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"BRAKES FOR LONG GOODS TRAINS."

BY

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In a former paper the Author endeavoured to place in outline before the members of this Society the principal problems involved in the design of a successful brake for a modern express passenger train together with some of the methods which have been adopted of solving them. In the present paper he proposes to deal, on somewhat similar lines, with the braking of a long train of goods wagons.

The provision of a satisfactory brake for such a train involves the overcoming of certain difficulties which are absent in the case of a passenger train. These are due principally to the great length of the former, the variation in the weights of the vehicles composing it and the impossibility of securing really tight couplings.

The functions of a brake on a goods train are threefold. It is required, firstly to pull the train up at stopping places and at any signals which may be at danger, secondly to enable shunting operations to be performed and, thirdly, to control the train on banks.

The satisfactory performance of these functions involves the following considerations:—

When pulling up the train at stopping places it should be brought to rest smoothly and without shocks likely to damage any of the wagons or their contents or to cause serious discomfort to the guard or engine crew. This, of course, also holds good when stopping at a signal but, for the latter class of stop, the brake should also be sufficiently powerful to enable the train to be run at a reasonable speed without fear of over-running the home signal should a "distant" be sighted at danger.

In shunting, the brake should be capable of being applied quickly, but without setting up undue shocks and, particularly, of being released quickly. Much time will certainly be lost if the driver has to wait long for the brakes to be released between each movement.

To control a train satisfactorily when descending a long bank the brake should be capable of being readily applied and released to any desired extent. By these means a constant scheduled speed can be maintained throughout.

But the function of the brake on banks is not only to control the speed when *descending*, but also to prevent the rear portion from running away should a coupling break when *ascending*. To do this the brake should be instantly applied and must be sufficiently powerful to hold any portion of the train which may break away.

To recapitulate briefly, an ideal brake for the class of train under consideration would be continuous, would stop the train without shocks and in a, minimum distance, would be capable of being applied and released quickly and to any desired extent, and would apply itself instantly in case of the trains parting.

How far these requirements are met with in the systems which have been devised will now be considered.

The oldest, simplest and cheapest system and the one most commonly met with in this country consists of a steam or other form of power brake on the engine, hand brakes on the wagons applied by means of levers at the side and a brake van fitted with a hand brake, at the rear of the train, in which the guard rides. A variant on this consists of having certain wagons, interspersed among the others, fitted with hand brakes applied by means of a wheel and screw operated from a caboose attached to the wagon in which a brakesman rides. This latter system is commonly employed on the Continent.

This type of brake will give rise to no dangerous shocks if properly handled, but is not suitable for making very quick stops, as the brakes can be applied on the engine and brake van only when running. It is not possible, therefore, to run a train of this kind at any speed.

A train of 60 loaded goods wagons will weigh, with engine and van, about 720 tons. The brakes on the two latter vehicles will exert a retarding force on the whole train of something like 1.1 %. Now on the level distant signals are usually placed 800 yards from the home. Allowing 400 yards sighting margin under average circumstances, should a distant signal be sighted at danger, it will be necessary to stop the train in 1,200 yards if the home signal is not to be overrun. To do this with 1.1 % retarding force the speed must not exceed 34.5 miles per hour. This then is the maximum speed at which such a train can be run on the level.

The type of brake under consideration is, however, quite suitable for shunting as the engine brake, which alone is used then, is quite powerful enough for the purpose and can be applied and released quickly.

When descending a bank the train has to be stopped at the top, where the guard pins down a sufficient number of wagon brakes to enable the train to descend in safety, and again at the bottom where they are unpinned.

This is unsatisfactory for several reasons. In the first place much delay is caused in stopping the train and putting down and taking up the brakes at the top and bottom of the bank respectively. In the second very little graduation is available as this can only be brought about by applying and releasing the brakes on the engine and brake-van. In the third, should the train attain too great a speed the brakes will not be able to hold it and it will run away, as the higher the speed the less the retarding effect of the brakes and, once the train is away at any speed, no more brakes can be put down. To avoid this it is necessary to make quite sure that enough brakes are down before starting and to descend the bank very slowly. This not only means delay, but may mean that steam has to be put on to pull the train over the less steep portions.

Should the train part when ascending a bank without a bank engine at the rear only the brake van is available for holding the broken away portion. The load which a brake van will hold varies, of course, with the weight of the van and the gradient. On a bank of 1 in 100 a 25-ton van will hold a load of approximately 840 tons and a 10-ton van one of about 450 tons. These loads may be taken as equivalent to 55 and 30 loaded coal wagons or 84 and 45 loaded goods wagons or 168 and 90 empties respectively. When deciding the maximum load of a train over a given road, therefore, not only must the tractive power of the engine be taken into consideration, but also the holding power of the van. Moreover, although the van will hold a given number of wagons at rest or stop them when moving very slowly, it will be powerless to do so should they be running at any speed. It is necessary, therefore, should the load approach the maximum for the van, for the guard to be on the alert and apply the brake immediately should a breakaway occur before the wagons have time to start running back at any speed.

This type of brake, therefore, while it has the advantages of being simple and cheap and requiring a minimum of upkeep has also the disadvantages that only a low running speed is possible, that much time and trouble are expended when descending banks with it and that the load which can be taken up a bank is limited not only by the engine but by the brake-van.

Continuous brakes are of two kinds, pressure and vacuum. The principles upon which these brakes work were described by the Author in his former paper above referred to. As, however, it is necessary that these principles should be fully grasped before it is possible to understand any discussion of the application of these brakes to goods trains it is, in his opinion, advisable, even at the risk of wearying some of his hearers, to repeat that description here.

The best known and most widely used compressed air brake is that manufactured by the "Westinghouse Brake Company." The "New York" air brake is, however, used to some extent in America, and the "Knorr" air brake in Germany. The principle of all these brakes is the same, they differ only in minor details.

There is a greater variety of brakes employing atmospheric pressure, commonly known as "Vacuum" brakes, but here again they differ only in details, the principle being the same. The best known type of vacuum brake is that manufactured by the "Vacuum Brake Company."

In compressed air brakes a steam pump is provided on the engine by means of which air is compressed into a large reservoir, known as the "Main Reservoir," to a pressure of about 90 lbs. per square inch. From this reservoir it is admitted, by means of a valve actuated by the driver, at a reduced pressure, usually about 70 lbs. per square inch, to a pipe running the whole length of the train, and known as the "Train Pipe." On each vehicle there is a small reservoir, known as an "Auxiliary Reservoir," a cylinder, the piston of which is connected, through a suitable system of rods and levers, with the brake blocks, and a valve, known as the "Triple Valve," in connection with the train pipe, reservoir and brake cylinder.

When air is admitted to the train pipe it so actuates the triple valve on each vehicle that air can flow from the train pipe to the auxiliary reservoirs, the brake cylinders being at the same time put into communication with the atmosphere. There is thus on each vehicle a store of compressed air at about 70 lbs. per square inch (apart from that contained in the train pipe) and, there being no pressure in the brake cylinders, the brakes are off. This condition is maintained as long as the train is running, the pressure in the train pipe being maintained by allowing sufficient air to be admitted to it from the main reservoir to make up for any lost by leakage, while that in the main reservoir is maintained by means of the pump.

When it is desired to apply the brakes, the driver so manipulates his valve as to cut off all communication between the main reservoir and the train pipe, and to allow air to escape from the latter to the atmosphere. This has the effect of reducing the pressure in the train pipe to a given extent according to the amount allowed to escape and the length of the train. The reduction of train pipe pressure so actuates the triple valves that all communication between train pipe and auxiliary reservoirs and between brake cylinders and atmosphere is cut off, and, at the same time, air is allowed to flow from the reservoir to the cylinders until the pressure in the former is reduced to that in the train pipe. The pressure thus produced on the pistons applies the brake. When a reduction of pressure of from 20 to 25 lbs. per square inch is made in the train pipe, the pressure in the auxiliary reservoirs and brake cylinders is equalised, and the brakes are consequently applied with their maximum force.

To release the brakes air is re-admitted from the main reservoir to the train pipe, thus restoring its pressure. This puts the triple valves into their original state, the auxiliary reservoirs are recharged to full pressure and the air in the brake cylinders is allowed to escape into the atmosphere, thus releasing the brakes.

In each brake van there is a cock by means of which the guard can allow air to escape from the train pipe, thus applying the brakes.

Should a train break away or should the train pipe burst or become broken in any way, all the air will, of course, escape from it, thus applying the brakes with full force.

In vacuum brakes, a vacuum of about 20 inches of mercury is created in the train pipe by means of an "Ejector" on the engine. This apparatus extracts air from the train pipe in the same way as the blast pipe and chimney extract it from the smoke box of a locomotive. On each vehicle is a cylinder, the piston of which is suitably connected to the brake blocks. The cylinder is in connection with the train pipe on both sides of this piston, on one side directly, on the other, through the medium of a non-return valve which is so arranged that air can flow freely from cylinder to train pipe, but cannot flow in the opposite direction, from train pipe to cylinder. The same vacuum is thus produced in the cylinder on both sides of the piston, as in the train pipe.

When running, the vacuum is maintained against leakage by means of a small ejector of similar design to the large one used for creating it, or, in some cases, by means of a pump driven from the cross-head of the engine.

When it is desired to apply the brakes, the driver admits air to the train pipe thus reducing the vacuum by an amount depending on the quantity of air admitted and the length of train. The air which is admitted to the train pipe flows freely into the cylinder on one side of the piston, thus reducing the vacuum therein to an amount similar to that in the train pipe. On the other side, however, the entrance of air is stopped by the non-return valve, and the vacuum on that side of the piston is maintained. There being thus a difference of pressure on the two sides of the piston it is drawn towards the side of least pressure thus applying the brakes with a force proportional to the amount by which the train pipe vacuum is reduced. To apply the brakes with their maximum force, the vacuum must be completely destroyed.

To release the brakes the vacuum is recreated, thus again putting the pistons in equilibrium.

In each brake van there is a valve by means of which the guard can admit air to the train pipe, thus applying the brakes.

Should a train break away or should the train pipe become broken in any way the vacuum will be completely destroyed and the brakes applied with full force.

Such then are the main outlines of the operation of pressure and vacuum brakes respectively. Pressure brakes carry a supply of compressed air on each vehicle, which, when the brakes are to be applied, is allowed to flow into the brake cylinder, while, with vacuum brakes, a vacuum is normally maintained on both sides of the brake piston and the brakes applied by reducing or destroying it on one side only.

Neither of these brakes in its ordinary form, as generally used on passenger trains in this country is suitable for long goods trains. Air is admitted to, or released from, the train pipe at the engine and some time is necessary for the action to pass along the train. The brakes at the front of the train will thus be applied before those at the rear. With a short train of tight coupled vehicles this does not give rise to any ill effects, but with a long loose coupled train a sudden heavy application would cause the brakes on the front portion of the train to be applied with so much force before those on the rear portion had begun to act at all that the latter portion would run violently into the former, setting up very dangerous shocks and possibly causing derailment. These shocks might also be accentuated by unequal brake power on different vehicles due to some being loaded and some unloaded.

Another difficulty is that of maintaining the pressure or vacuum. Not only does the large number of vehicles of which a long goods train is composed increase the amount of leakage, but this is considerably added to by the fact that it is impossible, at any rate under the conditions obtaining on British railways, to give the same attention to goods wagons as is given to passenger coaches. As a result the former will, on the average, be in a decidedly worse state of repair than the latter. This difficulty is particularly apparent in the case of vacuum brakes as these are more affected by leaks than the pressure variety.

Modified forms of both brakes have, however, been constructed and special trials made successfully on trains up to 100 wagons, but so far as the Author is aware, in no case have they been tried with the couplings as loose as those ordinarily used on English goods trains. Also, so far as he is aware, on no railway are really long trains of this kind fitted with a continuous brake throughout regularly running in ordinary service under the conditions obtaining on British Railways.

It is impossible, under ordinary circumstances, to give a goods wagon the full brake power required when loaded, as this would be much too high when it was unloaded and would lead to skidding of the wheels. The proper brake block pressure for any vehicle is about 80 % of the weight on the braked wheels. The tare of a 10 ton goods or coal wagon may be taken as about 6 tons. The goods wagon, when loaded, will usually carry about 4 tons, and the coal wagon 10 tons. The total weight of a loaded goods wagon is thus about 10 tons and the proper brake block pressure 8 tons, which is nearly 135 % of the weight of the empty wagon. It is usual to compromise by adopting about 100 % of the tare weight. This will amount to about 60 % of the weight of the loaded goods and 37 % of that of a loaded coal wagon.

Where, however, wagons are employed on a regular route and are consistently run loaded in one direction and unloaded in the other, it is possible to increase the working pressure or vacuum when hauling the loaded and decrease it when hauling the unloaded wagons.

Means have also been devised whereby an extra brake cylinder may be put into action when the wagon is loaded and cut out when it is unloaded and also for rapidly altering the leverage of the brake rigging. These, however, all add complications to the brake gear and are not very widely used.

Let us now consider the principle continuous brake systems which have been devised and tried for the purpose under consideration.

The main features of the "Westinghouse Brake Company's" design of pressure brake, which has been tried in Hungary and France, are as follows. The apparatus installed for running on the level is similar to that of the latest type of Westinghouse brake, as used on passenger trains. The special feature of this brake is the triple valve the action of which is as follows. When an application is made air is first admitted rapidly to the cylinder until a pressure of about 10 lbs. per square inch is attained. At the same time air is admitted from the train pipe into a small reservoir thus making a sudden light reduction of pressure and so rapidly propagating the action down the train. When a pressure of about 10 lbs. per square inch is attained in the cylinder a spring loaded valve closes and the subsequent filling up of the cylinder takes place much more slowly. By this means the blocks are rapidly brought up to the wheels and during the subsequent increase of pressure in the cylinders there is never any very great difference between the pressure in the first and that in the last vehicle of the train.

For descending long banks the vehicles are also fitted with the "Non Automatic Control." This consists of a second line of piping which is connected to the exhaust ports of the triple valves.

When descending a bank the ends of this pipe are closed. As soon as the speed requires checking a moderate application of the brake is first made in the usual way. After a time the driver's handle is put into the release position and the auxiliary reservoirs are recharged, the air from the brake cylinders being discharged into the closed auxiliary pipe, and air also admitted to it at the same time from the main reservoir. The regulation of the brake is subsequently effected by varying the pressure in the auxiliary pipe by admitting air direct from the main reservoir or discharging it into the atmosphere by means of a special valve on the engine.

The brake is operated to the rear end of the train, vehicles not fitted with brake cylinders being piped so as to allow the brake action to be propagated to any braked vehicles behind them.

A train pipe indicator is provided for ascertaining that all the couplings through the train are properly connected up and all cocks, with the exception of the end cock, open. This consists of a piece of apparatus so arranged that, after the train pipe has been cut off from the auxiliary reservoirs by the triple valves being brought into application position, the pressure in the train pipe is reduced by means of a reducing valve to 50 lbs. per square inch. By turning a cock the train pipe is then connected to a measuring reservoir containing only air at atmospheric pressure. When equalisation has taken place the pressure then existing in the measuring reservoir has a definite relation to the length of the train pipe connected to the engine and this length is indicated on a properly marked gauge attached to the reservoir.

The Vacuum Brake Company also have a design of brake for the same purpose. It has been tried in Austria and France. In this brake the working vacuum is 35 c.m. or about 13¾ inches. The brake is operated to the rear end of the train, vehicles not fitted with brake cylinders being piped. On each vehicle, whether braked or piped only, a "rapid acting valve" is fitted which opens to admit air to the train pipe and remains open for two and a half seconds. Between the train pipe and cylinder on each vehicle is a special non-return valve, so constructed as to allow the cylinder to be exhausted freely but to restrict the passage of air entering from the train pipe. A special portable valve is attached to the last vehicle of the train.

In making ordinary stops these valves are not operated, all the air used in controlling the train being admitted from the driver's valve. When it is required to stop specially quickly the driver's handle is put suddenly into its extreme position. This causes a rush of air to enter the train pipe and the rapid acting valve on the first vehicle is lifted and so causes a further admission of air which operates the next valve and so on throughout the train. By this means the vacuum in the train pipe is completely and practically instantaneously destroyed. At the end of 2½ seconds, however, the valves close and the air in the train pipe penetrating into the cylinders through the restricted aperture partially applies the brake, at the same time reforming a partial vacuum in the train pipe. At this moment the portable valve at the rear of the train opens and a return rapid action takes place from back to front. Any tendency to bunch the train during the first rapid action is thus counteracted by a tendency to stretch it during the second.

The portable valve also affords a convenient means of ascertaining if the brake is properly connected up throughout the train. When a vacuum is created and the driver's handle put into the full application position and immediately afterwards back into release position the needle of the train pipe gauge will first fall to zero and then rise again. If the brake is properly coupled up and in proper working order the return rapid action will take place on the opening of the portable valve and, on this reaching the engine the needle will again fall to zero thus giving the driver an unmistakable indication that all is well with the brake.

In 1919 Sir Henry Fowler and Mr. Gresley made some successful experiments with trains up to 101 vehicles. Each vehicle was braked and fitted with an accelerating valve and the passages between the train pipe and the cylinders were restricted so as to prevent a too rapid rise of pressure in the cylinder, but no provision was made for quickly exhausting the latter. Screw couplings were used and all the wagons were put into good order before the trials. It was found that 20″ of vacuum could be maintained, though with difficulty, and trials were also made with 16″.

On the G.W.R. a number of goods trains partially fitted with the vacuum brake have been running since 1905, the number of vacuum fitted vehicles not exceeding 35. No piped vehicles and no accelerating valves are used, but each vehicle is fitted with what is known as a "Moderating Valve." This is similar in action to the non-return valve used by the Vacuum Brake Company, that is, it opens to allow air to flow freely from the cylinders to the train pipe, but restricts the flow in the opposite direction. Some vacuum fitted wagons have screw couplings but the majority are fitted with the "Instanter" coupling. This is a three link coupling, the middle link of which is of special construction. It is in the form of an isosceles triangle, each side of which is looped outwards where it joins the base. When one of the adjacent links is pulling on one end of the base and the other on the apex the coupling gives a distance of about 7″ between the buffers, and is approximately the same length as an ordinary three link coupling. The middle link can, however, be readily turned so that its apex is downwards, the adjacent links pulling on each end of the base. The distance between the buffers is then only about $1\frac{3}{4}$″.

In pulling up the train at stopping places and signals all the above systems will do so without undue shock and in considerably less distance than the hand brake system first described. The actual distance will, of course, depend not only on the speed but on the proportion of braked to unbraked wagons.

In shunting the Westinghouse brake has the advantage of being much more quickly released than the vacuum systems.

With all continuous brakes shunting is usually complicated by the necessity for using screw connections, but with the "Instanter" coupling referred to above, coupling and uncoupling is almost as simple as with the ordinary three link connection.

The "Non Automatic Control," used with the Westinghouse brake for descending banks, is an additional complication which is not present in vacuum brakes. It has the advantage, however, of being positive in its action while vacuum brakes depend for their continued efficiency on the tightness of the chambers above the pistons. It would, of course, be possible to apply a non-automatic control to a vacuum brake, but this has not been thought necessary. To descend a long bank with a heavy train with the ordinary Westinghouse brake without the non-automatic feature is possible, but by no means easy, as the brake has to be released completely or not at all. Also each application takes a certain amount of air out of the auxiliary reservoirs and, unless time is allowed when releasing the brakes for them to be properly recharged, the power at disposal will be gradually dissipated. With vacuum brakes the source of power is never diminished except by leakage.

All brakes which are continuous throughout will apply themselves in the event of a break-away, and so prevent the back portion of the train from running back should this occur when ascending a bank.

The brake in use on the G.W.R. not being continuous throughout, will not do this, but the brake van need only have sufficient power to hold the unbraked wagons and not the whole train. This brake, however, although less perfect in this respect than those of the Vacuum and Westinghouse Companies described above, is well suited to ordinary working conditions as the unbraked portion of the train can be made up with any wagons on hand. It has, moreover, been in regular every-day use for nearly 20 years.

It will be seen from what has been said that the braking of long goods trains is, in practice, a long way behind that of passenger trains and that no complete continuous brake is in regular service on trains of this description under the conditions obtaining in this country. If any members of this Society contemplate specialising in brake work they will find ample scope for their talents in the development and perfecting of such a brake.

DISCUSSION.

In opening the discussion, the Chairman said they had listened to a paper which had been extremely interesting and which certainly kept up the Author's reputation. He had been dealing with a very interesting subject and one which was bound to come more to the fore as time went on. This problem of continuous brakes on goods trains would have to be faced on account of the tendency towards increased loads and speeds, evidence of which can be found in the way that distant signals were creeping further out and this could be seen quite near to Swindon. With the brakes at present in use safe working is maintained at the expense of long occupation of the lines over a given section. They had also to face the prospect that at any time the provision of continuous brakes on goods trains might be forced by law. He believed the Great Northern Railway claimed to be the pioneers of vacuum braked goods trains. He would be interested to know, approximately, the extent to which Westinghouse brake fitted goods trains were being operated in this country. The Author spoke of a 25-ton brake van capable of holding 840 tons. He would like to know whether that figure was based on a dry rail or if it was a figure which in practice would have to be taken as considerably less. He was pleased to see an old member and former secretary with them that evening. He believed he was engaged on one of the lines in India and it would be interesting to know his experience particularly as the Indian Railways were advertised by the Vacuum Brake Company as pioneers of completely braked vacuum trains.

Mr. W. H. Pearce said the Author had spoken of the "best known" brakes, but he had not said which was the "best." Of course, the best known were the Vacuum and the Westinghouse brakes. Could he give them any figures to show whether the G.W. type vacuum brake might possibly be considered the "best" if not the "best known"? The Author mentioned quick release as being one of the advantages of the Westinghouse brake. On the G.W.R. the period of release varied with different classes of engines. The larger engines were fitted with the four cone ejector while the smaller ones had only ordinary ejectors. On a train of 35 vacuum fitted vehicles the former was a great advantage. Nevertheless they were not allowed to increase the number of vacuum fitted vehicles when the better type of ejector was available. Could not the smaller engines be fitted with more powerful ejectors?

Mr. G. Ferguson said he was there that evening more or less a stranger to most of them, although he was known to some. In a few days he was going back to the Locomotive and Carriage Department of one of the Indian Railways. Over there the tendency was to increase the power of the locomotives in order to deal with the existing loads, but as soon as more powerful engines were available the Traffic Department still further increased the loads. They had a large number of powerful locomotives, but the question of brakes had not been properly considered. It had therefore given him great pleasure to listen to the Author's paper. He supposed that any discussion on the braking of long goods trains should have the effect of arriving at a better system or method of affecting such braking. He would suggest that they of the Indian Railways had nothing to teach, but everything to learn. The Author was an expert and he felt diffident about making any suggestions. He would mention, however, that there was in India a body known as the "Railway Conference Association." This comprised representatives selected from the various Railway Companies, and each representative had so many votes according to the number of miles of railway his company owned. It was the duty of this Association definitely to decide on what fittings should be adopted throughout India, both for broad gauge and metre gauge railways, and the decision of the Association was final and binding on all Railways throughout India. Thus, in place of having two or more brakes, as in England, in India there was one only so that, when a wagon came from one line to another, not only were the carriage examiners familiar with the brake, but the guards were also familiar with its working. Another point was that, on the metre gauge railways they had central couplings and buffers. The advantage of this was that all the wagons were closely coupled together and there was no space between the buffers. Thus the bunching and damage to headstocks which occurred when wagons were loosely coupled and the brakes were applied quickly were eliminated. Also there was no tendency to derail. He thought it would be an advantage if there was a similar body in England to decide on the standardisation of all fittings which could be put on all new stock coming along, if not on old stock.

Mr. C. T. Cuss said that while listening to the paper, he was struck with the great similarity between the problems the Author had been relating, and those written about between 50 and 60 years ago, which looked as though they had not made all the progress they might have hoped to do. It occurred to him that with the bicycle, which was of quite recent origin—within the memory of most of them—there had been considerable progress in braking. On the old bone-shaker the brake consisted of a handle and a piece of whipcord. Before getting to a hill the handle was wound a little way and a lever thus brought into contact with the iron tyre. Then came solid rubber tyres and the brake was applied in a similar way, as was also the case at first with pneumatic tyres. After a while it was seen that this led to waste of rubber and the point of application of the brake was changed from the top of the tyre to the inside of the rim and generally speaking it was there to-day, except, of course, in the case of motor-cycles. On railways the brake consisted of a cast iron block applied to the tyre 50 or 60 years ago, and much the same sort of thing is used to-day. He would like to know how much the stress on the frames of the engine caused by the brake blocks was responsible for cracks in the tops of the horn blocks. In the "Railway Gazette" for October 31st there was an account of a departure from the ordinary run of brakes, which was in use on the German State Railways. This was a roller brake, giving side contact on the tyres, and was intended to check trains running down gradients at certain spots and to regulate speeds. He would like to know the Author's opinion of it. It seemed to him that it was rather time a little departure was made experimentally to see if it was not possible to brake on the sides of tyres instead of on the periphery, which should have several advantages. Did the Author think there was any prospect of working in that direction?

Mr. A. W. J. Dymond referred to the question of shunting operations with continuous brakes, and asked for details of the coupling and uncoupling of the train pipes and whether any question of loss of time occurred due to this operation. He asked also whether knocking off was possible, i.e., detaching the vehicle from the train with the brake off and sending it down the line by the impetus from the remainder of the train. Also, could the Author give them any indication of the difference of time of application on the first and last coaches of a long passenger train? He also asked whether it would be possible to apply brakes on wheels by means of internal pressure on a drum, as in motor-cycle practice.

Replying to the Chairman's question regarding the proportion of Westinghouse brakes used in this country, the Author said that, as far as he knew, there were no goods trains running with the Westinghouse brake fitted. The N.E. Railway, which was a regular Westinghouse line, but was becoming a vacuum one at the time of the Grouping, and the. G.E., which was a Westinghouse line, both ran vacuum goods trains. The two great lines for running continuous braked goods trains were the G.W. and the G.N., and both were vacuum. With regard to the holding power of brake vans, he said that the figure he quoted was based on actual experiments made, with a margin allowed for safety. The trials were made on a dry rail, but goods brake vans were provided with a sand box and sand pipes so that in case of a slippery rail sand could always be used. In reply to Mr. Pearce he said that with regard to which was the best brake, that might be a matter of opinion. He supposed that if a representative of the Vacuum Brake Company, for instance, were asked he would have little difficulty in answering that question to his satisfaction. He (the Author) might say, however, in his experience, when the G.W. Vacuum Brake had been tried or compared in any way with other vacuum brakes, it had always come out on top. With regard to ejectors, he said they had, broadly speaking, two kinds—the four cone and the old standard, and the four cone was much more powerful than the other. If a driver had a leaky train and the pump would not keep the brake off, he had to keep it off by using the ejector, either continuously or at intervals. On engines having a No. 4 or smaller boiler, using the four cone ejector in this way would be rather a heavy strain on it. They were, however, experimenting with quite a new type of ejector, in which three cones could be operated separately from the fourth. With that ejector all four cones could be used when it was required to create a vacuum quickly, but if the pump was not up to its work, the vacuum could be maintained with one cone.* This ejector, he thought, might profitably be fitted on some of the smaller boilers. He was very interested in what Mr. Ferguson had said, and quite agreed that having one uniform brake was a great advantage. Many years ago, when the Board of Trade laid down that every passenger train was to be fitted with continuous automatic brakes, and after experimenting with several types, finally decided either the Vacuum or the Westinghouse must be used, he thought it was a great pity that they did not make one or the other of these compulsory. It looked as if continuous brakes on goods trains in this country, however, would be entirely vacuum. With regard to central couplings, these were, of course, a great advantage, and he wished they had the same sort of coupling here. There were, however, a good many wagons belonging to private companies in use, and it would be a big thing to convert them all. If only new wagons were fitted it would be a long time before these formed any appreciable proportion of the whole.

Replying to Mr. Cuss, he said that he believed that 50 years ago wooden brake blocks were used almost universally, not cast iron. With regard to stresses due to the brakes, he would not like to say whether any damage such as cracked frames had ever arisen from this cause. One difficulty, however, had been found with brakes on engines, and that was a tendency to loosen the driving tyres. On the Austrian State Railways, where they had long and steep banks to deal with, the engine brakes were only applied in case of emergency, the ordinary braking being done on the train. With regard to the roller brakes described in the "Railway Gazette," the arrangement was not used for controlling trains on the road, but was a Hump yard installation.

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*The new type of ejector, here referred to, has since been adopted as standard.

He should think it would be very expensive to fit, but would not like to express any opinion as to whether it was worth the money or not. With regard to brakes acting on the sides of the tyres, he did not at the moment see any objection to them, but if anyone began to work out the details he might run up against difficulties. With an inside cylinder engine, for instance, he might find some of the gear fouling the connecting rods. But still, it was a point which might be considered. With regard to wear on tyres, he did not think that the brake blocks were responsible for very much. He thought that if the unbraked leading wheel of a 2-4-0 engine were examined it would be found that the tyre was not worn appreciably less than, say, the tyres of the tender wheels.

Regarding the question of the time taken for propagating the braking action down the train, he said that on a train of 10 70ft. coaches, the brake was completely on in about eight seconds from the time of moving the ejector handle. With the brake adopted for long goods trains by the Vacuum Brake Company, he believed the action was propagated down the train almost instantaneously. Of course, the brake was not completely on until some time after the last valve had lifted. As to the time for releasing the brake, he was afraid he could not give any figures for that. It depended on the ejector used. Slow release was one of the weak points of the vacuum brake.

In reply to Mr. Dymond's question regarding brake drums, he said the same point had been raised in the discussion of his last paper. It might be difficult to squeeze the drum in on an engine, but on a carriage or a wagon the only objection he could see was the additional cost.

Mr. F. B. Morris said he would like to know how the accelerating valves used by the Vacuum Brake Company were made to close in 2½ seconds, also what was the advantage of the portable valve referred to on long trains? There was also another question. The Author referred to adjusting the brake power according to whether the train was loaded or empty. How was this brought about? Was it done by altering the working vacuum?

Replying to Mr. Morris regarding the closing of the accelerating valves in 2½ seconds, the Author explained the method by means of a diagram on the blackboard. With regard to the portable valve, the Vacuum Brake Company's claim was that if a brake application were made from the front of the train, however quick the action, the brakes were applied on the front of the train before they were at the rear, and bunching was bound to result. Their aim was to apply the brake from the front of the train at half power and then apply the other half power from the back, so that any bunching effect would only be at half power and would afterwards be neutralised by an equal stretching effect. He was rather doubtful as to the necessity of this, as he was present at trials in Hungary on goods trains up to 100 wagons with the Westinghouse brake, which had no such arrangement, and the stops were quite as smooth as those made with the vacuum Brake Company's brake. Regarding empty and loaded trains, he said he believed that altering the amount of vacuum for the whole train had not been done, but it would be quite possible. With vacuum-braked stock the usual method was to cut in an extra cylinder when the wagon was loaded. Another method was to alter the leverage of the brake gear. The Westinghouse Brake Company effected the change by having two governors so that, when working with a loaded train, the reservoir pressure was maintained at 120 lbs., and when working with an empty train on,e governor was switched out and another in and the pressure was maintained at 90 lbs.

Mr. H. G. Kerry said that the Author had referred to the difficulty of controlling a train down a long bank with the ordinary Westinghouse brake. He assumed this was due to leakage from the cylinders and reservoirs dissipating the whole of the pressure.

Replying to Mr. Kerry, the Author said that the trouble was not due to leakage, but to the use of air when applying the brake without sufficient time being allowed when releasing to recharge the auxiliary reservoirs. As these could only be recharged while the brake was released if sufficient time were allowed the train would attain too high a speed.

Mr. W. H. Pearce said that the Author had spoken favourably of central couplings, but he rather saw difficulties there. Would they not limit the maximum load, especially the starting load of which G.W. engines were capable to-day? It was usual to take 120 trucks, but if all were close coupled with central couplings the difficulty would be considerable.

Replying to Mr. Pearce, the Author said that gentleman was better qualified than himself to say how much this would limit the starting effect. He (the Author) was only speaking from a braking point of view.

Mr. E. H. Gooderson said he thought it would be a good thing if the brake block could be kept off the tyres. When going down an incline a great deal of heat was generated by the brake block rubbing on the tyre.

The Author said that no doubt heat was generated in this way, but he did not remember ever having heard of any bad case of heating of carriage or tender tyres, except when a brake had been dragging for a long time. The only trouble he had heard of was with driving wheel tyres which were sometimes loosened from this cause.

Mr. Cuss said that in a recent accident they read of a tyre rolling a long distance across a field, and he understood that this tyre was secured to the rim by bolts. This surprised him very much because so much attention had been given to the problem of securing tyres to wheels by shrinking them on and employing a fastening, so arranged that, if a tyre broke, it could not leave the wheel so long as the fastening remained intact. He would like to know the Author's views on this as a brake problem.

The Author said he did not see where the connection between bolted-on tyres and brakes came in, but he quite agreed with Mr. Cuss that the former were very undesirable.

A Member asked why a rail brake as used on electric tram-cars was not used on railways.

Mr. R. F. Wallington said that, in the case of a breakaway, the brake van had to be capable of holding the broken-away portion. The greatest tension on the couplings was nearest the engine, and there was some possibility of the whole train breaking away. In this case the brake van would have to be capable of holding a heavy load.

Replying to the question regarding rail brakes, the Author said that the principal objection he could see was that they would have the same effect as if the wheels were skidding. There was not the same power as with ordinary tyre brakes. The Engineering Department might also have objections. With regard to the brake van, on an ordinary hand-braked train, it must be capable of holding the whole train.

A Member asked if, after the vacuum brake had been applied and the vacuum in the reservoirs leaked down, it would be necessary to blow up again before the train could be stopped.

The Author replied that this was so. The same thing would also apply to the Westinghouse brake if the auxiliary reservoirs or cylinders were very leaky. With both brakes this, was not likely to occur at all, but if it did, it would be very unlikely to occur on more than one or two vehicles, and in this case the brake on the other vehicles would be available for stopping the train.

In reply to a question on regenerative braking, the Author said that this was largely used on tramways, but not so much on railways. It was the ideal way of stopping the train as it did not wear the tyre at all.

Mr. Gooderson asked what was the best speed at which to apply the brake, say, going down an incline. A certain amount of speed was necessary to get the maximum efficiency.

The Author said that with an ordinary brake the maximum efficiency was at no speed at all, just before stopping. If two bodies in contact are moving in relation to one another, the lower the relative speed the higher the efficiency of friction. With the ordinary type brake the retarding force is least at the beginning and grows at the end of the stop. Brakes have been devised whereby the loss due to this had been overcome to some extent. When the brake is first put on the blocks are pressed against the wheels with a pressure of, say, 150 or possibly 200 % of the weight on them. Immediately it is applied, however, the pressure begins to leak off, and as the speed decreases so the pressure decreases until a certain pressure is reached below which no leakage takes place. Some experiments were made in Germany recently with a new brake, which were described in the "Railway Gazette" a few weeks ago. There was an ingenious arrangement whereby one brake block on each vehicle was attached to a valve, and the tendency of the block to move round the wheel was resisted by a spring. As the speed decreased and, therefore, the co-efficient between the block and the rail increased, the tendency of the block to run round with the wheel increased, and the spring was compressed more. In compressing the spring a valve was opened which allowed some of the air to escape from the brake cylinder.

With regard to the overheating of the tyres going down gradients, Mr. Pearce said that on the Western Valleys the tyres were cooled by running water over them.

The Author said that this was news to him. He had known water pipes used for cooling the flanges when going round curves, but not for cooling the brake blocks. He thought it was a good thing to do so.

Mr. L. A. Wheel asked if the Author could see in the dim future any prospect of applying the regenerative braking system to goods trains. He said that the question of cost made it prohibitive on goods vehicles unless it could be done by means of compressed air. With regenerative braking there was torque in the axle and transmission through the spokes—problems which did not arise when the blocks were directly to the tyre, at any rate, not to the same extent.

The Author replied that he was afraid there was not very much likelihood of this coming to pass. It looked rather a big problem. It meant either fitting all wagons with dynamos expressly for the purpose of braking, or running multiple unit goods trains.

In closing the discussion, the Chairman said they had had a very interesting one, and they must thank the Author very heartily for his paper and the way he had replied to the discussion. It had been of great use to a large number of them, and the Society were fortunate in having the Author to give them that paper. One thing they had to realise was that no brake could be ideal and they had to put up with compromise.

In replying to the vote of thanks accorded him, the Author said that it had been a pleasure to him to be able to do anything for the Society. They certainly had had a very interesting discussion and he had learnt something from it himself. He thought there had been a tendency in their discussions rather to regard the person who read the paper too much as a lecturer and to make the discussion consist almost entirely of asking questions. Whoever was reading the paper and whatever the subject, he did not know everything about it. He himself was far from knowing everything about brakes, and he thought it would add to the interest and usefulness of the discussions if they could be more like the one they had had that night.