continue to increase both on account of higher labor costs and the exhaustion of the mines.

The second great reason for electrification mentioned, is the shortage of labor. Our country has been living in a fool's paradise for the past generation, drawing on the uneducated, poverty-stricken classes of Europe to furnish us labor for the menial tasks we have had to perform in the tremendous undertaking of building cities, railways and highways, and the production of coal, iron and steel.

That these ignorant laborers have, in many cases, been exploited, there is no room for doubt. This cannot be said to be the usual case. However, we are now suffering from an acute case of indigestion brought on by the unlimited importation of this inferior class of labor, which we have been utterly unable to assimilate, and which has furnished ready followers for the unscrupulous and anarchistic revolutionists who have come here from the hotbeds of Bolshevism in Europe. Thousands of these men are returning to their native lands where their services are badly needed. Thousands of others are preventing production more than they are assisting it. What will be the result of this in the long run it is difficult to foresee, but it seems certain that there will be a great shortage of labor in this country for many years to come if the country is to be developed as it should be. A shortage of labor means extremely high priced and, judging by experience, oftentimes inefficient labor, so that it will pay the railroad to make large investments in order to use more effectively the labor that is available.

The railroad must take a leaf from the experience of the housewives who have been forced to get along without help, due to this same shortage of labor. They are overcoming the difficulty by the introduction of labor-saving machinery of all kinds into their homes. Electricity is playing a great part in the emancipation of the housewife from drudgery, and it can do as much for the railways if properly applied.

A study of the proven advantages of electrification, before given, shows many places where labor can be saved, or where, if sufficient labor is available, a great deal more can be accomplished by a given number of men; increased capacity of tracks means increased ton mileage per man; increased capacity of terminals means handling more people or more freight per man, probably with less

effort on the part of the man than at present; less inspection and lower maintenance costs mean less labor. There are a great many places where labor can be saved. I have at present no definite figures as to the total amount, but it will unquestionably run into very substantial figures.

There is one place, however, where some accurate estimates can be made, and that is in the reduction in the number of coal miners required to furnish coal for the railways. In 1916 the average production of coal per miner was 896 tons of bituminous. At that rate a saving of 50,000,000 tons per year, estimated as the amount that could be saved by the electrification of one-half of the railways, would release approximately 56,000 miners or one man for every 2.6 miles of main track electrified. Add to this list the number of men who are employed in handling coal after it is mined, and before it reaches the locomotive, and the number will be multiplied.

Of course, these miners and railway men apparently saved by electrification will not lose their jobs. The amount of coal required for all purposes is increasing so rapidly the miners would all be needed, but the total number of them would not increase so rapidly as at the present time. The same may be said of the railways; electrification is a means of overcoming a labor shortage, not a means for throwing men out of employment; it is a means of increasing production of transportation which may ultimately become as necessary as the change from stage-coach to steam.

How electrification is to be financed is, of course, the question, after its advantages have been recognized, and this is just now really the most difficult problem of all. However, there is hope.

If the Congress passes suitable laws before the President hands the Railways back to their owners, the way will be opened to immediate electrification of roads where the necessity of greater capacity is felt, or the saving in cost of operation will carry the investment.

When it comes to electrification of terminals, such as those in Chicago where the financial burden of the railways seems greater than can possibly be justified by any advantage to the railways themselves, the public will have to pay for it either in increased rates or by taxation. Considering the increased valuation of property adjacent to the railways, it seems proper for the city to bear a considerable part of the cost, but whether the railways bear the entire cost or the cities bear a part of it, the electrification of the terminals of a great city should be undertaken only after the best thought available has been brought to bear on it. I repeat that there is more room for vision in this work than in any other problem in the railway field.

However much electrification may be desired either by the railways themselves or by the public, it will necessarily take many years to electrify those where the immediate necessity appears.

In the meantime, people must not become impatient; they must realize that, in proportion as electrification is rushed, mistakes will be made and some of the advantages may be lost. The big question of capacity, fuel conservation, shortage of labor and the improvement of terminals, will exert all the pressure toward electrification that the railways can stand.

Following the presentation of the paper Mr. Storer gave a brief description of the new Baldwin-Westinghouse passenger locomotive for the C. M. & St. P. R. R., of which the following is an abstract:

The general appearance of the locomotive is shown in Figure 1; the half running-gear in Figure 2; wheels, axle and quill drive in Figure 3, and main motor in Figure 4.

The locomotive weighs 275 tons, of which approximately 171 tons are carried on six pairs of drivers. The rigid wheel base is 16′ 9″, total wheel base 79′ 6″. The main running gear consists of two Pacific type running gears coupled back to back through a long coupling bar having the pins well inside the wheel base. This leaves each half of the wheel base free to follow the track independent of the other. The riding qualities are exceptionally fine.

The driving wheels are 68″ diameter, and each axle is driven by a 700 HP twin armature motor, giving a total one hour rating to the locomotive of 4200 HP. The two motor armatures drive a single gear carried on a quill surrounding the axle. The quill is connected to wheels as shown in Figure 3, through long helical springs. As there is a clearance of 1¾″ all around the axle, the quill and motor are free to move up or down as far as the journal boxes will permit.

The tractive effort at the one hour rating is 66,000 lbs., and the corresponding speed is 24 m.p.h. The locomotive is designed to handle a 950 ton passenger train on the 2 to 2.2% grades over the Rocky Mountains. While having ample capacity for tractive efforts on the grades, the locomotive will operate safely to 65 m.p.h. on the light grades.

Current is taken from the overhead trolley at 3000 volts D.C. This is applied directly to the main motors, but all the auxiliaries, with one exception, are operated at low voltage, the main source of which is a small motor generator set. This was installed primarily to furnish current for train lighting, but, operated in parallel with a storage battery on the locomotive, it also furnishes current for other purposes. There are also two low-voltage generators mounted on and geared to the inside axles of the bogie trucks, designed primarily to furnish current for exciting the main motors during regeneration on down grades. These are utilized at other times for drivng compressor and blower motors.

The biggest thing on the locomotive is the boiler which is used to furnish steam for heating the train. Together with tanks and accessories it occupies nearly one-third of the available cab space.

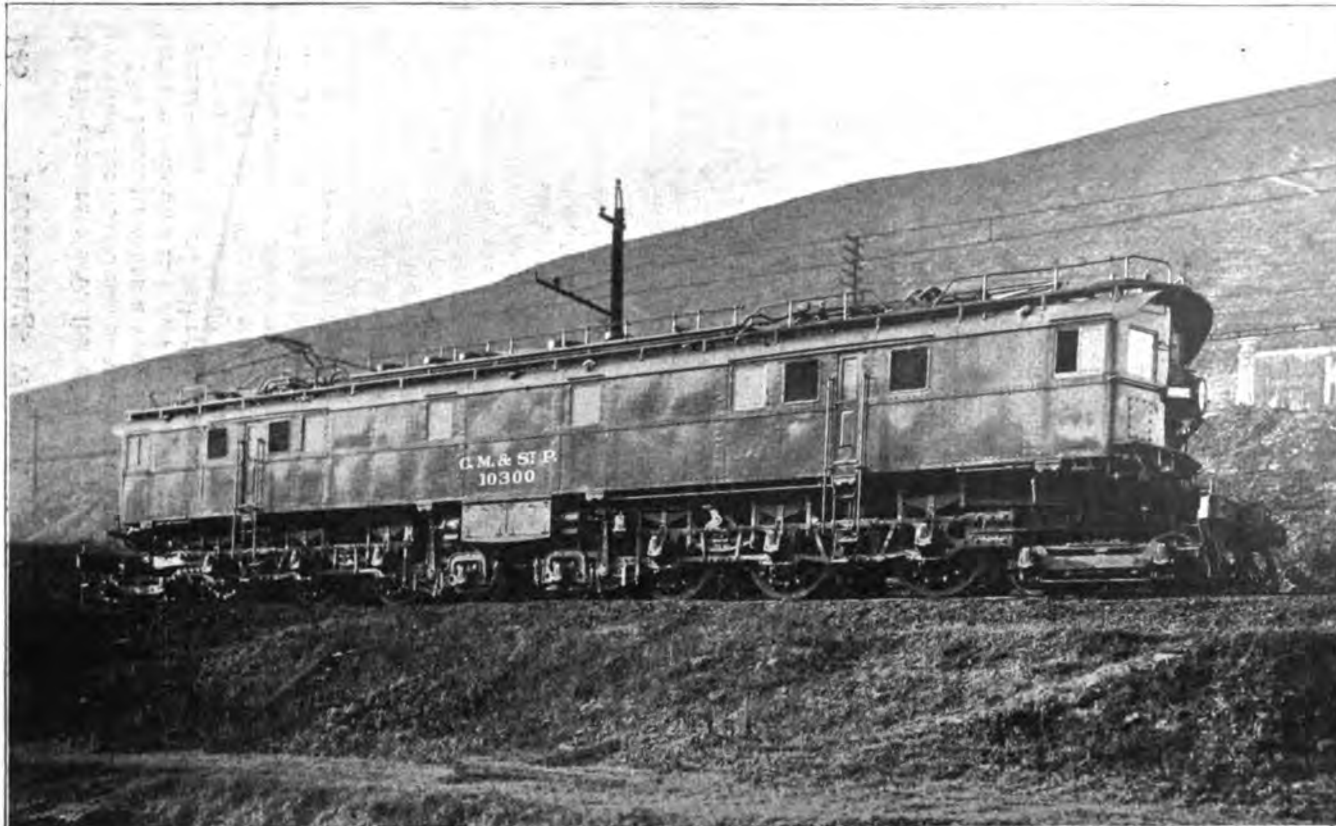

Fig. 1.

It will evaporate 4000 lbs. of water per hour. Storage tanks are provided for 30,000 lbs. of water and 750 gallons of fuel oil.

The locomotive has a very flexible control system. The six motors are combined in a new manner so as to have three fundamental speeds,—⅓, ⅔ and full speed, together with two additional speeds on each one of these by shunting the motor fields, making nine speeds in all. The master controller is very simple and easy to handle, and the transitions are very smooth.

The locomotive has a number of advantages that appeal strongly to the railway men, especially the stability of the regenerative and braking systems on the down grade. As long as there is power on the line the train is braked by regeneration, but if for any cause power goes off the line, the train can run to the foot of the grade under control of the air brakes, the power to drive the air compressor being furnished by the axle driven generators or the storage battery. The latter too is always available to furnish current for lighting the locomotive and for control circuits.

We have endeavored to combine the best known principles of locomotive mechanical design with the most flexible, stable and reliable electrical equipment that can be built.

THE PRESIDENT: Gentlemen, I think we are mighty fortunate in having this interesting talk. I have a few questions that I want to ask Mr. Storer, but I think that there is a gentleman here who can start the discussion a whole lot better than I can. I am going to call on Mr. Dodd of the General Electric.

MR. DODD (General Electric): Mr. President and Gentlemen: I do not believe there could have been a more opportune time for a paper of this sort to be presented than just this critical time in the history of the United States.

The question of the increasing need of electrification of railroads is one which is being impressed on us more strongly today than I think it has ever been before, and the questions which Mr. Storer has touched on, such as conservation of coal, the decreased cost of maintenance of locomotives with electrification are points which are vital. Take for just one illustration that question of cost of maintenance of locomotives.

About 1910 there were some averages published of the cost of maintenance of steam locomotives on railroads of the United States. The average ran about 10 cents per locomotive mile. A few years later that increased to 12 cents. Now, I do not know what the average cost is today, I should judge in the neighborhood of 20 cents.

Take as an illustration one road on which I have the figures for the last two or three years. The cost of maintenance on all steam locomotives on that road for the year 1916 was 12.7 cents per locomotive mile. The cost for 1917 was 15 cents per locomotive

mile and the cost for 1918 was 32 cents per locomotive mile. This represents a tremendous increase in the cost of operation of the railroads in the United States.

Contrast with that the published cost of maintenance appearing in the Interstate Commerce Commission reports of electric locomotives on roads which have been already electrified:

COST OF MAINTENANCE ELECTRIC LOCOMOTIVES. I. C. C. REPORT—1917.

Chicago, Milwaukee & St. Paul	9.62c per loco. mi.
Michigan Central	6.42c per loco. mi.
New York Central	4.01c per loco. mi.
Pennsylvania	5.77c per loco. mi.

Speaking approximately, we can estimate that under similar service the cost of maintenance of the electric locomotive will be one-half as much as the steam locomotive, and when your cost of maintenance of steam locomotives runs up to the records that we have today, 32 cents per locomotive mile, it indicates the possibility of a tremendous saving in the cost of operation. In view of these two factors alone, the question of saving fuel and the question of saving in the maintenance of locomotives, it seems to me that this paper comes at a very critical and a very opportune time.

There are one or two points that I would like to call attention to and emphasize in Mr. Storer's paper. He says, we do not expect to see all the railroads in the United States electrified. Well, I have been rather conservative on that question, but the things that I have seen the last two or three years make me a little more liberal today than I have been.

If you go West on the Chicago, Milwaukee & St. Paul to the beginning of the electrification at Harlowton, you will find a matter of about 90 miles of heavy grades over the Belt Mts.; then comes about 50 miles of prairie, where the road lies as straight as a ruler. The rails run clear out of sight, straight ahead as far as you can see. Then there is about 50 miles across the Rockies; then comes 200 miles of level; then there comes about 50 miles through the Bitter Roots. The reasons for electrification were those mountain ranges, where there are grades running from 2% to 2½%; but in between lies prairie where the road is perfectly level, and where it runs through a desert country. You may see ranches, or stretches of country covered with sand and sage brush; but nothing like the populousness or wealth of the country we see in Illinois and Indiana. Off hand, you would say that territory would not pay for electrification. Perhaps in itself it is not worth electrification, but it is worth electrification because it connects up congested points that are worth electrification. Keep that proposition in mind.

New York City is electrifying its terminals; Philadelphia is electrifying its terminals. There is more reason for electrifying between New York and Philadelphia than there is for electrifying 200

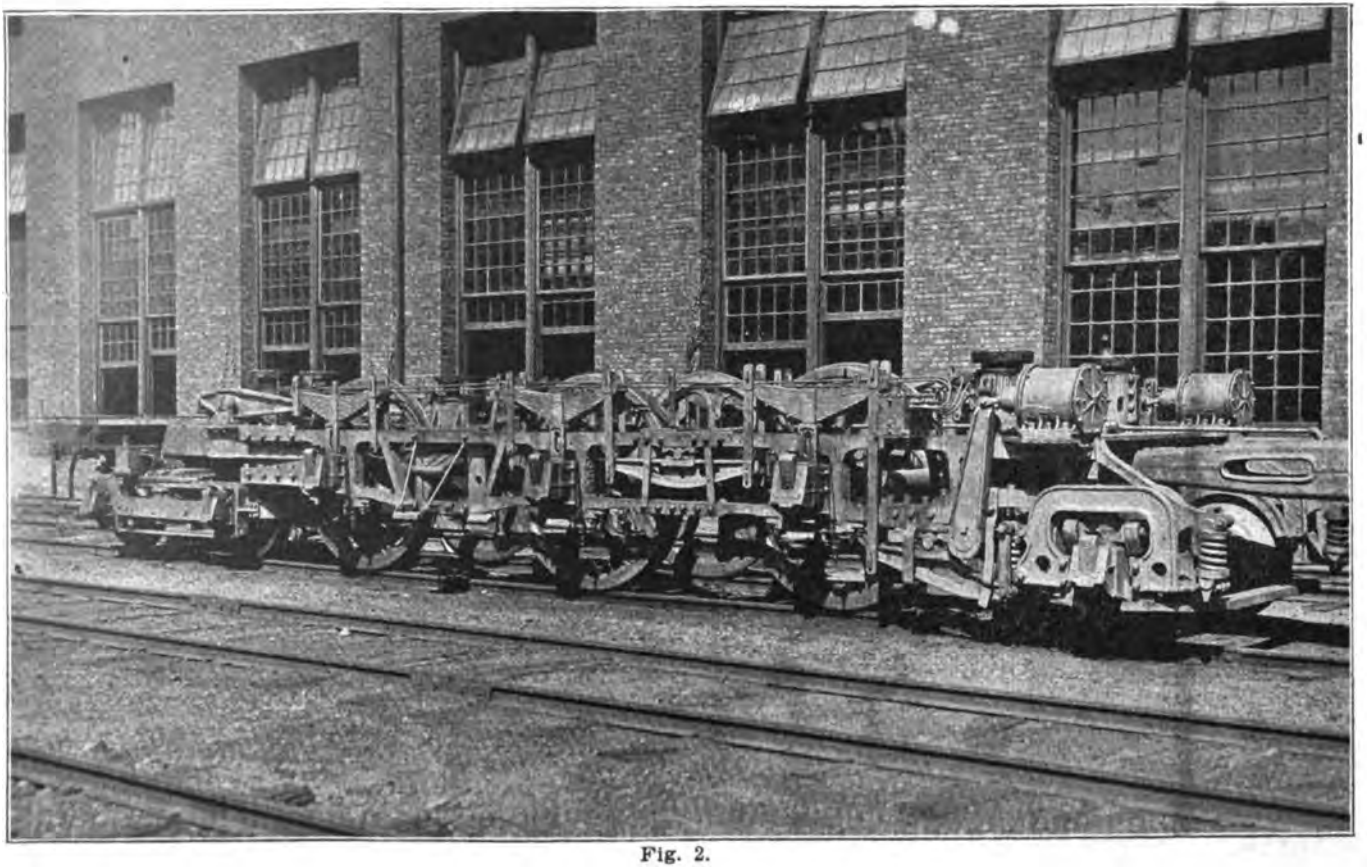

Fig. 2.

miles along the Deer Lodge River. If congestion of traffic in Chicago justifies electrification; if congestion at St. Louis justifies electrification of terminals, what reason is there for saying that the connecting links do not warrant electrication?

What I have seen within the last year has made me feel a great deal more optimistic on the value of electrification and on the fact that really within a reasonable time—of course it is going to take time, but what I mean is that we are within sight of the time when we are going to take up this question of electrification of railroads on a larger scale and spread over distances that we have never thought of before.

Now, Mr. Storer and I belong to the same church and we have preached our faith in the electrification of railroads for a number of years, and we have often been looked at by some people as if they would say, "Well, figures don't lie, but liars can figure." Now the question comes up, why is it that after all this talk and after all these facts—of course the facts Mr. Storer has presented are facts we knew fifteen to twenty years ago, only they are illustrated with modern figures—why is it that electrification has not gone ahead more rapidly? Well, there are a great many people who cannot believe a thing until they see it. They want to see it in real, practical operation. But today we have real examples of electrification in actual operation.

The Frenchman really has the right idea of this thing. If you have read the story of the development of electrification in Europe, you will know that the French some years are started the question of electrification. Like all democracies, they made the mistake of letting the question get into politics. They had to buy one locomotive from one manufacturer and one from another, until they bought six. They tried them out, and the thing rested there until the war came on; until the tremendous cost of coal and the tremendous shortage of man power, aroused them to the necessity of going ahead and doing something definite. Then they appointed a commission of real men, not politicians; they appointed practical men, and this commission set to work and investigated what really had been done. They went over to Italy and investigated what the Italians had done; they went over to Switzerland and investigated what the Swiss had done; they went—well, there was one place they did not go. (Laughter.) But, joking aside, I want to say Germany never did give us anything of value in the form of railway electrification. All the electrification that was done in Germany was experimental, was testing. They have never shown us an example of real railroad electrification, and for a rather peculiar reason. Because the German made the mistake in his electrification of adopting the same method that gave him such an advantage in military and commercial lines—the decision in advance by absolute authority.

You cannot develop an industry, particularly such as we have been working in, you cannot develop such a thing by laying down

an absolute rule to begin with. The thing has got to be developed step by step, and the Germans made the mistake of appointing a certain Geheimrat Wittfeld at the head of their railway electrification, and he laid down certain absolute rules that all electric locomotive had to conform with, if they were to be considered for German railway electrification. That is why they have never accomplished anything of value in this line.

The French Commission, I say, studied the work that was done in Italy, and they studied what was done in Switzerland and they came over to America and made a very exhaustive study of the work we had done in America, and finally they made a report, which presents a plan on a consistent basis on which they will develop for the next twenty years in the electrification of roads in France.

Up-to-date we have got what we did not have twenty years ago; we have got definite examples of successful railway electrification that the men in the field can study and find out what is the right way, not only theoretically, but practically, to go ahead with this question of electrication, and I wish I had forty years of work more before me, because I believe in the next forty years we will see tremendous progress in the art of railway electrification.

Of course, there are some men that do not believe a thing until they see it, and some men do not believe even if they do see it. I am reminded of an illustration that occurred at our Erie Works. We had an exhibition test of one of our new locomotives for the Chicago, Milwaukee & St. Paul. Some of you gentlemen were present at that test. The locomotive was tested pulling trains and also running light. Then we gave a demonstration of regeneration. As Mr. Storer has already described, by regeneration we mean that when going down grade, with a heavy grade, the motors of the locomotive at the head end of the train can be used to act as generators and feed back power which can be used pulling some other train up the grade or emptied back into the general system of transmission.

At the Erie test we did not have any grade and we did not have any heavy train, and so, to illustrate this question, we used two steam locomotives, one a Pacific type, weighing 80 tons on drivers and the other a Consolidation weighing 120 tons on drivers. We connected the three locomotives in tandem and started them down the track. They got to a speed of 25 to 30 miles, then the engineer of the electric locomotive began feeding current back, and the engineers of the steam locomotives opened up their throttles and by the time they came up past the group of observers, they had those throttles wide open, steam and smoke pouring out of the funnels, and the air vibrating with the throb of their exhausts. You knew they were working, knew they were putting power into them. If you were watching the meter on the switchboard, you saw that they started out pulling about 500 horse power, as they came up to speed

Fig. 3.

the engineer shut off his power, and the meter swung to the other side, showing as high as 2,000 horse power going back to run the factory. It was really a very spectacular exhibition.

The engineer on the steam locomotive was one of the kind of men who would be interested, a wide-awake fellow, very much interested in the job, had been doing his level best to help us out and put his power on when he was called upon to do so. He did not understand about where the power was going to. When we explained the way the power he was developing was going back over the trolley to the power house, he scratched his head and said, "Well, that sounds right, sounds right, she was pulling some I can tell you, but there is some fake about it. I know that little wire up there was not taking all the power we were putting into it."

Mr. Storer, when they do not believe it when they see it, the case is really hopeless.

THE PRESIDENT: There is another gentleman here tonight that is connected with an electric railway that was formerly a steam railway. I think it was back in the times of the World's Fair that we had little Vauclain compound engines on the Elevated. I want to ask Mr. Johnson if he will say a few words?

MR. H. A. JOHNSON (Chicago Elevated Railroads): Mr. President and Gentlemen, I was not connected with the elevated railroads at the time we had the steam engines; that was before my time. They were little Baldwin compound engines: we had them both on the Lake street and on the South Side. The roads were electrified before I started in with them, about fifteen years ago.

The electrified operation on the elevated railroads would not give you very much of an idea of what could be obtained in electrifying steam railroads. Within the last three or four years I have also been connected with the high speed Interurban Road that runs from Chicago to Milwaukee, and there we have had a great many problems which are more or less similar to the steam railroad problem, handling local service, through fast passenger service and freight service.

Two years ago, during the severe winter, we were quite a little cramped for freight power. At that time we had obtained some fairly large business, as we were handling most of the freight business into the Great Lakes Naval Training Station, and the electric locomotives that we had were badly overloaded, and it was a question of obtaining some more power. The president of the company called me into his office and he said, "How would you like to get a couple of steam engines to help you out?" I said, "No, I do not care for steam engines."

I could immediately foresee the trouble that we would have during that severe weather with engines freezing up. I knew the steam railroad men were having all kinds of trouble, so we got along without the steam engines. We did get some additional elec-

tric locomotives to help us out, but during that winter we had a very good example of the difference in reliability and the amount of work which can be obtained from an electric locomotive, as compared with a steam engine. Those locomotives were on the road day and night continuously, operating nearly 24 hours every day. As Mr. Storer has pointed out, it is only necessary to have a few minutes for inspection to keep the locomotive in good running condition. A few minutes for oiling, a few minutes for looking over electrical equipment, and the engine is again ready to go. At that time we inspected them once a week, during the rest of the week they were on the go all the time.

Another thing has often impressed me, and that is the reduction in maintenance and shop equipment. We have had quite a number of steam railroad men visit the elevated shops, especially some of the men in Chicago on account of the talk about electrification of terminals here, and every one has been impressed and has always mentioned the fact "I do not see how you can keep so much equipment on the road with such small shop facilities." The answer is that you do not require the large shop facilities that you do with steam locomotives.

Before going with the elevated roads I was in the shops of the Burlington as special apprentice, so that I have been able to see a little of that side of the game, too. From the operating standpoint I think that those two things are probably the most impressive to an operating man. The greater reliability, the greater mileage that can be obtained in a given time, the smaller shop facilities and the less attention that an electric locomotive requires as compared with a steam locomotive.

At the present time we have a problem on the north side. The branch of the Chicago, Milwaukee & St. Paul that runs through Evanston, as you probably know, has been electrified for some time, and the passenger service has been handed by the Northwestern Elevated; the freight service is still being handled by the St. Paul with steam switching engines. On account of the density of the passenger traffic and the frequency of trains, the freight service was formerly handled at night. Recently the residents have complained about the noise to such an extent that it was necessary to take off the night engines and do the work in the day time. I believe they are now using two 84 ton switchers to do that work. We will take over that freight work some time during the year 1920, and we figure that one 50-ton electric locomotive will handle it. There is another example of the greater amount of work which an electric locomotive will do.

THE PRESIDENT: Gentlemen, I know you have got a lot of questions you will want to ask the speaker, now, let us have the questions. You fellows that are up on steam locomotives, you ought to be able to corner him. Have you any questions?

Fig. 4.

MR. LESLIE R. PYLE (Fuel Conservation Section, U. S. R. A.): I believe it would be interesting information if Mr. Storer would furnish, to go into the proceedings, the necessary data to show where electrification would save two-thirds of the fuel used by railroads. He quotes Mr. E. W. Rice, President of the A. I. E. E.

It is also claimed that the electric locomotive will haul the train much faster over the entire division than the steam locomotive. The Milwaukee should have by now, sufficient data to show the average speed in miles per hour of freight trains on their electrification. I believe it would be well to include this data in the proceedings.

Mr. Storer outlined what he considers good train dispatching. It is a fact that if we could have this same kind of train dispatching for the steam locomotive, we would eliminate a great many of the wastes which he claims the electrification will overcome.

For this reason, we should have some practical tests covering fairly representative periods showing the average train load and speed in miles per hour as compared with locomotives in the same service. This should be over a division long enough to make the comparison practical.

THE PRESIDENT: Is there any one here from the Milwaukee? We asked Mr. Warnock to be here, or have some one here to talk about their electrification. Can you answer that question, Mr. Dodd? Can you help out on that question of Mr. Pyle's?

MR. DODD: I cannot answer that question in regard to the miles per hour. The question has not been presented to me before this in just that way. I think I can answer the other question that he asked, and that is, how we get at this saving of coal.

The easiest way is to quote actual records. If you study the records of the Butte, Anaconda & Pacific Railroad or of the Chicago, Milwaukee & St. Paul, you will find that during the year before they had electrification there were a certain number of tons of coal used to move a certain number of tons of freight, and the year after they had electrification there were a certain number of kilowatt hours used to move a certain number of tons of freight. Reduce that to a common denominator—

THE PRESIDENT: Mr. Dodd, will you kindly come forward so that all may hear?

MR. DODD: I say, by measuring the number of tons of coal necessary to move a certain number of tons of freight by a steam locomotive, and getting a record of the number of kilowatt hours necessary to move a certain number of tons of freight, in electric service, we get the relation between the number of tons of coal and the number of kilowatt hours that it takes to do the same work, and it figures out that about seven pounds of coal on the tender of the steam locomotive is equal to one kilowatt hour delivered at the substation. Now, for use on an electric locomotive, we can produce in a power house a kilowatt hour for from 1½ to 2½ pounds of

coal; there is your three to one ratio. I believe that answers your question.

If you want to start from the number of pounds of coal necessary to produce a horse power hour in a boiler and calculate the efficiencies step by step, you can calculate the power losses that produce the difference, but the comparison of records as I have quoted answers your question.

MR. PYLE: How much of that is lost in transmitting to the transformer?

MR. DODD: Of the power generated at the power house it might be fair to estimate 5% loss in transmitting to the transformers and 35% more to the locomotive wheels. My comparison was based on a kilowatt hour delivered to the transformers at the substation.

THE PRESIDENT: Mr. Pyle, I will see that your question is also submitted to Mr. Warnock, so that if he cares to he can submit the information.

I will ask the Secretary to read a communication from Mr. Bilty:

MR. C. H. BILTY (Mech. Engineer, Northwestern Region U. S. R. A.): The paper presented by Mr. Storer comes at a most opportune time, following a period where we all have been forced to economize in fuel to the very greatest extent, and points to one of the ways in which further economies in fuel may be realized, as well as certain other advantages in railroad operation, by electrification of steam railroads.

While initial cost of necessity must be high, and more so in congested terminals than in open single track country, still when it is realized that coal docks, cinder pits, turntables and standpipes can be eliminated, also that there is no necessity for inspecting, testing and washing out boilers, and where bad water holds no terrors, an idea of the possible economies that can be effected is realized.

Electric locomotives can make greater mileage between periods where terminal attention is required, and this attention when due is much less than required by the steam locomotive, so that the electric is available for use a much greater time than is the steam.

The regenerative braking feature has worked out very successfully, and when operating returns a substantial amount of power to the distributing system, while at the same time is retarding the speed of the train down grade at a constant speed, with no running in or out of slack, account entire train being bunched against head end, with a resultant saving in the wear and tear on brake rigging, brake shoes, overheated wheels, broken or pulled out draw bars and draft rigging, and at the same time the regular air brake equipment provides an auxiliary or reserve braking system complete in itself, thus providing double the safety in descending long mountain grades.

The electric locomotive operates nearer to maximum capacity than does the steam locomotive, as the power is unlimited, and while

difficulty is experienced in maintaining steam pressure in extremely cold climates on the steam locomotive, it is almost the opposite effect on the electric, as they operate most efficient under these conditions.

Extra stops for coal and water has been eliminated, also non-revenue load now carried by steam locomotive tender, and any increased weight that may be carried by the electric is used for tractive weight.

It is interesting to compare the claims of electric operation with actual performance, and feel that Mr. Storer has confined his paper in this respect, well within the bounds of what actual present day operation will demonstrate.

The transition period apparently is accomplished with little confusion, and it is possible to arrange shops and machinery originally provided for steam locomotives to handle the electric locomotives without extensive changes or installation of equipment, and electric locomotives as a rule are kept in a constant state of good repair by doing the work frequent and rigid inspections develop is necessary.

On one extensive installation it developed that due to the constant attention given electric locomotives, that but 6.0% were out of service for all causes, including one wrecked, while in the case of steam locomotives, if a condition approaching 10% is attained, it is considered very good.

It would appear that for some time to come, with the necessary additions that will be required to the present number of steam locomotives, and branching out and adding to the present railroad mileage, which will also require additional power, that there need be no fear that scrapping of present equipment will be necessary by the electrification of roads.

As brought out by Mr. Storer, congestion of railway terminals is greatly relieved by electrification, and this feature has, I believe, been demonstrated to the satisfaction of all interested. Over certain mountainous sections now electrified, the average speed of the electric freight locomotive is the same as the average speed of steam locomotives operating in comparatively level country, and heavy steam locomotive approaches these grades with trains of about two-thirds the tonnage the electric locomotive handles over the mountain, or in other words the electric locomotives will take over the mountain in two trains, what was brought over comparatively level country in three steam hauled trains.

It was rather surprising to learn of the intelligence displayed by the motormen on these electric locomotives, who originally were steam locomotive engineers, and their familiarity with the different phases of operation, not only of the locomotive, but of the power plants and sub-stations as well, and would indicate that the steam engineer can readily adapt himself to the changed conditions.

The feeling expressed by a motorman, who had graduated from the ranks of steam engineer, that on a steam locomotive he could

discover a defect in three minutes that would require three hours to correct, while on the electric locomotive it would require three hours to locate the trouble and three minutes to fix it, is more imaginary than real, and these former steam engineers rapidly learn the operation of electricity is not so mysterious as they at first feared.

To one considering electrical operation it would appear the art has advanced to such a degree, and there has been a sufficient number of installations to cover most all conditions of service, and varied types of locomotives have been designed and in operation, that necessary data and statistics are available to assist in selection of installation and type of power best adapted to meet the conditions under consideration.

THE PRESIDENT: Is Mr. Puette of the New York Central, here? You were asked to discuss this paper, do you care to say something on it?

MR. PUETTE: I do not believe so. I do not think I am in position to talk on electrification of steam railroads.

THE PRESIDENT: Do you have any questions that you would like to ask the gentleman?

MR. PUETTE: Well, we may think of something a little later on.

THE PRESIDENT: Is Mr. Lesure, of the Pennsylvania here? Any one from the Pennsylvania who can talk about their electrification? Any one from Detroit? Michigan Central? Is Mr. Nash here? That clears up everything except those questions, gentlemen.

I would like to answer one thing that Mr. Dodd said, while you are waiting. He commented on the increase in the cost of repairs on the steam locomotive as compared with the electric. I should like to point out that I think that that increase is largely brought about by the increase in the wages of the men, and I think that you are going to find that same increase in the wages of the men that work on the electric engine.

MR. J. W. MOTHERWELL (Ashton Valve Co.): The question of the electrification of railroads is essentially a financial problem. If as the writer of the paper states, it is possible thereby to save fifty million tons of coal by electrifying half of the railroads of the United States—this figured at $3.00 per ton,—the saving effected would thus amount to $150,000,000.

In addition thereto, other economies of operation are claimed, but the writer has never seen any definite figures based on present installations to show just what same amount to when compared to steam operated railroads. The saving in coal figured on a 10% interest basis would only justify the expenditure of one billion and a half dollars, which would hardly cover the cost of electrification of the principal railroads between New York and Chicago—certainly not half of the railroads in the United States.

The progress that will be made in the future in the electrification of railroads will naturally depend upon the economies that can be

effected and proven to justify the financial interests of the country to carry the burden of same.

THE PRESIDENT: It looks right now as if it would be difficult to finance the steam railroads, let alone electrifying them.

There are two or three questions that I want to ask the speaker. In the application of electrification to switching terminals. It seems to me that there is going to be a great deal of difficulty stringing wires overhead, so that there will not be trouble. It is going to be just about as complex as switches on the ground, and when a trolley pole gets away, it seems that there is a chance to tear down some of the overhead structure.

The speaker spoke about the electric engine doing away with the tender. Well, he does away with the tender all right, but he has a trolley wire and he has some sub-stations that he has to substitute for that tender and there is quite a lot of money tied up in that, too.

Down there where it is shown that 13% of the freight through the entire country, is non-revenue freight, he figures that that would be reduced to about three per cent with electric locomotives. As I read the paper, it is based on the fact that the tender on a passenger train weighs about 10 per cent of the weight of the train, which is true, but on a freight train it does not weigh anywhere near 10 per cent. So, taking all in all, I hardly think he would reach that 10 per cent, although maybe he figures that when an engine is electrified he has not got to haul so much coal to the coaling chutes to take care of the engines.

Another thing, I should like to ask Mr. Storer, is the voltage of the train lighting system the same as the voltage of that little generator that he has on the bogie truck, as I rather gather from what he said that that might be used to light the train, if necessary.

MR. WALTER H. EVANS (Tool Steel Gear & Pinion Co.): I should like to ask Mr. Storer whether or not the development of the art has advanced at this time sufficiently to justify a very general application of electrification to the railroads. That is to say, as Mr. Dodd mentioned, we have understood that the development has been going right along and very likely will progress in the next twenty-five to thirty years equally as much as it has in the past. The question is whether we are going to have the experience of the old early electrified street cars where they had to tear out what had been done, to put in more modern, up-to-date equipment later on.

THE PRESIDENT: Mr. Storer, do you want to answer?

MR. STORER: I am glad we have had such a general discussion, especially glad to get the data Mr. Dodd has given.

Now in regard to some of these questions. First, the President asked about the overhead construction in yards. That is more of a theoretical bugbear than it is an actuality. It gives very little trouble. The New York, New Haven & Hartford has very large

classification yards electrified with 11,000 volts alternating current on the overhead wires and they run right along with practically no trouble at all. Their little switcher locomotives handle the service, and stay right out in it a month at a time, seldom going to the shop for anything. Of course, they do not use the trolley pole, they use the pantagraph, with a sliding shoe crosswise. These are four feet long, and flat, with horns which project beyond to keep them from getting off the wire or hooking under some of the others. I think that while with a new line there is more or less trouble usually from catching this pantagraph shoe in the overhead construction, until it is finally adjusted, yet, with a little experience it can be put up so that there is no serious trouble, and in any case it does not need to continue any length of time.

In regard to the voltage for train lighting, on the Milwaukee locomotives it is substantially the same as that of the axle generators. The axle generators are not intended primarily for lighting the train, but they are arranged to give 90 volts by automatic control, while the train lighting requires from 75 to 85 volts. They could if desired be constructed so as to charge the batteries also. The motor generator and storage battery in the locomotive are controlled at 80 volts constant pressure, which is the maximum that is supposed to be required for charging the batteries in the train

Mr. Evans has inquired about the state of the art, whether that is such as to justify electrification on any considerable scale. I should be the last one to say that the development of electric locomotives and their application has reached the limit. I would not for one instant say such a thing, but there is no question but that the state of the art is such as to render the electrification of any road in the country entirely practicable so far as engineering is concerned. Now, it may be that some future development will render present installations obsolete, but it is problematical, and if it is practicable at present to give so much better operation than is practicable or possible with the steam locomotive, why, the time to do it is to do it now if you can get the money. That, as Mr. Motherwell has explained, is the whole proposition, the big thing, to get the money. Just how it is going to be financed I do not know, but I do believe that the economies as a whole will total up to such a figure that will make it not only expedient but highly desirable to electrify.

Mr. Pyle has asked for information to prove my statement that probably two-thirds of the fuel used by steam railroads would be saved by electrification. The most convincing evidence is the kind already given by Mr. Dodd, who gave the result on the B. A. & P. Ry., where it was found that seven pounds of coal on steam locomotives was equivalent to 1 KW hr. of electrical energy delivered to sub-station. In that particular case the electricity is generated by water power, but it is well known that any decent steam plant

will generate electricity on not more than 2¼ lbs. of coal per KW hr., so that, as Mr. Dodd said, there is the 3 to 1.

However, that may be a special case, so a few calculations may help, bearing in mind that conditions vary widely in different places. The saving in fuel results from three causes.

1. The high efficiency of the modern central power station as compared to that of the steam locomotive.
2. The large auxiliary and stand-by losses of the steam locomotive.
3. The reduced ton mileage due to smaller consumption of fuel, and to elimination of the tender.

The modern central power station, with large steam turbine units will develop 1 KW hr. with from 1 to 2¼ lbs. of coal. With a reasonable load factor 1.2 lbs. of coal is within commercial range. This is equivalent to .9 lbs. of coal per HP hr. The efficiency of transformation, transmission, substations, trolley and locomotive is of the order of 60%. Therefore 1 HP hr. at the locomotive drive wheels will require $.9 \div .60 = 1.5$ lbs. of coal.

The steam locomotive, according to Mr. J. E. Muhlfeld, in a paper in the Railway Age Gazette, December 19, 1919, will, with the best hand firing, consume from 2.5 to 3.4 lbs. of coal per 1 HP hr. Assume an average of 2.9 with an efficiency of 90%, and the HP at the drivers requires 3.2 lbs. of coal. This is under the best conditions.

The auxiliary and stand-by losses are of a very indeterminate character, and cannot be accurately estimated, but we have Mr. Muhlfeld's authority that the ordinary steam driven air compressor takes from 70 to 85 lbs. of saturated steam for every 100 ft. of free air compressed to 100 to 130 lbs. A 100 ft. compressor will run not less than 50 and probably as much as 75% of the time to supply air for brakes, auxiliaries, and leakage, and will thus use from 2500 to 4000 lbs. of steam per hour, or enough to develop from 140 to 220 HP hrs. if used in the locomotive cylinders. This is an appalling statement, as it indicates that the compressor alone may take more than 20% as much steam as is required to pull the train. This is at least seven times as much as an electrically driven compressor would take. The losses from radiation, stand-by, and cleaning fires will easily amount to 10% more, bringing the coal for 1 HP up from 3.22 lbs. to 4.25 lbs.

The reduction in ton mileage is due to the smaller coal consumption of the railroads and to the elimination of the locomotive tenders. The tenders on passenger trains alone represent 10% of the total tonnage. The tenders on freight trains will average much less, but will probably amount to from 3 to 5% of the total tonnage.

Non-revenue tonnage on the railroads all over the country averages 13% of the revenue tonnage. This does not consider tenders. A reduction of only one-half of this would more than make up the balance of the 10% claimed. It therefore seems certain that the ton mileage would be reduced at least 10% by electrification. This would add another 10% to the coal for the steam locomotive, bringing the total up to approximately 4.65 lbs. for the steam locomotive, as compared to 1.5 lbs. for the electric. This is more than three times as much, and yet no allowance has been made for bad firing, either hand or stoker, which will add from 10 to 40% for leaky engines, or for the saving in electric power due to regeneration with electric locomotives on moutain grades, which in the case of the C. M. & St. P. Ry. amounts to about 11% of their total power consumption. Bearing these facts in mind, it seems that my statement that electrification would save two-thirds of the coal is very conservative. It is true that much has been done, and much more can and will be done to improve the efficiency of the steam locomotive, but it has a long way to go and every improvement means greater complication, higher maintenance cost and lower mileage.

THE PRESIDENT: I see Mr. Wanamaker over there. I did not mean to overlook you, Mr. Wanamaker.

MR. E. WANAMAKER (C. R. I. & P. R. R.): I have not very much to say. I have been listening very well, and the time is getting short.

The study I have been making the last few years has indicated to me beyond a doubt that electrification is extremely feasible over a very large percentage of our railroads, both prairie and mountain, especially as regards heavy terminals. Certainly it is a financial proposition. I do not think it is entirely within the province of the engineer to say what shall be electrified and what shall not. It is largely within the province of the financial man, but I think these discussions have certainly demonstrated the fact that it is from an economical standpoint a very desirable thing, and when electrification, or electrical operation of railroads, is understood by railway operating people, and railway operation is understood by electrical men—which Mr Storer has brought out before—there will no longer be any mis-mating of the team that is so necessary to do the job properly when the money is available.

About the bugaboo of money—I am not a financier by any means, but what is the money that is required to electrify a railroad? What do we do to electrify a railroad? We can convert some copper and iron and a few other materials from one existing form into another and as long as we have tied up the enormous amount of labor in this country to operate railroads by steam locomotives, could not we take 15 or 20 per cent of that labor and put it on another job? It will not require any more money of the United

States to take that 10, 15 or 20 per cent of that labor that is now being paid actual dollars to mine coal or to do this or to do that, all those things which are so necessary for steam operation. Let those fellows go to work on this conversion and it is not going to take any more money than it took before. It is simply a matter of taking that money and bringing it into another branch of the service, and by so doing you will readily increase the percentage of capital and percentage of labor that can be converted from a purely non-essential productive standpoint when we are operating the steam locomotive, into the more productive operation of the electric locomotive. I do not mean this on a broad scale, I mean that wherever revenue is demonstrated to be below the point of economy, as demonstrated by the engineers.

For instance, on a railroad of a thousand miles, it is merely a question of when the team meets and they divert certain moneys that are going out for certain non-productive effort so that the result will be a gradual turning of that money into another channel, and I think that is a thing we are all looking forward to.

There is no bugaboo about electrification, and the saving of coal is an enormous thing and we do have to look into it, not only the saving of coal, but the absolute efficiency. If we are all going to ride in automobiles and we are going to have to have these necessities—luxuries yesterday, necessities today—certainly we have got to get economical production. If we can, with a certain piece of electrified line reduce the number of men employed on that line, we have made one grand start.

Capital says on one side, "What we want is more production. Money can produce, the same as labor. Now is our money being shoved on the job today so it is productive, or is it not?" It is my idea that a lot of our money is not working efficiently in this country today. We are spending our money to buy labor that is not efficiently productive in many instances and where that is found, why could not we gradually change that thing over to get our money and our labor producing efficiently that which is necessary for the people as a whole? Especially is that necessary now that we are getting into the shortage of labor.

Indeed, the times will never be like they were before. There was a time when we had the small steam locomotive and the equipment and all that we have had heretofore. The labor did not amount to such a large proportion then. It was one dollar a day for a man a day, if you had a dollar, you had a man. The more dollars you got, the more men you got. You raised up the price, whatever it was and put the balance in profit and if you did not have anything left, you raised the price. But you cannot do that any longer.

THE PRESIDENT: Gentlemen, the hour is getting late, and I think it is time to close.

MR. SHARP: I should like to make a motion that we extend a vote of thanks to the speaker for coming to us here and giving us such a very able paper.

The motion was seconded by Mr. LaRue.

THE PRESIDENT: Moved and seconded that we extend a vote of thanks to the speaker of the evening for the paper he has presented to us. All in favor signify by saying aye. Contrary no. Carried.

Adjourned.