### ELECTRIC RAILWAY DEVELOPMENTS.

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In view of the recent great developments and extensions of the electric railway, a general review may be of interest. When, as to-day, the reports of the proposed electrification of steam roads become so common as to cause little wonder, well may the question be asked, "What will it all lead to?" Still another question insists on coming to the surface, viz.: "Is the A. C. motor likely to revolutionize electric traction?" Although the answers to these questions depend largely upon future developments and therefore cannot be exactly predicted, some conclusions can with certainty be drawn. The trend of developments is of special value in attempting to outline what may be expected in the future.

During the last ten years the electric railway business has developed far more rapidly than any other of comparable size. This is particularly true abroad, where over 90 per cent of the present roads have come into existence through displacement of horse or steam, or by new investment, during that period. In no other country than the United States has there been great development along the line of interurban railways, which require heavy equipment, operating at moderately high speeds.

The engineers of this country have so perfected and standardized the direct current equipment for this class of service, that there is little improvement to be expected in that line. The operating characteristics of suburban and interurban systems are not usually very dissimilar from those of ordinary city lines. Although the load is not distributed so evenly over these systems as in city railways, the concentration due to higher speed and heavier equipment is not so serious as to require any fundamental change in the character of the system. The economical limit of speed and weight of train units for this kind of system depends chiefly upon the one condition of distribution of the load. The gigantic undertaking of the New York Central Railroad to handle all trains within 35 miles of New York city by electricity is so far the greatest proposed development along this line. There has been much criticism and discussion as to whether some other system would not better fulfill the requirements of the case. It is not difficult to show that the choice made was the best one, because it rested on the fundamental consideration that no system of traction has yet been devised which can in any way compete with the standard D. C. system, on roads where the load has fairly even distribution.

Although a single New York Central passenger train will require upward of 2,500 K. W. at times, this energy is such a small proportion of the total average load on a section fed from one power house, that the system can still be classed with those having a distributed load; the sole difference being that this one is on a scale of magnitude almost undreamed of a half dozen years ago. There were many problems to be solved in this undertaking and the bold way in which the choice of the type of motor for the locomotive was worked out is an indication of the technical ability of the engineers employed. The new motors are unique in that the armatures are mounted on the car axles. The absence of gear losses makes their operating efficiency very high. Because of the simplicity of construction and consequent small depreciation made possible by their design, it is the best motor so far designed for use in high-speed D. C. locomotives.

These new electric locomotives are designed to haul a 450-ton train at a maximum speed of from 60 to 65 miles per hour. At present the New York Central's heaviest passenger trains entering New York city weigh about 875 tons, and more than one locomotive will be required to haul them at such speed.

It is seen upon analyzing the New York Central's proposed electrification, that the operating characteristics are not the ordinary ones of steam trunk lines where heavy fast trains are run at infrequent intervals. There has in fact been nothing of importance done or even attempted along this latter class of service, which will be called heavy concentrated loading.

The nearest approach to such service is found in some of the heavy interurban lines; the limit of speed and distance is soon reached in these lines using D. C., because of the great cost of delivering the current to the train. The third rail has extended this limit but slightly.

Five or six miles is the limiting distance of economical distribution at the standard voltage of 600. If a single station or sub-station can distribute to a distance of five miles in each direction, then stations must be built every ten miles along a line of railway. A concrete example will show how unsuited such an arrangement would be for heavy concentrated loading. Suppose a railway line 100 miles had only one train in operation. If this train required 1,000 K. W., then the power house capacity would be 1,000 K. W. and each sub-station 1,000. There would have to be eight sub-stations or a total sub-station capacity of 8,000 K. W. The conducting system would also have to be sufficient at every part to deliver 1,000 K. W. economically to the train. The investment in transforming or generating equipment must be all out of proportion to the power used in such service. The case assumed is an exaggerated one for the purpose of illustration. The principle involved is really the root of the difficulty which must be overcome before ordinary steam traffic can be replaced by electric.

In order to overcome the difficulties, either the characteristic of the traffic must change from large-train units at infrequent intervals, to distributed service, or the distance to which energy can be efficiently delivered to moving trains from one station must be increased. The former solution may in some cases play an important part, but the general solution of the problem rests with the latter method, in which the first necessary requirement is a high voltage of distribution to the train. If a much higher voltage than 600 is used, the third rail is entirely unsuited. It would be too dangerous to life and can not be well enough insulated for good operating conditions. A higher distributing voltage, then, necessitates the use of a trolley wire overhead. Satisfactory trolley collecting devices have already been developed but much remains to be done in the way of making high trolley voltages safe. In D. C. use the trolley voltage is limited by the motors. Much higher voltages than 600 can not be successfully commutated on one commutator.

If two motors could be made to operate well in series and in that way double the trolley voltage, it would be possible to efficiently distribute the current to a distance of about 25 miles. In spite of the reasonableness of this scheme some engineers dismiss D. C. systems from serious consideration in connection with concentrated loading.

Several systems have been devised for using A. C. distribution at high trolley voltages. Some of these use D. C. and others A. C. motors. There is no voltage limitation in these systems, theoretically, which necessitates placing the power stations closer together than other conditions of economy require and the transforming equipment need be no greater than the motor capacity in use. All stations would be power houses and the great length of line fed from each station would make its load sufficiently constant for economical operation.

The most important of the proposed systems can be classified under three heads:

1st. Those using rotary apparatus on the locomotive for converting A. C. to direct, for the D. C. motors. The Ward-Leonard system is a notable example of this arrangement. It is particularly adapted for moving heavy trains.

2d. Those operating by means of induction motors requiring polyphase distribution to the train. The tests at Zossen, Germany, were made with this system and although speeds up to 135 miles per hour were easily reached, this system has proven itself absolutely unsuited for general railway service.

3d. Those using a single-phase A. C. motor with the speed characteristics of a series D. C. motor.

The induction motor is inherently a constant-speed motor and is therefore not suited for traction. On the Continent there are several roads using polyphase induction motors, but the railway engineers of this country have been conservative and unwilling to introduce such a system which could not compete with standard D. C. systems. Their stand against the polyphase motor is justified by financial considerations and has not been due to any lack of progressiveness.

It is only within the last year that a successful single-phase A. C. motor has been developed and as yet it has not had a thorough test under the severe conditions of actual service. In order to have an efficiency and lightness at all comparable to the D. C. series motor its air gap must be made extremely small. Whether the air gap can be made small enough for the motor to have a good efficiency and at the same time stand up under usage, time alone can determine.

The fact that the motor can operate equally well on D. C. will doubtless hasten its development, and even though this motor does not succeed in solving the problem of concentrated service on heavy passenger and freight lines, it seems well suited to the lighter concentrated service of long interurban lines. Unfortunately the motor has a commutator, which is, if anything, more troublesome than that of a D. C. motor. However, the voltage impressed on the motor need not depend on the trolley voltage but can be transformed so as to give the best conditions for commutation.

A comparison of A. C. series with the D. C. series motor equipment, does not show all the advantages to be in favor of the former. Nor is it probable that the A. C. system will ever displace the D. C. system in certain kinds of service. The car equipment for A. C. costs more than for D. C.; is heavier and of slightly lower efficiency except during acceleration. These disadvantages must be more than offset by the smaller amount of trolley copper and elimination of rotary sub-stations, made possible by the A. C. motor in order for it to successfully replace its D. C. rival. It is likely that each system will have a place of its own.

The foremost engineers of the country are so contradictory in their opinions of the present status of the problem of A. C. versus D. C. and their predictions of the future development are likewise so diverse that there are evidently many points which cannot be definitely settled until further development takes place. The probability of the series A. C. motor revolutionizing electric traction is very remote.

On a system of very dense traffic heavy trains might not introduce a seriously great load on the station feeding even a comparatively short section, and it may be that some road like the New York Central will attempt the electrification of a considerable portion of their system along the same lines as their terminal plans now under way, i. e., using D. C. at standard voltage. If any line should make such a change it might be that competing lines would find their passenger traffic so reduced that in order to retain it they would be obliged to also electrify their passenger traffic. There is no doubt that the traveling public desires transportation by electric traction and that the change to electric by any steam road running fast long-distance passenger trains, will bring about a great increase in the amount of business. Probably in no system will the outlay of capital for electric operation be as small as for steam operation, neither will the decrease of operating expenses under electric system pay for the interest on the larger invested capital, but the greater traffic and consequent greater earning capacity of the road *will* more than pay for the increase of outlay. Electrification means more than a mere change of equipment; it involves an improvement in traffic conditions which is bound to favor the electric system. The preference of the public for electric traction is shown in almost every case where an interurban line parallels a steam line. Practically all of the local traffic is taken from the steam line even though the schedule made by the interurban is slower. This competition has been felt so keenly by the managers of steam roads that they have attempted to prevent the building of electric roads paralleling their lines.

There have been a few cases where the steam railway has operated an electric road acquired because of competition as an auxiliary to their steam system. This is a legitimate undertaking and has the advantage of educating the steam railway managers to the advantages of electric traction. Some such educational process may be responsible for the change of attitude of steam railway engineers and managers which has occurred during the last year or two. In place of the hostility and skepticism of the couple of years ago regarding any encroachment of electric traction upon steam roads the present attitude is one of expectancy—of waiting for such developments as will permit of the use of electric locomotives in place of steam.

As the cost of fuel will necessarily increase with time, there will be an increasing necessity for changing from steam to electricity because of the better fuel economy of the stationary engine over the steam locomotive. The saving in cost is especially great when water power is available along the route.

In the rapid development of scattered interurban lines there has been little effort until recently to develop through traffic. In this respect the conditions are like the early days of steam railways when it was necessary to change cars fifty times between New York and Buffalo, when each individual road in trying to work out its own salvation lost sight of the necessity of working together for the common good of all. Fortunately for trolley lines the voltages used on D. C. systems are nearly all standard and there is no difficulty in consolidating systems and so developing long-distance service.

A general survey of the situation in this country indicates that the further developments in electric railways will occur as a gradual extension into the realm of steam railroads, rather than any sudden displacement of steam equipment. It is hardly possible that in a period of six or eight years the electric locomotive will become a serious menace to the steam locomotive, although it is the firm belief of the writer that eventually all steam traction will be superseded by electric.

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The greatest problems of American agriculture are not the narrower technical ones, but the relations of the industry to economic and social life in general. Agriculture has not as yet been able to call to its aid in any marked degree those forces and tendencies which have culminated and been of such economic value in the general business world, in the great productive and distributive aggregations. The complete solution of the economic ills of American agriculture may not be in co-operation, and yet in both the productive and distributive phases this is perhaps the most apparent remedy. Co-operation in distribution has made a beginning, but co-operation in production is still almost unknown.