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Air Brakes for Electric Cars

BY

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WILMERDING, PENNA.

Air Brakes for Electric Cars

IT will not be necessary for the purpose of this paper to go into the history of Power Brakes to any great extent as a paper, presented by our Mr. R. A. Parke at one of your meetings about two years ago, covered the development of the Power Brake from its earliest use up to the present time.

The object of this paper will be more to outline the situation as it confronts us at present.

When the Electric Motor began to supersede the horse and cable on the surface lines, the cars were universally of the single-truck type, which fact accounts, in a very large measure, for hand brakes being continued as the standard for several years after electric cars came into general use. As this type of car weighed but from seven to ten tons, and the first motors, as you know, were of low capacity, the speed was necessarily slow, so that hand brakes served the purpose for the time being.

When new rolling stock was purchased, however, each lot was heavier than the former until the limit of practicability in single-truck car construction was reached and double-truck cars appeared on the scene.

This brought a demand for multiplied-power hand brakes, and very soon we had Friction Brakes, Electric Disc Brakes, Geared Hand Brakes, Magnetic Brakes, etc., without number. This paper will refer particularly, however, to Air Brakes for Electric-Car Operation.

There are several very important reasons why air brakes are now considered to be an essential part of the equipment for an electric car, either for operation as a single vehicle or in trains with other cars, and these might be referred to in the order of their importance as follows:

Economy of Operation

It is now a well established fact that the matter of applying air brakes to electric cars has proceeded beyond the point where the first cost is the main consideration.

In the earlier stages of the development of electric cars the first cost of any item of equipment was a very important factor, as the roads were changing from other power to electricity and the necessary expense being heavy, every item that added to the capital account was closely scrutinized, and large numbers of electric cars were originally put into operation with hand brakes. In some of our large cities to-day a large number of cars are being operated without power brakes. Part of this number, however, are not adapted to the use of air brakes, as they are single-truck cars; they will be operated with hand brakes until they are displaced in the ordinary development of the properties by double-truck cars, which latter will undoubtedly be equipped with the latest devices now under discussion.

It has been possible to gather statistics covering the past few years of operation which show that the power consumption is largely effected by the brake apparatus. Without going into the matter in detail, it will no doubt be sufficient to state that the difference in the cost of operating an electric car equipped with hand brakes, and one equipped with air brakes, is over 10 per cent. This is readily accounted for by the fact that it is necessary for the purpose of safety to operate through the streets in congested districts of cities and towns with the shoes close to the wheels on hand-braked cars, in order to prevent accidents; but with the car having air brakes the shoes can be left free from the wheels, as an emergency application can be made without the time element which would be necessary with the hand-braked car.

The development of your properties has now proceeded to the point where you are able to secure information along these lines, and it is very gratifying to the writer to say just here that the electrically-operated railroads in New England give more careful attention to the details of statistics covering all points of operation, and the waste ends are cared for better in this district, as a general proposition, than in any other section of the country; we feel competent to speak in this connection as it has been our pleasure to solicit business, and become more or less intimately acquainted, with the roads in all sections of the United States.

Saving of Time in Operation

Another important factor entering into the application of air brakes to electric cars is the saving of time in operation.

On the steam railroads the handling of trains with hand brakes has been discontinued for so long a time that it is a matter of surprise to us now when, through unforeseen circumstances, we see a freight or passenger train being completely handled by hand brakes. One of the most important factors in inducing the steam railroads to adopt air brakes on their cars was the improved facility for operation which pertained with the power brakes over and above that they were able to do with hand brakes. As an illustration of this point we might mention just here that on one of the roads running into this city, not long ago there was a failure of the air-brake equipment through accident so that it was necessary to operate a passenger train some 200 miles by hand brakes. You will be interested to know that the train was nearly two hours behind schedule time for no other reason than that extra caution was necessary, and the additional time required to stop the train with hand brakes made it impossible to make schedule time.

This has just as important a bearing in the operation of an electric car, although it has not come as prominently to the front as it will from now on. Electric cars and trains are now being operated on faster schedules and closer headway, and any equipment which increases the efficiency of rolling stock is considered more importantly, now that all such items are taken into consideration in the operation of electric roads. This will also be an important factor in the operation of electric trains on branches of steam railroads, which we all shall live to see developed to a very great extent in this immediate vicinity. It will be absolutely impossible to carry on the work of development of electric train operation on steam railroads without the use of some of the improved air brake devices which are now in use and which are being developed (as will be later described in this paper), as one of the reasons for the operation of trains on steam railroads with electricity instead of steam, as at present, is the improved acceleration possible with electricity; and if improved acceleration is an important factor as a time saver, then the same saving in improved deceleration will have just as important a bearing on the situation.

Safety

Another important factor requiring the application of air brakes to electric cars is the question of the factor of safety necessary to meet the present operating conditions. While we have put some other features ahead of this factor in importance, it is the writer's opinion that in certain instances an improved factor of safety is one of the most important considerations before the managerial departments of electric railroads to-day.

The accident account, and consequently the claim department of all public utilities in our country to-day, especially the railroad companies, is too heavy a strain upon the finances, and a proper consideration of safety devices and appliances to reduce the accident account cannot be too strongly urged by all interested. On the steam railroads of this country, much has been done towards the adoption of standards covering the appliances and devices upon the cars which have to do with the safety of the passengers and employees, and it is the writer's impression that the time is at hand when these matters should be given consideration by our general association,—The American Street Railway Association, proper, and also the Mechanical Association,—to the end that certain standard practices should be recommended for use under certain conditions on all electric railways.

Such recommendations could consistently cover the proper strains and stresses permitted on the draw bar and foundation brake rigging, and the compulsory application of power brakes to cars of a given weight and for speeds in excess of some stipulated normal speed.

The use of the air brake to improve the factor of safety was, of course, one of the first considerations making the application of air brakes necessary to electric cars, but at the present time the conditions are changing to such a great degree that what was necessary three or four years ago to simply improve on hand brakes, does not meet the present conditions any better than the hand brakes did at that time.

Within the past few days, the writer took occasion to time the speed on an inter-urban electric railroad operating out of Chicago, Illinois, and between several stations in an hour's run, the train of three cars reached a maximum speed of sixty-four (64) miles per hour. It is manifestly evident that what would not constitute an emergency at six to ten miles per hour with hand brakes, or ten to thirty miles per hour with ordinary air brake appliances, would certainly be an emergency at the above mentioned speed.

Unless proper consideration is given to the extreme maximum speed at which the cars are likely to run to make up time after a delay, serious accidents are likely to occur. It is just as essential that the appliances on the car should be such as to make a stop possible in the same number of feet at sixty miles per hour, as has heretofore been possible at thirty miles per hour; and as you are all more or less familiar with this subject, it is only necessary for us to mention that the improved appliances are necessary to meet the new condition of heavier cars and higher speeds. These improved appliances are particularly important upon electric inter-urban roads operating on the surface through cities and towns, and in inter-urban service where grade crossings are a rule.

Operating Conditions

With this mention of the particular reasons which have had much to do with the application of air brakes to electric cars, we shall be glad to proceed with a description of the conditions of electric-car operation as they confront us to-day, and the necessary air-brake equipment to meet the different conditions described.

During the development of electrically operated roads up to the present time, the tendency has been to increase the size of each individual vehicle, until we now have inter-urban roads operating electric-motor cars weighing as much as 98,000 pounds, complete, without live load.

It has been the practice up to this time to operate electric cars as single units on surface and inter-urban lines, but it is now becoming evident that there are certain disadvantages in this line of development towards single heavy vehicles for inter-urban service, some of which might be mentioned as follows:

First—It is necessary to operate the heavy vehicle at all times during light and heavy traffic.

Second—It is necessary to have large motors on all axles of these heavy cars in order to get proper acceleration, and in order to do this the floors of the cars have been raised to such a height above the pavement level that it is getting more and more difficult to handle passengers in and out of the cars with proper facility.

Third—In order to carry such a heavy vehicle it has become necessary to have broader treads to the wheels and deeper flanges, and as these cars are usually required to operate into a city at one end of the line, these wide treads have reached over the rails on to the paving blocks, and the deep flanges have interfered with the ordinary special work which was designed for lighter city cars only.

Fourth—The length of these heavy vehicles is necessarily such that operation around 35 and 40 feet radius street-corner curves is very unsatisfactory.

Fifth—The size of the motors and weight of these large single vehicles are such that it is necessary to break very heavy currents on the platform of the cars if the ordinary type of controller is used. As the development of the hand controller has not proceeded at a corresponding rate with the increase in the weight of the equipment, as above mentioned, our present hand operated controllers are not generally well suited to the handling of the large currents necessary for operating four-motor equipments of 75 H. P. each, or 300 H. P. on a vehicle, as is regularly done in and out of Indianapolis and other like centers. The tendency, therefore, is toward multiple-unit control, even on single vehicles; with this device the contacts are made and broken underneath the car floor instead of on the platform, and the advantage is also secured of being able to operate the vehicles in trains, each unit being self-accelerating.

These and other disadvantages which might be mentioned, are partly accountable for the present tendency of the pendulum to swing back in the other direction toward equipment of modified weight (say not to exceed an average of 50,000 pounds per vehicle), to which the above mentioned disadvantages would not apply. In order to handle the heavier traffic of rush hours, Sundays, holidays, etc., the tendency is now throughout the country almost generally toward the operation of these medium weight vehicles in trains of from two to five cars. As it is very much easier to get extra conductors than motormen, the length of trains can be readily increased during the rush of business rather than add additional single heavy vehicles above mentioned, taking both motormen and conductors.

Of course, for elevated railroads and electric branches of steam railroads, the operation of electric cars in trains has been the standard practice since the lines were changed from steam to electricity, but it is only recently, in fact just now, becoming the rule with the surface lines to operate electric cars in trains.

For the purpose of describing the variations of air brake equipment for electric cars to meet the present conditions pertaining throughout the country and New England, we should like to mention several methods of operating electrically propelled cars. Each method of operation has distinctive features to the extent that a certain air brake equipment is better adapted for one method of operation than another. These methods might be mentioned as follows:

First—Single-car operation.

Second—Two-car train, the front car being a motor car, usually with four motors of such capacity as to haul a second car as a non-motor trailer. The front car is arranged to be operated singly the major portion of the time, only hauling the trailer during rush hours, or on holidays, etc.

Third—Two-car train, the front car being a motor car, of sufficient power to haul a second car as a non-motor trailer, just as above mentioned, but in this case the pair of cars are arranged to be operated together the greater part of the time, and the single car operation of the motor is a secondary consideration.

Fourth—Two and three-car trains—no longer. All cars in the train being motor cars, essentially for operation on the streets of cities and towns and in inter-urban service, and each car arranged to be operated as a single unit, when desired. This would require each car to be complete with brake valves, compressors, etc.

Fifth—Three-car trains—no longer, when one or two of the cars may be non-motor cars.

Sixth—Trains of four or more cars, each equipped with motors, compressors, and complete air-brake equipment.

Seventh—Trains of four or more cars, when part of the cars only are motor cars, completely equipped, and the balance are non-motor cars.

Eighth—Trains of any length, hauled by a completely equipped electric locomotive, all the other cars in the train being trailers and the supply of air entirely dependent upon the compressor of the locomotive.

It will be at once apparent to you that one standard air-brake equipment could not be used for all of these several and separate conditions.

For the single car operation, above mentioned, it has been standard practice to use what we commonly term the "Straight-Air" brake, but it was early discovered that such an equipment would not serve for the proper handling of cars in trains, and as far as steam railroads are concerned it has been some years since "Straight-Air" was used, except as an accessory on locomotives to secure independent locomotive brakes for certain purposes.

The Master-Car-Builders Association and Master-Mechanics Association of the steam railroads took official action some years ago to condemn the use of "Straight-Air" as a standard for train handling, and as we have just mentioned the tendency of electric roads to use train operation, it will at once be evident that a change in the air brake equipment is necessary to meet the new conditions. What is commonly known as "Automatic Air Brakes" will, of necessity, be used.

On the steam railroads of this country, the air brake equipment is commonly termed "Quick-Action Automatic" and for the different methods of electric-car operation above mentioned, the "Quick-Action Automatic" air brakes could probably be used, but there are several reasons why the "Automatic" equipment, as commonly used on the steam railroads, will not exactly meet the electric-car operating conditions. While the "Automatic" air brakes, as now in use on the steam railroads, will undoubtedly serve in their present form to meet the steam-railroad conditions for some years to come, the fact remains that such "Automatic" air brake equipment was not originally designed for widely varying conditions of operation such as pertain on your electrically operated roads; and there are several particular reasons why it does not meet all of the different methods of electric car operation, most of them new in air brake practice.

First—The applications of the brakes on electric cars are likely to follow in such quick succession that enough time would not elapse to permit the proper recharging of the auxiliary or braking reservoirs on the vehicles.

Second—The flexibility of a graduated release of the brakes is absolutely necessary for electric-car work to assist in making smooth stops, with due regard for standing load. With the standard automatic equipment the release of pressure from the brake cylinders is complete when once started.

Third—A prompt response of the brakes in application or re-application after a release is very essential. This is not always possible with the standard equipment, as the recharge of the auxiliary reservoirs is so slow that the brake-pipe pressure might be higher than the auxiliary pressure just when an application was desired; this excess must be drawn down and considerable time lost in getting an application.

Fourth—The equipment of motor cars with automatic brakes, that were to be operated singly, was early found to be impracticable on account of the fact that so small a brake-pipe volume as that on one car, especially when small piping was used, prevented any flexibility whatever in the graduations of applications of the brakes, and there being no graduations of release possible, the cars could not be handled with the necessary smoothness.

Fifth—The standard automatic equipment was designed for use with an air supply on the head unit in the train *only,* therefore, when motor cars came to be coupled up together, each completely equipped for use as the head vehicle, whenever desired, the problem confronted us as to whether it would be better to have each motor car equipped with a compressor of large capacity sufficient for the whole train and use only the compressor on the head unit as heretofore, or have smaller compressors on all motor cars of the train and arrange to have the labor divided up between them.

There are arguments in favor of both methods, but the latter has come into more general use, making changes necessary in the standard equipment to secure equal division of pump labor.

Air Brake Equipment

With this general description of the conditions which we found confronting us, it will no doubt be of interest to have some information as to the variations of air brake equipment which would be recommended for each different and distinct method of car operation.

Equipment SM.

Referring again to Method No. 1, single-car operation, would say that this method has been the standard practice up to this time on perhaps the majority of the electric roads of this country, as heretofore mentioned in this paper.

It has been, and will no doubt continue to be standard practice, to use straight-air brakes for single cars, as the variations of the weights of the cars and the variations of speeds at which each car is likely to be operated are such that the air brake apparatus is required to have the extreme of flexibility in every direction.

It will not be necessary for us to go into details in regard to the straight-air brake equipment, as you are all familiar with that type of the air brake as now applied to your electric cars.

The straight-air brake consists essentially of an Air Supply, a Main Reservoir and Brake Cylinder, a Foundation Brake Rigging to communicate the braking effort from the brake cylinder to the wheels; a Brake Valve for admitting the air from the main reservoir to the brake cylinder and in turn releasing the pressure; also a Governor or Automatic Regulator for controlling the pressure in the main reservoir and cutting the pump out of operation when the desired maximum pressure is reached.

As far as the ordinary single-car service is concerned such an air brake serves the purpose exceedingly well, as the desired flexibility in the matter of graduations of the application and release of the brakes can readily be secured, and this apparatus is usually of such a type that the ordinary motorman can become familiar with its operation to the extent that very satisfactory results can be secured. It can be said, however, that with heavier cars and higher speeds, it is necessary to have additions and refinements, even to the above mentioned Straight-Air Brake, in order to properly meet the requirements of the situation.

In the event of the cars being very heavy, and the maximum speed reaching a rate of fifty (50) to sixty-five (65) miles per hour, it is absolutely necessary to have an additional braking effort to stop the rotation of the armatures at these high speeds, and to stop the heavy vehicles approximately within the distance that the stop would be made at a lower speed or with a lighter vehicle. While such additions and refinements have not generally been added to the straight-air brake equipment, the demand is beginning to be felt owing to the fact that these conditions of operation are becoming more general. In other words what would serve properly for handling a car in the ordinary service requirements of the brake might not serve to prevent an accident in an emergency at maximum speed. In order to meet such a situation it is necessary to arrange the brake valves so that in ordinary service applications (to make the regular stops), the maximum pressure in the brake cylinders would not be reached so promptly, whereas in an emergency the maximum pressure should be secured in the shortest possible instant, because it is ordinarily impossible to add braking effort to the wheels at high speeds sufficiently to cause them to slide, the co-efficient of friction being extremely low at that time. If the same braking effort were used at slower speeds in the ordinary service requirements of the brake, flat wheels would inevitably result, so that two separate conditions must necessarily be met with the same brake valve. With the lighter cars and slower speeds that obtained at the time of the earlier adoption of the straight-air brake, no special necessity existed for such an arrangement.

Another refinement that could be added to the straight-air brake would be additions to the equipment to secure a uniform application of the brakes at a uniform pressure at all times without regard as to whether the maximum or minimum main reservoir pressure existed at the time the applications were made. Such an addition becomes more necessary when the cars are sufficiently heavy to require the use of 12-inch, 14-inch and 16-inch air-brake cylinders, where the piston area is so great that a variation of ten to twenty pounds in the pressure per square inch makes so great a variation in the braking effort that uniform results of operation are impossible.

For single-car operation, therefore, the straight-air brake, with such additions and refinements as have just been mentioned to meet the changing conditions, will no doubt serve for a long time to come; but when the method of operation is such that the cars are to be connected in trains, such an equipment would have too many shortcomings, particularly in the matter of low factor of safety, as it is necessary to use between the vehicles flexible connections, which are more or less unreliable, and in the event of a rupture of them, which very often happens, certain devices are necessary to secure an application of the brakes even in the event of such an accident.

We beg, therefore, to now refer to the other conditions of operation which will call for an entire change in the matter of air brake apparatus, which will come more properly under what is generally known in the railroad fraternity as *automatic air brakes.*

Equipment SME.

Referring to method of operation No. 2, two-car trains, consisting of a motor and trailer, where the motor is required to be operated singly the major portion of the time, but to have arrangements in the air brake apparatus for handling a non-motor trailer during rush hours, Sundays, holidays, etc.

We would refer you to an air brake apparatus which is but one step away from the straight-air brake, which has just been discussed. Such an equipment would contemplate the handling of the motor car continually by "Straight-Air" just as would be done if the trailer proposition were not to be considered, and when a trailer car is added, it is also handled by "Straight-Air" during the application and release of the brakes in the ordinary service requirements of operation, so that all of the flexibility of operation incident to "Straight-Air" is secured.

It is the general policy of our Company to confine the use of "Straight-Air" brakes to single car operation, but the conditions of operation just described, having the operation of the motor car as a single car during such a large part of the time, made it advisable for us to furnish a combination arrangement which would have the straight-air features most prominent; but also embody that factor of safety in an emergency,—and when we ordinarily speak of an emergency we mean the necessity for the car or train to be stopped to save life or property, or an accident to the flexible connections or piping,—whereby the brakes are applied automatically just as though the complete automatic equipment were used.

With such an equipment, a second hose line is added, and on each vehicle is placed a small triple valve, similar in design to the plain triple valve used in connection with our Equipment AMS, although not identical, viz., a plain triple valve without graduating valve. The valve body is much shorter than any other triple valve which we use, as there is no travel of the slide valve except to secure an emergency application. Main reservoir pressure is connected to the slide-valve chamber. The piston is at rest against the graduating spring, so that no movement of the piston can take place without sufficient differential to compress the graduating spring. The function of this triple valve, therefore, is to apply the brakes automatically only in the event of a rupture in the hose connections or piping, or in the event of the emergency position of the brake valve being used.

This second hose connection is in reality a train line, in which pressure is maintained at all times through the feed-port past the triple piston, above mentioned, and also through the feed or supply ports in the brake valves on the motor cars. But it differs from a train-line in the fact that no reduction is made in the pressure of this line in service position of the motorman's brake-valve handle.

The brake valve in connection with this equipment is in reality the special feature of the equipment, as it is a composite valve through which straight-air applications are made in the ordinary service requirements, and an automatic application of the brakes by a reduction of the pressure in the second hose line only in the emergency position of the handle.

The particular reason for the use of such a combination straight and automatic air brake equipment for this method of operation refers to the use of the straight-air in making the brake applications, rather than have the triple valve operate for each brake application of the motor car when being operated singly.

Having the straight-air and automatic features of the equipment all in one brake valve, so that the motor is ready at all times to be coupled to a trailer, is a decided advantage over plain straight-air, and it also has the advantage of preventing the motorman using an excessive amount of air in the ordinary running of the car as is now the case with the ordinary straight-air brake, as the motorman is apt to make an emergency application during nearly every stop; but with the equipment just described, if the emergency position were used and an application of the brakes made with the automatic side of the equipment, the time required to get a release of the brakes would soon cause the motorman to refrain from using the emergency application, as he would soon find it paid to be more careful if he wished to make any time over the line.

This equipment, having the straight-air feature so prominent in it, is, therefore, recommended for use on two cars only, as above mentioned, and particularly where the trailer is hauled only a very small portion of the time, in which event the motor car could be handled by straight-air and yet have the increased factor of safety of the automatic side of the equipment as a reserve in the event of a break-in-two or a rupture of the piping.

Equipment AMS.

Referring again to method of operation No. 3, viz., a two-car train consisting of a motor car and a non-motor trailer, just as above described, but in this event the conditions mentioned cover the two cars being operated continually together. This, therefore, would eliminate the necessity of having a straight-air brake pure and simple for the handling of the motor car singly, and if certain features were added to the automatic equipment in

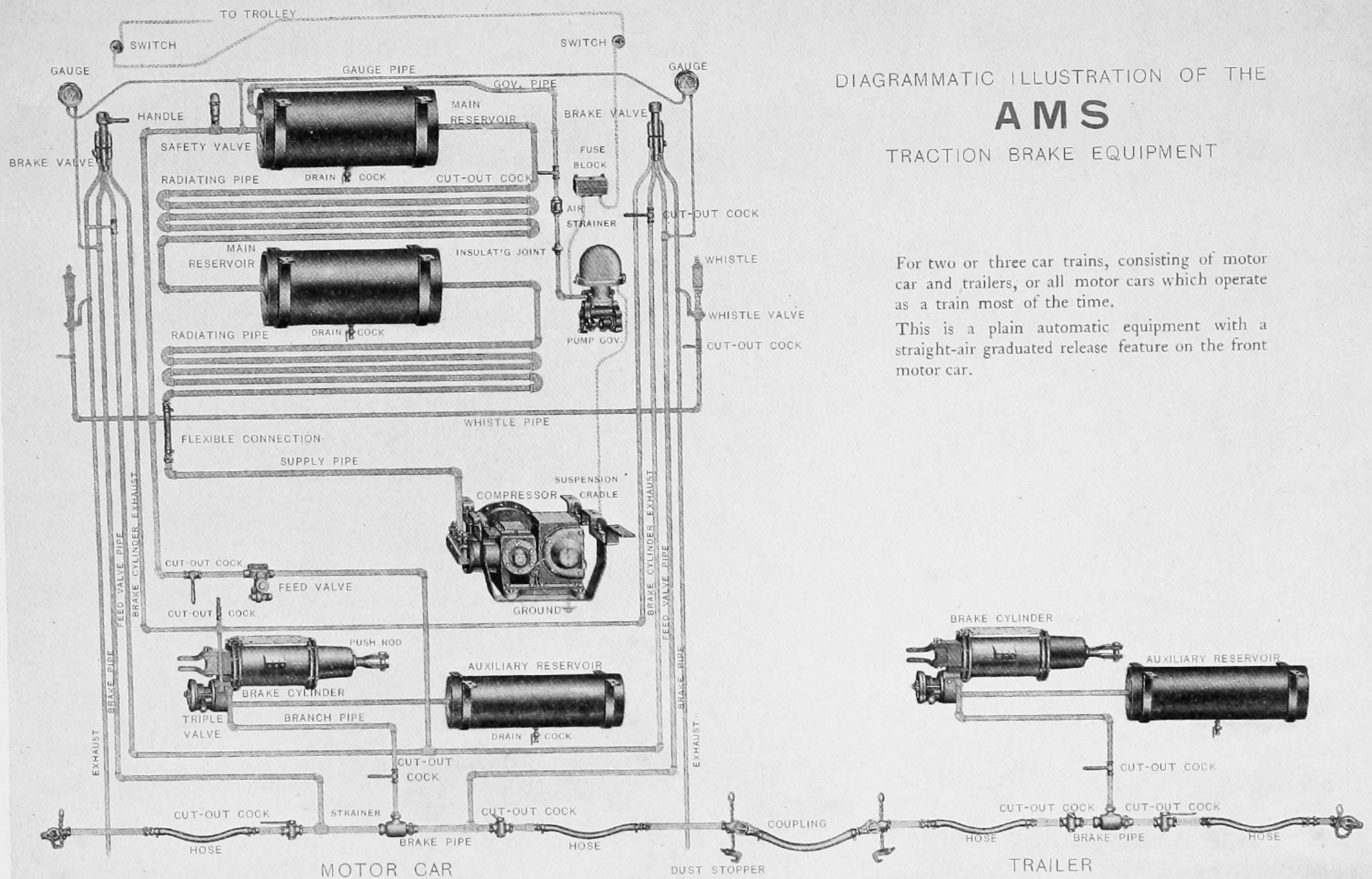
DIAGRAMMATIC ILLUSTRATION OF THE

AMS

TRACTION BRAKE EQUIPMENT

For two or three car trains, consisting of motor car and trailers, or all motor cars which operate as a train most of the time.

This is a plain automatic equipment with a straight-air graduated release feature on the front motor car.



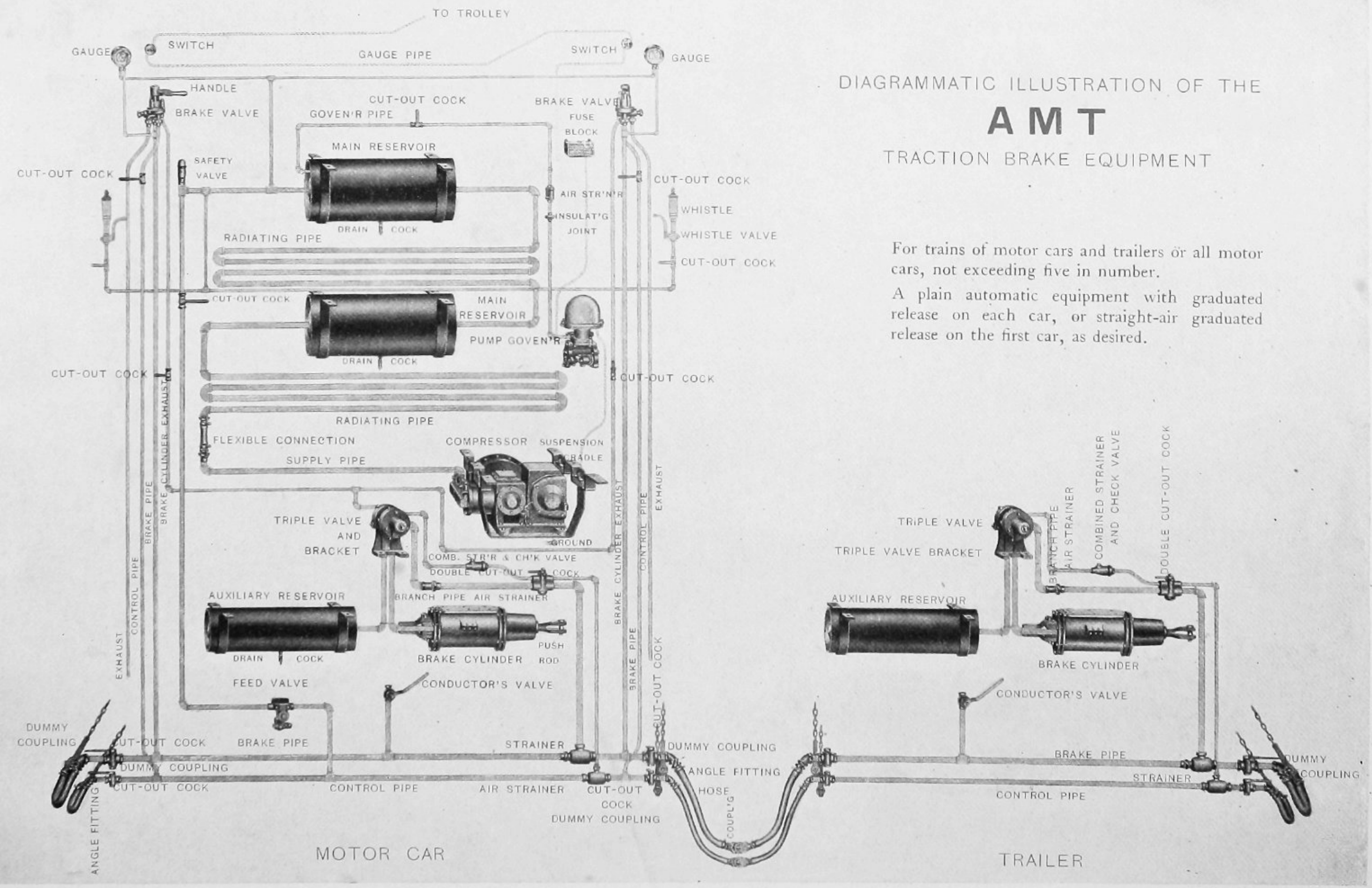
DIAGRAMMATIC ILLUSTRATION OF THE

AMT

TRACTION BRAKE EQUIPMENT

For trains of motor cars and trailers or all motor cars, not exceeding five in number.

A plain automatic equipment with graduated release on each car, or straight-air graduated release on the first car, as desired.



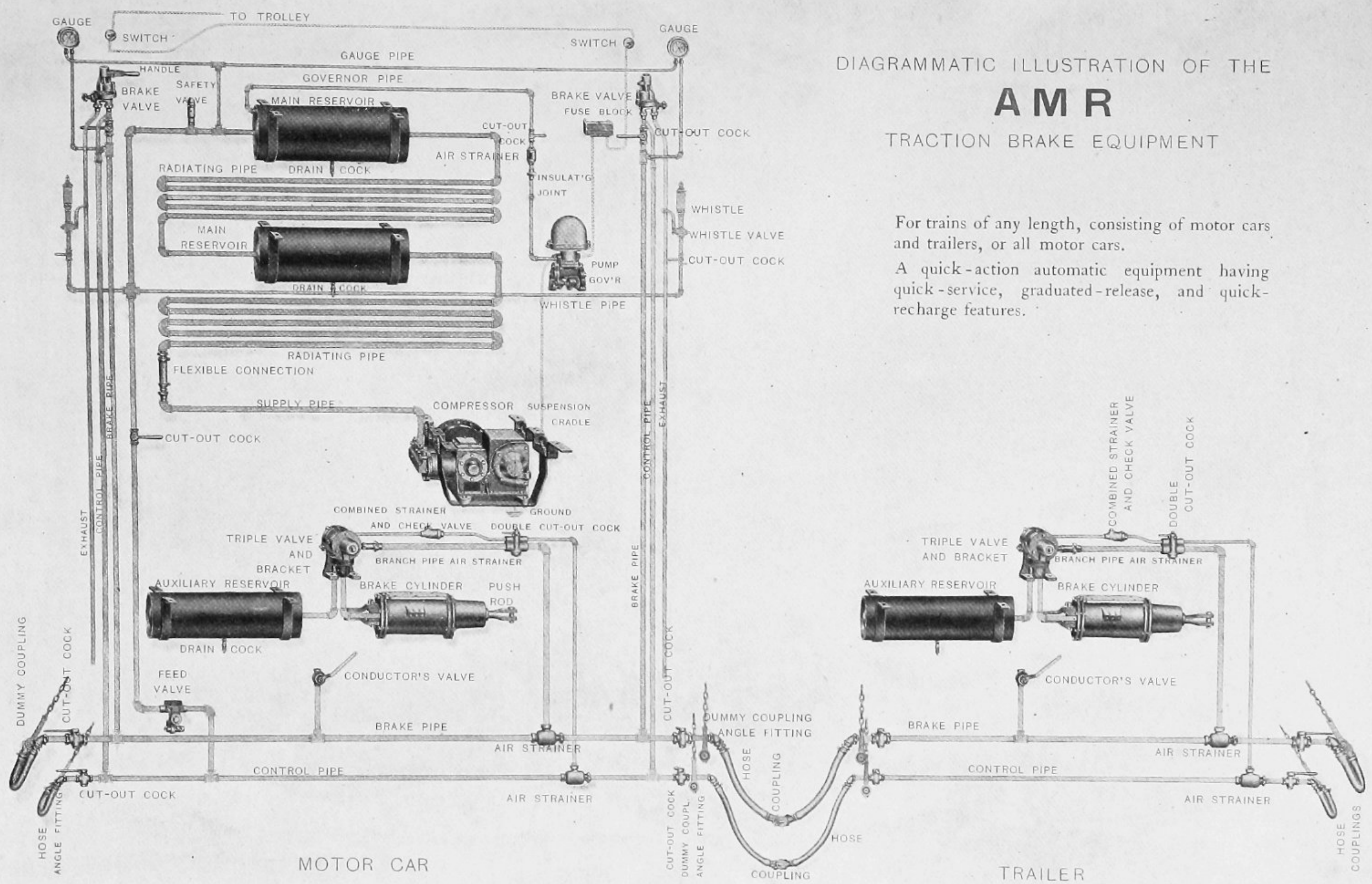
DIAGRAMMATIC ILLUSTRATION OF THE

AMR

TRACTION BRAKE EQUIPMENT

For trains of any length, consisting of motor cars and trailers, or all motor cars.

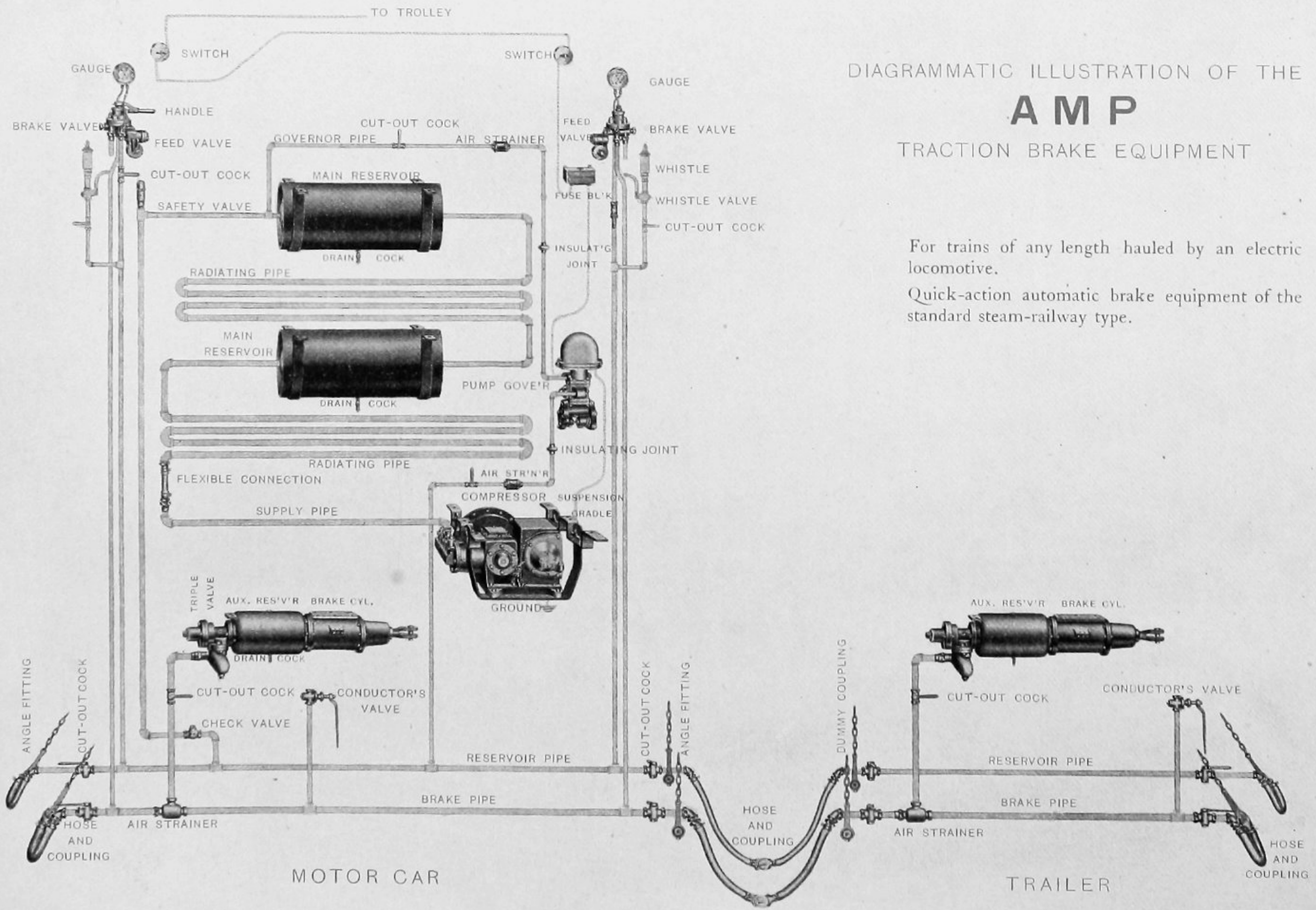
A quick-action automatic equipment having quick-service, graduated-release, and quick-recharge features.



DIAGRAMMATIC ILLUSTRATION OF THE
AMP
TRACTION BRAKE EQUIPMENT

For trains of any length hauled by an electric locomotive.

Quick-action automatic brake equipment of the standard steam-railway type.



the matter of a straight-air release of the brakes from the brake cylinder of the head car, and if the brake applications could follow each other immediately without danger of depleting the pressure in the auxiliary reservoirs, the conditions could be better met with automatic brakes than with straight-air.

Such an equipment is our AMS.

This equipment consists of a very simple brake valve in the release position of which a wide open connection is made from the feed valve to the brake pipe, so that the feed-valve pressure is on top of the rotary at all times and not the variations of main-reservoir pressure. The applications of the brakes are made in the regular automatic way by the reduction of the pressure in the brake pipe, both in service and emergency.

The triple valve is of the plainest type without a graduating valve, but this triple is arranged with a quick-recharge feature through a check valve of such capacity that the recharging of the auxiliary reservoir occurs in exact proportion to the release of the pressure from the brake cylinder and the recharge of the brake pipe, so that one application can follow another in as quick succession as desired. In making the applications of the brake with this triple valve, the graduating spring is compressed slightly in service position of the triple so that the lapping of the valve is done by the spring pressure moving the main slide valve back, instead of having a graduating valve. The graduations of application of the brake are refined by the use of a rather small auxiliary reservoir volume, of such size as to secure 50 lbs. equalization with five inches of piston travel, by the use of which we can secure the graduation of application to such an extent that the car can be handled smoothly. There is no graduation whatever in the release of the brakes at the triple valve, but this feature is accomplished in this equipment by piping the exhaust of the triple valve to the brake valves, in the release position of which there are really two positions, trailer release and motor release. In making a release of the brakes, therefore, during a stop, the first movement to release position permits the pressure to escape from the trailer-car brake cylinder, as both triples have gone to release by the recharge of the brake-pipe, and both auxiliaries have been recharged, but the pressure is held in the brake cylinder of the motor car, if so desired, by the use of the "Holding Position," and the graduations are made by the use of the straight-air release feature of the brake valve out of the motor car cylinder.

At the first glance it might occur to you that this method of making a stop would lead to unsatisfactory results, but where we have installed this equipment we have arranged for a braking effort on the motor car slightly in excess of that on the trailer car, so that when a brake application is made the slack runs in, and by the method of release above described, the slack remains bunched until the stop is completed. We have had this equipment in operation since last November, and no two-car trains are handled more smoothly than we are able to do with this equipment by the method above described.

The fact that this equipment is purely automatic, and requires the movement of the triple valve during each application, makes it essentially an equipment for train service; in other words, this equipment is to be recommended for use on two-car trains where the cars are likely to be operated together the major portion of the time, whereas if the trailer operation is secondary and the motor car is likely to be run alone the major portion of the time, then possibly Equipment SME would be preferable.

There are advantages, however, in the use of this equipment over the SME, and it will no doubt find general preference. The fact that the above mentioned results can be secured with but one hose line is certainly a great advantage for surface car work, and the fact that the brake applications are made automatically on each vehicle, and practically simultaneously, is an advantage over straight-air operation for trailer cars, as with small piping a certain time element must come in between the application of the brakes on the front and rear cars with straight-air, and we doubt whether two cars can be handled as smoothly with straight-air as we are now doing with this equipment.

This equipment is not recommended for use on trains of two motor cars, but in the event of its being used for that service the pump labor could be divided on the motor cars by the addition of a second hose line.

The advantages, therefore, in this equipment are particularly in the fact that two-car trains can be handled with the high factor of safety of automatic brakes, as one application after another can follow in quick succession, the auxiliary reservoirs being immediately recharged, and any rupture of the piping or breaking-in-two of the train will immediately apply the brakes on both vehicles; also by the use of the straight-air motor-release feature the train can be handled as smoothly as desired, as above described.

This equipment is the automatic brake in its simplest form, and yet at the same time designed to meet the new conditions of surface car operation in two-car trains where a lighter car is hauled behind a heavier motor car.

Equipment AMT.

Referring again to methods of operation Nos. 4 and 5, two and three-car trains, all motor cars or motor and trailers in multiple-unit-control trains. This method of operation approaches, and in fact, is train operation in the full sense of the word, and is, therefore, completely away from the necessity of any straight-air brake features as ordinarily understood, unless it would be to facilitate the handling of one of the motor cars singly, if such operation should seem to be necessary. For such a condition of operation our equipment AMT would be required.

This equipment is essentially an automatic brake and is designed for either a single pipe line or with an additional control pipe line, if desired, depending upon the operating conditions of the road on which it is to be installed.

The equipment also consists of a very simple brake valve, in the release position of which a wide open connection is made from the control line beyond the feed valve to the brake pipe, therefore securing feed-valve pressure on top of the rotary just as with the AMS equipment, preventing the overcharging of the brake pipe, and, consequently, of the auxiliary reservoirs on the front cars of the train. This particular feature cannot be made too much of as it is a very important point in connection with the handling of short trains, and especially single cars with automatic brakes; it is always essential to have a quick response of the brakes at all times, and this cannot be done with the ordinary method of having main-reservoir pressure on top of the rotary valve, especially with the quick-recharge triple valves. With this feature the flexibility and quick response incident to straight air in the application of the brakes can be secured, and this feature, in connection with the quick recharge of the auxiliary reservoirs, and also in connection with the graduated release feature, makes it possible to handle short trains with automatic brakes with a flexibility and safety not possible heretofore. The applications of the brakes are made in the regular automatic way by the reduction of pressure in the brake pipe so that the triple valve moves both in service and emergency positions.

The triple valve is of the plain type, but is arranged with a slide-valve graduating valve, which controls the graduations of the brake applications together with the graduations of the release, and also the recharge of the auxiliary reservoirs. The graduations of application of the brakes with this equipment are refined by the use of a rather small auxiliary-reservoir volume, of such size as to secure 50 lbs. equalization with five inches of piston travel, just as with the AMS equipment; but this equipment has the *graduations of the release of the brakes at the triple valve,* which the equipments heretofore mentioned do not have, and in addition to this the M-10-A Brake Valve is regularly furnished with a straight-air release position, just as with the AMS equipment, and this can be used or not as the circumstances seem to warrant, as hereinafter mentioned.

This equipment is designed for use on trains consisting of all motor cars, or with mixed motor and trailer cars, as may be desired, but the mixing up of trains with motors and trailers brings in certain changes in the specifications, so that it is important to determine the prospective method of handling trains which will most likely be the most prominent, and equip the cars accordingly. For instance, where the trains are to consist of all motor cars, it is possible to secure satisfactory results with the use of but one hose connection between the cars and at the same time divide up the pump labor in a very satisfactory manner.

With a single-pipe system on a motor-car train the pumps are absolutely independent of each other, but the pump on the head car will be required to furnish additional air to the extent of supplying the amount taken from the brake pipe in making the applications of the brakes. Other than this the pump labor will be evenly divided, and for the ordinary installation of *motor car trains* with multiple-unit control this equipment should be recommended with specifications for single-pipe system.

Where the cars have pneumatically operated doors or other devices, such as trolley catchers, etc., depending upon the main-reservoir supply being constant, it would hardly be safe to recommend the use of but the single pipe as in the event of a pump failure in the train, some special arrangements would be necessary with the single-pipe system to supply air for the doors, etc., from the brake pipe; also if the front pump failed it would be necessary for the motorman to go back to the next car having a pump in order to operate the brakes on the train, and as this is likely to bring on complications it would be more advisable to recommend the single-pipe system for use on trains of *motor* cars only that have *no other pneumatically operated devices.*

The single pipe can also be arranged for use on mixed trains of motors and trailers, but as in this event it would become necessary to add a reinforcing reservoir as part of the trailer equipment, it would perhaps be more often advisable to apply the single-pipe line only to trains of motor cars, as above mentioned.

By the addition of a second hose connection between the cars, which would serve to connect up the control pipe between them, the pump labor would be more evenly divided than with the single-pipe system, and at the same time no complications would result in the event of a failure of one of the pumps in the train, as in this case the other pumps would simply divide up the work of the idle compressor. This also applies in the event of there being other pneumatic devices on the cars, depending upon the main-reservoir supply being maintained constant.

We have mentioned these differences between the single and two-pipe systems in this paper, as it will often be necessary to work out these combinations to suit the conditions on each road, and if these points are borne in mind the best equipment for each particular condition can readily be determined upon.

The reasons for this equipment being limited to use on three-car trains regularly will readily be understood as pertaining particularly to the triple valves having no quick-action features, although the emergency-application ports are very much larger than the service ports, and the emergency application on a short train will be secured with the same rapidity as though the quick-action features were in the triples. But as the train increases in length the time element increases so rapidly that it would not be advisable to apply these plain triple valves to a longer train than three cars regularly, and possibly with some exception four cars.

Where this equipment has been used, the trains have consisted of two motor cars, weighing approximately 50,000 pounds each. The reason why this equipment was used in preference to the AMS for these two-car trains was particularly on account of being able to secure the graduation of the release of the brakes on the second car of the train instead of letting the complete release take place there, as with the AMS equipment. With both cars weighing 50,000 pounds each it will readily be appreciated that it is more necessary to continue the braking effort on the second car during the graduations of the release of the brakes in making a stop than would be the case where the second car was but half the weight of the first.

With the installations that have been made so far, the straight-air release has been installed also, but this feature was particularly designed to permit the handling of a single car with the flexibility of straight-air rather than to use it in connection with the handling of two-car trains.

The advantages in the use of this equipment are, therefore, in the quick-recharge feature of the triple valve, together with the graduated release at the triple valve, and the straight-air release at the motorman's brake valve; and with these features two and three-car trains can be handled with a smoothness that is not possible with equipment AMP, and at the same time a single car can be handled as well as with the straight-air.

With this equipment, as well as with all the other new equipments mentioned in this paper, all of the parts of the apparatus are designed to secure the lowest possible cost of maintenance and repairs; as, for instance, the triple valves are of the new pipeless design, so that they can be readily removed for inspection and cleaning without the necessity of breaking any pipe connections whatever, insuring more frequent inspection, better maintenance, and, therefore, better operating results, and the maintenance of triple valves is a very important item from a commercial standpoint.

Equipment AMQ and AMR.

Referring now to methods of operation Nos. 6 and 7, viz., four cars or more, all motor cars or motors and trailers in multiple-unit-control trains.

This is train operation, the same as the conditions just described, except that the train may be extended in length to any number of cars desired. As the trains increase in length the time of serial action increases, unless special arrangements are made in the air brake equipment to offset the length of the train.

This condition of operation would call ordinarily for the standard automatic quick-action air brakes, but the trains being electrically operated bring in new conditions as mentioned in the earlier part of this paper, and the new conditions of having each unit self-accelerating and each motor car equipped complete with compressor, brake valves, etc., made it necessary to provide for the division of pump labor and arrange to use each independent air supply on the motor cars for securing refinements in the air brake equipment not possible in steam railroad operation. Such air brake equipments are now designated as our equipments AMQ and AMR.

These two equipments are practically the same, the only difference between them being the fact that with equipment AMQ the triple valve has the brake pipe and control pipe connection made to the triple valve direct, whereas with equipment AMR the R-1 triple valves are of the pipeless variety just mentioned.

These equipments are designed for use on trains of any length, particularly, of course, on longer trains than three cars, and have all the features of quick recharge and graduated release that have just been mentioned as pertaining to equipment AMT, and have in addition the regular Westinghouse quick-action features in the triple valves and a new departure in the matter of a *Quick-Service* feature.

With these equipments the straight-air release feature at the brake valve can also be applied, if desired, as the number M-8 brake valves are intended to be designed to have this feature incorporated if it seems advisable. These equipments have a similar brake valve to the AMS and AMT equipments heretofore mentioned, with a wide open connection in release position between the control pipe and the brake pipe, with feed-valve pressure on top of the rotary to prevent overcharging of the brake pipe and to secure quick response to the brakes at all times.

These equipments are *automatic air brakes* of the *highest type* with all of the additions and refinements which the present passenger-car-train operation requires.

The particular conditions which necessitated the development of these equipments were mostly found upon the elevated railroads in this and foreign countries.

Some of the worst accidents on the elevated railroads heretofore have been due to the fact that one application after another of the brakes could not follow in quick enough succession with the standard automatic air brake equipment, and as the trains are continually being operated on closer schedule, it became apparent to our Engineering Department that some improvements were necessary, and it is certainly gratifying to know that not only this feature has been incorporated in these equipments now being described, in the matter of quick recharge of the auxiliary reservoirs, but that other and perhaps equally important features have been included. The graduations of the release of the brakes have not heretofore been possible with automatic-air-brake equipments, but with the present equipments this is possible to any degree desired. As five-pound graduations of the release can readily be secured, and as the trains can be handled smoothly with ten-pound graduations of the release, it is manifestly evident that the necessary flexibility in this respect is in these particular equipments.

The next matter of importance is the quick-service feature, which is an arrangement of ports in the triple valve to secure the use of brake-pipe pressure to aid in raising the brake-cylinder pressure in service applications of the brakes and reduce the time of serial action through the train, whereas this feature has heretofore been confined to the emergency application of the brakes only. With this feature the time of the serial action of the service application of the brakes through the train has been reduced at least half, so that longer trains can be handled with greater smoothness and facility than could be done with the former equipments. This feature also materially reduces the amount of free air required, and, of course, reduces the compressor labor proportionately.

Another feature of importance from an operating standpoint is the maintaining of a balance between the brake-pipe and auxiliary-reservoir pressures, so that a quick response of the brakes can be secured at all times. This has been found to be one of the most desirable features in this as well as the AMS and AMT equipments heretofore mentioned, as this point has been more frequently mentioned by motormen as pleasing them than any other feature, perhaps because it comes first more readily to their notice.

Another important feature in these equipments is the fact that the pump labor on the train can be uniformly divided, especially if the control pipe is connected up from vehicle to vehicle with a second hose connection. The same variation of conditions as mentioned in connection with the AMT equipment would apply to these equipments as covering the arrangement of single piping and two pipes between the cars.

All of the operating results can be secured with a single-pipe connection, but there are some complications in the matter of hauling trailers and in the event of pump failures which make it more advisable ordinarily to use two hose connections between the cars.

It has been possible to divide up the pump labor in electric-car trains heretofore fairly satisfactorily, but in order to do this it has been necessary to have a reservoir hose line from vehicle to vehicle; in addition to this a balance wire or balancing governor pipe also from car to car, except in such individual cases where we have installed our governor auxiliary control valve to save the necessity of using a balancing wire between the governors.

It is certainly a very important engineering accomplishment that all of the features above mentioned could be incorporated in one equipment, and to have *Graduated Release, Quick-Recharge of Auxiliary Reservoirs, Quick-Serial Service Application, No Overcharging of Brake Pipe, Prompt Response of Triple Valves after Full Release, Independent Operation of All Compressors in a Train, and a Single Hose Pipe only to accomplish this under ordinary conditions, is almost beyond belief.*

The most prominent installations that we have at present of these AMQ and AMR equipments are,—the complete equipment of 418 cars on the Metropolitan West-Side Elevated Railway Company, of Chicago, Illinois; and the complete equipment of about 175 cars on the electrically-operated division of the Long Island Railroad, Brooklyn, N. Y., besides trains on the Boston Elevated and the Manhattan Elevated.

Equipment ET.

Referring now to method of operation No. 8, electric locomotive hauling trains of trailers.

This method of operation is the standard for steam railroads and covers the handling of a train with a locomotive at the head end, and consequently one source of air supply. The standard automatic air brake equipment will serve for train operation of this kind for many years to come, especially as far as the cars are concerned. There are features, however, which can be added to the equipment on the locomotive requiring some changes in the ordinary standards, and such are now embodied in our equipment ET.

This equipment is distinctly for locomotives, either steam or electric, the particular features being the independent control of the brakes on the locomotives, a "Holding Position" to retain the locomotive brakes when releasing train brakes, and maintained pressure in the brake cylinders on the locomotive at whatever point desired.

This equipment was designed for use on steam locomotives, but the same conditions that made its development necessary, apply with equal force to train handling with electric locomotives. While originally designed for use with but one brake valve, we can now equip an electric locomotive with a double-end arrangement; or it is even possible to equip an articulated electric locomotive, each half with a double-end set, so that each may be operated separately at times, and all of the benefits of the equipment are secured without complications.

With this equipment on a locomotive, the highest speed passenger trains can be handled as well as freight trains, or switching can be done with equally satisfactory results.

Electro-Pneumatic System No. 3

After this description of the equipments that are each fitted to a particular condition and method of car operation, you will no doubt be interested in the details of an equipment or schedule that is the latest development in air brakes; by its use all of the above conditions can be met and, at the same time, each of the equipments heretofore mentioned can be retained on the cars or locomotives ready for instant use. This is our electro-pneumatic system No. 3.

This schedule is not, in the strict sense of the word, an "equipment," as it consists of additional devices to be used in connection with any of the equipments above mentioned.

These devices consist of electric tops for the brake valve, a 600-ohm rheostat on each vehicle from which the train brakes are operated, an additional safety valve for the brake cylinder, special switches for cutting in and out the electric side of the equipment, electric jumpers and sockets for carrying a two-line electric circuit through the train, and a special bracket on which is mounted the electric application and release magnets. To this bracket is piped the triple valve exhaust, and connection also is made to the auxiliary reservoirs. This applies to any of the equipments above mentioned.

The object of this electric equipment is to further refine the application and graduation of the release of the brakes, and at the same time secure absolutely instantaneous and uniform results on each vehicle in the train, no matter what the length of the train might be.

The electric top for the brake valve, above mentioned, is simply an arrangement of electric contacts used in the pneumatic release position of the valve. The method of operation of this equipment is as follows:

The pneumatic side of the equipment is left intact, is complete and in reserve at all times for immediate use. The electric contacts which operate the electric equipment being in full release position of the brake valve, the triples are therefore in release position and the auxiliary reservoir fully charged. Under such conditions the triple valve exhaust would be open to the atmosphere through the pipe up to the electric bracket above mentioned.

The first movement of the brake-valve handle slightly to the right closes a circuit which energizes the exhaust magnet, closing the valve in the exhaust pipe so that the exhaust is sealed to the atmosphere. This might, therefore, be termed "Electric Lap Position." The next slight movement to the right energizes the application magnet, which permits auxiliary reservoir pressure to flow into the brake cylinder *through the triple valve exhaust,* as long as the handle is kept in electric application position; but by bringing the handle back slightly to the left to electric lap position, the brake-cylinder pressure is held on all vehicles as the exhaust to the atmosphere is still sealed by the current passing through the release magnet.

The graduations of release are then made by moving the handle still farther to the left, breaking the circuit which energizes the exhaust magnet and permitting the brake-cylinder pressure to pass to the atmosphere; these graduations of application and release can be made in this manner to any degree of fineness desired.

It will readily be appreciated that all of the above mentioned operations have been accomplished without the movement of the triple valve proper, and while air has been taken out of the auxiliary reservoirs, the recharge of same has been continually taking place. Even though this schedule were used in connection with our standard automatic air brakes, there would in reality no time element be necessary to secure one application of the brakes after another as rapidly as desired, as the recharging of the auxiliary reservoir goes on continually, and would under all ordinary circumstances undoubtedly keep up with the use of the air by the electric devices in the manner described.

With the new quick-recharge equipments, however, the use of the air from the auxiliary reservoir, as described, cannot be sufficiently rapid to get ahead of the maintenance of the pressure through the brake-pipe and control-pipe feed-up ports, as we have found by experience that the auxiliary-reservoir pressure remains practically constant.

It will readily be appreciated from this description that we have practically electric straight-air on each vehicle with a uniform braking head of 70 pounds, or whatever the feed-valve pressure is arranged for.

It will be noted, therefore, in connection with the electric operation of the Pneumatic Brake, as above described, that we have gone far beyond anything heretofore possible with straight-air. There is absolutely no time element whatever in serial action from vehicle to vehicle, as the same results are being accomplished at each brake cylinder throughout the train simultaneously.

As an illustration of this point and the use of this flexibility, we might report just here that the operation of train "A," as we call it, on the Boston Elevated, on which this electric schedule is being used in connection with equipment AMR, the electric side of the equipment being used continually, is undoubtedly the most satisfactory in every way of any train now being run in the United States. The stops are as short in total time from the initial application of the brakes to the time the train is at rest, and at the same time the break away from maximum acceleration is smoother than possible with any automatic equipment. This statement would seem to be an anomaly, as it would at first glance appear that if we started the stop slowly and had a uniform deceleration that the time of making the stop would be increased. We find that while the electric-application valves are arranged with rather small ports, so that the initial pressure is secured slowly, this is offset by the fact that there is absolutely no time of serial action necessary, and, therefore, the total pressure in all of the cars is really being delivered in a shorter space of time than with the ordinary Pneumatic Automatic Brakes. The base of the deceleration curve is as short, if not shorter, than with automatic brakes, and by the use of the refinement of graduations above mentioned we were able to secure a curve that is practically a straight line, as the brake-cylinder pressures can be kept in the exact ratio of the decrease in speed and the resulting increase in the co-efficient of friction.

These points are well illustrated on a series of charts and blueprints, which can be secured from our Engineering Department, by application.

A further and perhaps just as important operating advantage of this equipment, which is, of course, a commercial advantage as it is an economical feature, is the fact that the amount of air used in operating the brakes is very much less than with any other equipment, even the Straight-Air. This point will readily be appreciated when it is remembered that a direct connection is made from the auxiliary reservoir to the brake cylinder by the electric valves without having been obliged to make any brake-pipe reduction or other waste of air to secure a brake application; and as these electric valves are of rather small portage, as above described, the possibility of too much air being used is reduced to a minimum. It is not too much to say that with the ordinary motorman the amount of air can readily be reduced to 50% of what is ordinarily required with automatic brakes.

The saving over Straight-Air is also considerable as it is ordinarily necessary to fill the pipes from the brake valves through the train and to the cylinders during each application, and this is avoided in the manner above described.

Another great advantage of this electric addition to automatic equipments is the fact that we find in practice very uniform and satisfactory results can be secured with inexperienced motormen. The reason for this will readily be appreciated when it is called to your attention that the movement of the brake-valve handle to secure the electric operation of the brakes covers but a very small range, and, therefore, the graduations are readily secured; and whatever is aimed at by the motorman for one car is secured on all the vehicles at the same time. The movement of the brake-valve handle, and the *time for permitting it to remain in one position is the same for any length of train,* so that the element of judgment necessary for the motorman to have with other equipments is almost entirely eliminated by the use of the electrically-operated brakes.

It is our belief, therefore, with the advantages above described, as well as others which might be mentioned, the electrically-operated pneumatic brakes have come to stay, especially with electrically-operated roads running trains of varying lengths. The additional electric apparatus necessary to secure these results do not stand in the way of its adoption, as electric-railroad officials are familiar with more complicated devices for every-day use; whereas with the steam railroads, it may be a longer time before it will be used to any extent.

With this electric equipment there are some additional refinements which will no doubt be developed when the adoption of it becomes more general; these will relate to the operating of the brakes on trains of motor cars entirely electrically so as to avoid having hose connections between the cars, and thus saving some expense. But the tendency is at present, and perhaps for some years will be, to have the pneumatic automatic brake complete back of the electric, ready for immediate use, as is at present intended and above described, since all that would be necessary to secure an application of the brakes in the event of a failure in the electric current, would simply be to move the brake-valve handle further around to the right, to regular automatic service or emergency position and the triple valves would immediately operate in the ordinary manner. In event of a continued failure of the electric brakes, through the loss of a rheostat or other device, the run or even the day's run could be completed by the use of the pneumatic brakes on the train as at present.

We shall also see developed an automatic arrangement for securing proper deceleration without the use of any judgment whatever on the part of the motorman, just as is now done with the automatic acceleration secured by the use of the multiple unit control.

Another refinement will relate to the equal division of pump labor on trains with single-hose connections between the cars. These features are certainly possible and quite probable, and we shall no doubt see them developed by our Engineering Department at no very distant date.

It has been the purpose of this paper to illustrate the conditions as we now find them on electrically operated properties, and to make it plain that our Company, through the Commercial and Engineering Departments, has left no stone unturned to meet, or at least be prepared to meet, every exigency of the situation, and we are now prepared to furnish air brakes to secure the best results, no matter what sort of an operating proposition is put to us.

Respectfully submitted,

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Western Manager The Westinghouse Air Brake Co.

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