10th August, 1893.

RAILWAY BRAKES.

By Richard Morse.

The following paper on the above much discussed, but all important, subject was suggested to its author from a consideration of the circumstances attending the disaster which befell the train at Peat's Ferry some years ago. Disasters of all kinds are generally the occasion or forerunners of much mental activity which rarely fails in its purpose to supplement, in a large measure, man's mastery over the forces of nature. They reveal the weak places which before had remained undiscovered. The author is indebted to the disaster referred to for the light thrown upon the defects in the brake used when it occurred. Is will be remembered that, subsequent to the accident, the brake question generally was voluminously discussed, but in such a partizan spirit, that the author, despairing of obtaining an unbiassed opinion on the subject, determined to investigate it for himself; the results of this investigation are embodied generally in the following paper:—

In the year 1878, upon the London and Brighton Railway, a series of valuable experiments were made by Captain Galton on the action of Friction Brakes on railway trains. A special van, provided with three speed indicators, and three dynamometers with the necessary gearing, was used throughout the experiments. Of the speed indicators, one designed by Westinghouse was self-recording; the principle upon which it worked consisted in its controlling the escape of water under pressure, by means of a small valve loaded by centrifugal force, the arrangement being such that the higher the speed the indicator was driven at the greater the pressure exerted on the escape valve, and the higher, therefore, was the pressure maintained in the chamber with which this valve held communication. The chamber received water from pumps driven by a belt off one of the axles which also operated the weights that supplied the centrifugal force alluded to. The action of these weights were similar to that of the ball of a steam engine governor. When revolving they fly apart, and thus keep the valve on its seat. As is well known the centrifugal force exerted by revolving weights, varies as the square of the velocity at which they are driven. This being so, the pressure on the escape valve similarly varies, or, what is equivalent, varies as the square of the velocity at which the train is moving. The pressure in the chamber which is caused by the speed, was made to register the speed in miles per hour, by means of an ordinary pressure gauge having the dial or face suitably graduated. The foregoing describes simply the registration of the speed which left no record behind.

The registration of the variable and decreasing speed, after the application of the brakes, was effected by placing an ordinary steam indicator in communication with the chamber, and which was brought into operation simultaneously with the application of the brake. The diagrams thus produced, afforded the fullest information as to the efficiency of the brakes. The other two indicators were designed by Stroudley; one was driven from a braked, and the other from an unbraked axle. The difference between their indications represented the amount of skidding which took place. Stroudley's Indicator consisted of a small fan having straight vanes revolving in a brass casing full of oil or water. The centrifugal force generated, caused the water to be maintained in a graduated glass tube at heights varying with the speed at which the fan was driven. The dynamometers were simply Richard's Indicators in communication with cylinders containing water acted upon by the pressures required to be measured. They registered three things, viz., the *direct pressure* of the brake on the wheel; the force produced by the wheel tending to carry the brake blocks in the direction of its *revolution*; and the *stress* on the draw-bar or *tractive force.* The three were placed on a table in the centre of the van, their drums being made to revolve by means of cords operated by a water clock. This instrument consisted merely of a hydraulic ram, loaded by a weight, a hydraulic accumulator on a small scale in fact. At the beginning of each experiment a small cock was opened which allowed water to run out, and the weight to descend, causing the mechanism to revolve at an ascertained and uniform speed.

It may be here remarked that at the trials which were carried out at Newark, in 1875, trustworthy evidence was sought respecting the retarding force of the brakes within given distances of 200ft. by means of electric apparatus, which was brought into circuit by contact pieces placed on the rail at those distances. Although efficiently carried out, this method proved vastly inferior to that adopted by Galton, and explained above.

Having briefly described the instruments used in connection with the experiments, reference will now be made to some of the results obtained.

It was found that the co-efficient of friction, between the brake block and the wheel, increased when the velocity diminished, until skidding took place, when the force opposing the progress of the van was immediately relaxed. As is well known, the best results were obtained by pressures which just permitted the wheels to revolve, and which were necessarily variable pressures. Another result deserving notice, was that the *frictional resistance* required to produce skidding, depended *very little* upon the speed. In one experiment, for example, in which the velocity was 60 miles per hour, 2,000lb. frictional resistance skidded the wheels. The speed being reduced to $\frac{1}{4}$, or 25 per cent., it only took 2,160lb. or 8 per cent. extra to produce a like effect. It was also found that the frictional co-efficient *decreased* during the time the wheels and blocks were engaged. An experiment, during which the speed and brake block pressure remained constant, showed that, after 10 seconds had elapsed, the frictional resistance fell from 2,000 to 1,400lb., a reduction of 30 per cent.

Guided partly by the information afforded by the experiments as outlined above, the author gives us what appears to him to be the necessary qualifications of a good brake :—1st. It should be *continuous*—every wheel in the train must come under its influence. 2nd. It should be *automatic.* A separation of any part of the train should ensure instant braking. 3rd. It should be such that the driver can at *any time* ascertain its efficiency. 4th. Its *effective retarding power* over a train during a lengthy application, should, if required, be *continuous*, notwithstanding leakages or otherwise. 5th. It should be capable of *instant application*, with a force nearly sufficient to skid the wheels. And 6th. Since this force increases the frictional resistance with the decrease of train's speed, it must be capable of *adjustment* at will by the driver. If the description of a theoretically perfect brake were the *raison d'etre* of the paper, a seventh condition might be added, viz., that it would fulfil all the previous six conditions, and, at the same time, usefully conserve the energy which is now wasted in bringing a train to rest. The author, however, is content to treat of the brakes from the standpoints of the six conditions laid down, and leave the latter aspect of the question for some more able pen.

Goodeve mentions a steam brake, which is, he says, largely used on the Continent, and which aims at conserving the energy as above. Its action is as follows :—A small jet of water is first sent into the exhaust pipe of the engine, which is then reversed. The pistons are thus turned into pumps which force the steam back again to the boiler, and, at the same time, draw in the mixed steam and water at a temperature of 212° Fah. produced by the jet. Passing into the cylinder its temperature is raised, and by compression is raised still further. The work thus done finds its equivalent in the arrested motion of the train, which converts energy into heat, and stores it up instead of allowing it to be dissipated. While upon the question of conservation of energy, the author thinks that a large annual saving might be made by locating railway stations at the top of an incline, of such a height and contour as would correspond to the action of a good brake. If, in practice, this could be done, a train might be brought to rest without much loss of energy, as the impetus given to it when *descending* from the station would restore the energy again—less friction and resistance of air—when *ascending* to the next. The Switchback Railway will, no doubt, be suggested to the members. The qualifications above mentioned will enable members of this Association to judge how far they bear upon the different brakes which will now in a general way be treated of. The brakes mentioned in the following description have been selected on account of some worthy feature connected with them. They are intended to illustrate the various processes of evolution undergone from time to time, until they arrive at the present state of development. Whether this state is as perfect as it might be, the author leaves the members to form their own opinions after becoming acquainted with what he has to say upon the subject.

When examined before a Select Committee on Railways, in 1841, the celebrated George Stephenson seems to have been impressed with the necessity there existed for adopting a system of self-acting brakes. The author cannot do better than quote from his biography, by "Smiles," to show what were his opinions at that early period, and to what extent those opinions affected more modern brakes:—" He early (says Smiles) entertained the idea that the momentum of the running train might itself be made available for the purpose of checking its speed. He proposed to fit each carriage with a brake which should be called into action immediately on the locomotive at the head of the train being pulled up. The impetus of the carriages carrying them forward, the buffer springs would be driven home, and at the same time, by a simple arrangement of the mechanism, the brakes would be called into simultaneous action; thus the wheels would be brought into a state of sledge, and the train speedily stopped. This plan was adopted by Mr. Stephenson before he left the Liverpool and Manchester Railway, though it was afterwards discontinued; and it is a remarkable fact that this identical plan, with the addition of a centrifugal apparatus, was afterwards received by M. Guerin, a French engineer, and extensively employed on foreign railways." Further on, in the some biography, Stephenson is reported to have said:—" I believe that if self-acting brakes were put on every carriage, scarcely any accident could take place."

Sanders' Automatic Vacuum.

This brake consists of two independent brake diaphragm cylinders of different diameters, which are in communication—the larger one direct, and the smaller one through a retention valve—with a single train pipe running throughout the train. The diaphragm rods are attached to the ends of a lever fulcrumed at the centre, and operating a smaller lever on the same centre connected to the brake block rods. By exhausting the air from the train pipe, and from the back of both diaphragms, the brakes are kept from the wheels, owing to the superior pull exerted by the larger diaphragm over the smaller one. Upon re-admitting the air into the train pipe the vacuum above the large diaphragm is lessened, while that above the small one is preserved intact by the retention valve above alluded to. The diaphragm is thus forced up and the brake applied.

The Gresham, or Vacuum Company's Automatic Brake.

(Plate III).

This brake seems to be the climax of preceding vacuum brakes. It embodies the experience gained during many years of experiments and actual working, and is worked with one train pipe. Instead of a diaphragm a piston is used, which works in a cylinder enclosed in a wrought iron reservoir. It thus outwardly appears like one cylinder. A peculiar feature, and one in which much of this brake's excellence is deemed to reside, is that the piston is packed with a rolling rubber ring, thereby ridding the surfaces in contact of much friction. Another striking feature in connection with the brake is a combined vacuum maintaining and brake releasing valve. This ingenious little apparatus, which is no larger than a small lemonade bottle, consists of a gunmetal casting, having communication with the train pipe, and top and bottom of brake piston. It contains a ball valve which permits a vacuum being created and maintained above the piston, and thus performs the first-named use. To enable it to perform its second use—viz., that of a release valve, the ball is enclosed in a light metal cage attached to a hand lever. By operating the lever, the ball is raised from its seat and the vacuum destroyed by admitting the air through a small chase or groove. A diaphragm ensures the reseatment of the valve. Quite recently a Rapid Action Valve has been added to the list of improvements in this brake. It consists of a small perforated casting placed between the train pipe and the brake cylinder. This casting contains within it two valves. One is connected to a diaphragm at its upper end, and during ordinary working is kept upon its seat by the outside air pressure acting through the perforations in the casing, owing to the seat being slightly larger than the diaphragm. Through this valve runs the passage from the train pipe to the brake cylinder. In a cavity in this passage is a small ball valve. When it is required to make a quick application of the brakes, the air passing through the train pipe into the brake cylinder is admitted in greater volume than in ordinary breaking, and forces the ball valve up into a seat, closing the passage and at the same time lifting the first mentioned valve. The lifting of this valve brings the ball into collision with a stop on the cover, which unseats it and allows the air to pass immediately into the brake cylinder through the perforations in the casting. During trials near Sydney made by a Board of Inquiry about the middle of 1891, this brake, fitted with the Rapid Action Valve, was fully applied on a train comprising 50 trucks in 3·313 seconds.

A later form of the Sanders' Brake has been introduced, and the difference between it and that of the Vacuum Co. seems to be, that in the former the pressure is admitted on the top, and in the latter, on the bottom of the brake piston. Also, that in place of the usual piston packing adopted in the former, the latter has an anti-friction rolling ring, the chief defect of which is its liability to become twisted occasionally. (Note Notes on Board of Trade Returns *Engineer*, October 29th, 1886.) The Vacuum Company's method of admitting the pressure on the under side of the piston, is a manifest improvement on the Sanders' system, inasmuch as the vacuum in the reservoir is kept from the influence of any leakage past the piston rod.

WESTINGHOUSE BRAKE (Plate IV.)

This brake is now operated from one train pipe, which, drawing its air from the main reservoir, traverses the train, connecting indirectly to the subsidiary reservoirs and the brake cylinders, which are now connected together. There are three leading characteristics embodied in this well known braking system, viz., the Driver's Valve, the Hose Coupling, and the Combined Automatic Action and Graduating On Valve, termed in common parlance a triple valve. The Driver's Valve is an ingenious piece of mechanism, but as it does not affect the main issue it is not the author's intention to describe its various details. The most notable feature connected with it, is the method adopted for exhausting the train pipe.

In the ordinary Driver's Valve, many of which are now in use, this was done as follows:—The pressure in the pipe is maintained by a valve held to its seat by a spring which reacts in the upper portion of the driver's handle. When it is desired to exhaust the train pipe, the handle, which is screwed into the main body of the valve, is turned so as to unscrew ; this movement reduces the pressure on the aforesaid spring, and allows the valve to lift. An Equalizing Driver's Brake Valve has lately been introduced to do away with a difficulty which frequently occurs in connection with the ordinary driver's valve, especially on long trains. It has been found that upon suddenly closing the valve subsequent to a large exhaustion of air, the pressure mounted up sufficiently at the front end of the train to operate the triple valves and release the brakes on the vehicles nearest the engine. The Equalising Valve is designed to overcome this difficulty; in the body of the valve casing, immediately over, and in free communication with the train pipe, is placed a piston about $3\frac{1}{2}$in. diameter, called an equalizing piston. The stem of this piston protrudes downward, and is formed at its end into what is called an exhaust valve. This valve seats over a communication leading from the train pipe to the atmosphere. A small reservoir is in free communication with the top of the equalizing piston. To apply the brake lightly, the driver allows air to exhaust from the small reservoir; this reduces the pressure on the top of the equalizing piston, which is forced up by the greater pressure in the train pipe. The exhaust valve is thus unseated and allows air to pass from the train pipe to the atmosphere. When its pressure is reduced slightly below that in the small reservoir, the valve is automatically returned to its seat. To apply the brake quickly and with considerable force, a rotary valve, by means of the drivers handle, is given a further turn which allows air to exhaust *direct* from the train pipe. There are several other points of interest in this valve, which, with the one already explained, indicates that its present development is the result of much thought and experience.

The hose coupling referred to is effective though simple in its construction, and its very simplicity renders a description of it almost unnecessary. The process of coupling up forms the joint, and thus preserves the pressure in the train pipe, while the reverse of this allows the air to escape, thus applying the brakes.

If it is required to maintain the pressure intact in the train pipe, separate cocks have to be manipulated, and the liability to overlook them presents a real source of danger. That this is so, the evidence given below affords ample testimony. At one time the Westinghouse Company adopted an automatic coupling, but reverted again to the one just alluded to. It may be interesting just here to refer to a statement by the chief engineer of the North-Eastern Railway Company, Mr. T. E. Harrison, in a report to his directors, dated Newcastle-on-Tyne, 24th April, 1879. Treating of hose-couplings, the report states:—"A great improvement has been made in the couplings of the carriages. There used to be a cock at each end of each carriage, and before removing a carriage from a train it was necessary to turn four cocks to completely shut off communication, and cases have occurred where, from carelessness, a cock has not been reopened, and thus the air pressure was shut off from the hinder portion of the train. To meet this, Mr. Westinghouse has introduced valves into the couplings, and the mere act of disconnecting closes the valves and retains the air and the act of re-uniting the couplings opens the valves and makes again a free passage for the air through the main pipes." No doubt the automatic coupling, above mentioned, as adopted by the Westinghouse Company, is that referred to by Mr. Harrison in his report over fourteen years ago. The Board of Inquiries report on brake tests, made on the Western Line, N.S W., and dated 29th June, 1891, refers to the separate cock system thus:—On every waggon fitted with the Westinghouse Brake there are three cocks, and when coupling or uncoupling takes place two of these cocks are always used, so as to distribute or retain the pressure in the train pipe, or to prevent the brakes being applied.

"The Vacuum Brake Company claim it as one of the points of superiority in their apparatus, that no risk is run from cocks being turned in the wrong direction, and when it is pointed out that in a train of fifty vehicles, fitted with the Westinghouse gear, there are no less than one hundred and fifty cocks, it will, we think, be readily seen that at country stations, where unskilled men have to couple and uncouple trains, a considerable amount of risk may be expected to arise from the misuse of these details." The late Mr. D. H. Neale, in the minority report, issued by the above Board of Inquiry, gives modern evidence of the necessity for the separate cock system in the following statement:—"While cocks require care and intelligence in working, they are of great practical convenience in such cases (speaking of shunting), and though it is perfectly possible to work the Westinghouse Brake without any cocks, the inconvenience of so doing should be as apparent as in the Vacuum Brake." The representatives of the Westinghouse Company maintained that the lamentable accident at Peat's Ferry was due to a shut cock. The author has seen the brake rendered useless from a like cause, as on one occasion a train in which he was travelling overshot the platform fully half a mile. The Vacuum Company, in setting forth the advantages of their brake, make the following statement:—"When desirable, cocks are applied to the ends of the carriages, but are not recommended, owing to the danger of the porters leaving them closed." What stronger condemnation than the above is needed of the separate cock system? The most prominent feature in the Westinghouse Brake system, is the combined automatic action and graduating on valve, more familiarly known as the triple valve. Plate V shows the valve in four stages of development. In Fig. 1, its present and latest stage, it is in association with a quick action valve, so that instead of it being a triple valve, it is more of the nature of a sextuple valve, except that the piston of the quick action mechanism does not perform a double use as does its neighbour in the triple valve proper. Describing first the triple valve mechanism:— This comprises a cast iron casing which contains accommodation for a small piston and two valves, one conical, and the other a slide. The latter has within it three ports, viz.; a main,