triple valve as well as electrical appliances. He had already extended his remarks to perhaps an undue length, and he would simply conclude by saying that it was a wise man that stuck to a good friend when he had got one and that the Automatic Pressure brake, although capable of being improved, was one of the most valuable and trustworthy appliances that science had introduced for the safety of the travelling public.

Professor Warren, stated that his remarks would be mostly of a general nature. He thought Mr. Selfe was to be congratulated for having brought before the Association a subject of so much importance, not only to engineers, but to the general public. With regard to the Burlington brake trials, referred to by Mr. Selfe, he considered that the experiments on brake p ressure speed, and distance run after the application of the brakes, to be a most valuable addition to the data obtained by Captain Galten on this subject. The author had already explained to us that the competing brakes were the Carpenter, the Westinghouse and the Eames, the Hanscom having practically withdrawn from the trials after a few unsuccessful attempts. The most remarkable stops were made by the Carpenter and Westinghouse brakes, with the valves actuated by electricity, the former stopping a train—consisting of thirty-three loaded and 17 empty trucks—travelling at twenty miles an hour, in 172 feet; and the latter in 200 feet. It was found that when electricity was used to actuate the valves there was less shock felt in the rear car, and merely an elastic surge of the train felt in the front car. When, however, the valves were actuated in the ordinary way, by means of air, the shock was considerable, notwithstanding the fact that the distance travelled after the application of the brake, was three times as great. These were important facts and clearly demonstrated that to stop a freight train of fifty cars in the shortest distance, it was necessary to apply the brake blocks as nearly as possible at the same instant to every car if we would minimise the damage to rolling stock; and it was most desirable that this should be effected by the same medium as that used for applying the brake under ordinary circumstances, namely, air. He (Professor Warren) considered that

electricity should not be used as it would be uncertain in its action when operated by ordinary drivers, and quickness of action could be obtained by other means. The retarding power necessary to stop a train of a given weight and speed on a level or on an incline may be calculated with great accuracy in the following manner.

Let x = the percentage of retarding effect on a level line
" x_1 = the additional percentage of retarding effect on a gradient due to the force of gravity
" X = the total percentage of retarding effect on a gradient
" d = distance run, in feet, after application of brake
" n = gradient expressed as 1 in n feet
" v = velocity in miles per hour
" p = pressure on brake blocks
" a = co-efficient of friction

On a level road Captain Galton found that $x = \frac{3{\cdot}34}{d} v^2$ and $x_1 = \frac{100}{n}$

and therefore $X = x + x_1 = \frac{3{\cdot}34}{d} v^2 + \frac{100}{n}$

So that the total retarding force on a level line, or on a gradient, may be easily calculated. The brake pressure was found by dividing this percentage of retarding force by the co-efficient of friction, thus :—$P = \frac{X}{a}$ or $= \frac{x}{a}$ according as the stop is effected on a gradient or level line. The co-efficient of friction was, however, by no means an easy factor to determine, nor had Captain Galton completely solved the question for all cases. It was, however, proved by Captain Galton—

1. That for a given amount of friction between the brake-blocks and wheels, the force required to skid the wheels is independent of the velocity.
2. That the co-efficient of friction diminishes as the speed of the train increases and with the time the brake-blocks are in action.

Hence, it followed that the wheels would require a much greater force to skid them at high velocities than at low velocities, and a train which might not be skidded when the brakes were first applied with full force, would certainly be skidded as the velocity of the train became gradually reduced, unless the pressure on the brake-blocks was released. Taking all these facts into

consideration, it would be seen that in order to calculate the brake pressure which would stop a train, under given conditions as to speed and gradient, it was necessary to determine the average co-efficient of friction for the length of stop in question, which could best be done by plotting the results of the experiments which had already been made as ordinates and abscissa for co-efficient and speed respectively; bearing in mind that the co-efficient would be increased as the speed was reduced, and reduced as the time taken to stop the train increased.

If this co-efficient be divided into the percentage of retarding force found by the former, the result would be the minimun brake-pressure, that is to say, the brake-pressure that would be necessary if every wheel in the train was supplied with brake-blocks. It generally happened, however, that there were a number of wheels which were not braked, in which case the percentage of retarding force which would be necessary to counteract the momentum of the unbraked revolving wheels, had to be added to the percentage found by the formula referred to, dividing by the average co-efficient of friction. In fitting a train with a continuous air-brake, we had so to arrange the size of the brake-cylinders and the leverage, whether for air or vacuum, that the pressure on the wheels was the greatest possible, which would just not produce skidding under ordinary circumstances. In the experiments made by Captain Galton, on the Lancashire and Yorkshire railways for example, the maximum brake-pressure had been 90 per cent. of the weight of the carriages braked. In Victoria and in South Australia, the maximum brake-pressure was also at 90 per cent. In New South Wales it was somewhat less.

With regard to the brakes described in the paper. The advantages possessed by the Hanscom brake, had been fully explained by the author, and the Automatic Vacuum brake, and the Westinghouse automatic brake had also been fully considered. The two latter brakes had gained such notoriety lately in this colony, and had been so fully discussed in the *Daily Telegraph*, that they must be very familiar to every member present. During the last three weeks, he had an opportunity of enquiring into the

working of the Vacuum and Westinghouse brakes in Victoria and South Australia. As Chairman of the engineering jury at the Adelaide exhibition, he had to deal with these brakes. The jury, however, did not feel themselves called upon to decide a question from exhibition models, which was a disputed point with engineers. The question could only be settled in a satisfactory manner by means of experiments on running trains coupled with the experience which had been gained in the use of the brakes both here and in other colonies. The jury decided that each should have a first award, although one member protested against the decision, he being in favor of the Vacuum, receiving a higher reward. A few experiments had been made on the exhaustion of the auxiliary reservoirs in the exhibition model of the Westinghouse brake. A few experiments had also been made on the time taken to fill the auxiliary reservoirs. In order to see how these experiments correspond with those made on trains, he had made experiments on the presence of Mr. Thow, locomotive engineer, South Australia, and Mr. Roberts, assistant locomotive engineer on a train of nine carriages, 315ft. long, measuring from tender buffers. It took 5 full manipulations to exhaust the air in the auxiliary reservoirs, from 75 to 25 pounds per square inch with the donkey going full speed, and the pressure in the main reservoirs, varying only 2 or 3 pounds from 85 pounds during the experiment. It had taken 6 minutes to charge the auxiliary reservoirs from 25 pounds per square inch to 75 pounds per square inch. The pressure in the auxiliary reservoirs had been measured by means of new Westinghouse gauges placed on the front and rear carriages. The gauge in the last carriage had taken a few seconds longer than that on the first, to indicate the same pressure. The experiments had been repeated several times with similar results, and no signs of leakage could be detected. The experiments on the train in the Redfern yard, had given about the same results with regard to exhaustion, but the reservoirs under the carriages had been filled in half the time. The exhaustion had taken much longer in the exhibition model, and the filling had been effected in 1 minute and 25 seconds for 9 reservoirs, and 3 minutes for 15 reservoirs.

An experiment had also been made on the exhibition model of the Vacuum brake, in order to test the leakage past ball-valve or rolling ring in cylinder, with a view to its efficiency when used on long inclines. The Vacuum had been destroyed in the main pipe from 22 inches to 10 inches, and the pressure on the gauges attached to the reservoir above the vacuum cylinders had been carefully noted. After two hours the greatest reduction of pressure was found to be four pounds. The gauges had been carefully watched by one member of the jury during the whole time.

Mr. Thow, locomotive engineer, South Australia, had thoroughly tested the leakage due to a total destruction of the vacuum in the main pipe, with the result that in the worst case it had taken two hours to leak off. If one half the time which was necessary to be expended in the examination of the parts of the Westinghouse brake would be taken in a similar examination of the Vacuum brake, there need be no misgiving on the leakage question raised by Mr. Campbell, the engineer for the Westinghouse brake. The ejector in ordinary working would overcome the leakage completely. He had examined an application of the Vacuum brake to freight trains, in company with Mr. Thow, which had given excellent results with regard to economy and efficiency. He had examined the Westinghouse brake as applied to trains in Victoria, in company with the Engineer, Mr. Allison Smith, who had thoroughly organised this department. The parts of the brake were periodically examined, and the drivers were instructed and examined in the use of the brake. He said that he rode down the Picton incline yesterday on the engine of the Melbourne express, and saw the Westinghouse used in a most skilful manner by the driver.

With regard to the exhaustion of the auxiliary reservoirs. It had never been contended that the auxiliary reservoirs must necessarily be entirely exhausted when the brake was used on long and steep inclines, but that they might become entirely exhausted by the unskillful use of the brake, and that under any circumstances, they must be partially so. He quite agreed with Mr. Selfe's remarks on this subject, that the brake-power could be exhausted

in a running train was now a fact; and a very difficult one for the Westinghouse Company to explain away, even if we ignored the lesson taught, us by the Peat's Ferry disaster.

The Vacuum brake on the other hand could be thoroughly relied upon to develope its full power in 20 sec., and to maintain that power for two hours or more if necessary. When the vacuum was partially destroyed on an incline, it was equally reliable. It had also the advantage in simplicity.

The President asked Mr. Campbell, the engineer for the Westinghouse Brake Company, if he would not like to speak.

Mr. Campbell said it would not be fair for him to speak just now.

The President said he was sure it would be fair for Mr. Campbell to speak. There were a number of gentlemen present who desired to hear him. The chances were that the discussion would be further adjourned. As a matter of courtesy to Mr. Campbell they would like to hear him speak, but if he did not intend to do so, he (the speaker) would call on someone else.

Mr. Campbell said he had been so much engaged since the last meeting, that he had not had an opportunity of preparing diagrams, but if the discussion were postponed, he would in all probability execute some diagrams. He understood that the Peat's Ferry accident was not to be gone into. The cause of the accident had been referred to pretty plainly, so if it were to be gone into, he would like to deal with it properly. He was sorry he was not present when Mr. Adams spoke. He believed that he had said that the Westinghouse brake could not be worked down an incline of that character (referring to diagram) without accident.

Mr. Adams (decisively): No!

Mr. Campbell: Well, a few days ago, it was reported that the driver started at the top of the incline with 80 pounds, and it was 70 pounds when he reached the bottom. He did not, however, mean to say that the Westinghouse brake could not be exhausted. He thought any piece of mechanism using a fluid, could be exhausted. So far as the brake power on a train went, he had to admit he could scarcely follow Professor Warren's figures; but he

would like to avail himself of the opportunity of putting down a few figures. He then gave a series of illustrations regarding the retardative effect of brakes upon a train going down an incline.

Continuing, Mr. Campbell said as regarded the Westinghouse and Vacuum brakes, at the previous meeting he had given some figures which he had taken from the Board of Trade Returns. He found from the figures supplied by the Board of Trade, that the Vacuum brake, which was being pushed very much in this colony just now, failed twice as often as the Westinghouse brake did. Now, he would put a question to Mr. Adams. He (Mr. Campbell) wanted Mr. Adams' acceptance or denial of these figures. He would like to have a commission composed of members of this association to sit on the matter. Why, on looking through the book he found that there were seven instances in which the driver failed to get a vacuum at all.

Mr. Adams here asked Mr. Campbell if he had the latest returns from the Board of Trade.

Mr. Campbell did not think he had the latest returns that had been issued.

Mr. Adams said, if what had been stated by Mr. Campbell were true, he could not alter it.

Mr. Campbell said that if the Vacuum brake, with all its simplicity, failed twice as often as the Westinghouse brake did, it showed that there must be something inherently weak in it. He had taken an average of the figures given, and if the Board of Trade Returns were true in stating that the Vacuum brake failed twice as often as the Westinghouse brake did, where was its simplicity. These figures should be gone into. He would be very happy to go into Mr. Adams' publications singly—one after the other—and if he could not prove that what was asserted was false, he would be prepared to forfeit anything they liked.

Mr. Granlund, the representative of the Westinghouse Brake Company, spoke in defence of that particular form of appliance. He thought that for many reasons the Westinghouse brake might be considered to be very much better than the Vacuum brake. The brake itself—that was the three parts which constituted the brake

—was very simple. If there were any dispute about the action of the triple valve, they would show by ocular demonstration what it could do. The Westinghouse Brake Company had always courted publicity, and their trials were open to the public. They were not secret trials. They would like Mr. Adams to fix up an apparatus; they would ask Mr. Selfe to do the same; and they would also do so on their own account.

A member: Who is to pay for this?

Mr. Granlund: Well, we will pay for ourselves, and let the others pay for themselves. Let the thing be fairly tried and tested, and then, if we are worsted, we will submit; and if we are beaten, we will "draw in our tail," pay expenses, and go home.

Mr. Granlund then made a lengthy reference to Professor Warren's figures, and said it was patent to everybody that on a running train one application of the brake would be sufficient to stop it, if the train were properly fitted.

Professor Warren: Quite true.

Mr. Granlund: In no country in the world was the rolling stock fitted with such a low brake power as in New South Wales. It was larger in Victoria than in this colony. An automatic continuous brake was mainly an emergency brake—one to be applied in the quickest time and at the shortest notice. In the Peat's Ferry train, there were four carriages fitted, out of nine and with that low brake power they would be very much inclined to say that if any speed over twenty-five miles an hour were got up, the brake would not be sufficient for the train. The Westinghouse Company were only responsible for the brake. The Railway Department were responsible for the fitting of the train. He only wished to add that the company which he represented would like to see full, fair, and public trials. They did not go by mere assertions; they wished to have facts and proof of those facts, and they were quite willing to bring that about by any means in their power.

The President then said that the hour was getting late, but if any of the members wished to speak they could do so. He might mention that special reference had been made to some trials that

took place on the previous saturday, to which (on behalf of the Association) Mr. Pollock and himself were invited. As special reference had been made to these particular trials he had no hesitation in making a statement as to what actually took place on that occasion, but he considered that the object of this meeting was to discuss Mr. Selfe's paper, and he did not feel justified in making any mention of it just then. But at the same time, on behalf of the Association, he would be very glad to make a statement, and Mr. Pollock or himself would be very pleased to answer any questions that might be put to them on another occasion.

Mr. A. D. Nelson said it was not his intention to say anything upon this question that night. He had been rather inclined to take part in the discussion, but after the remarks of their President, prior to the renewal of the debate, he had had the wind completely taken out of his sails. He moved that the discussion be adjourned.

DISCUSSION RESUMED.

A sketch of the new triple valve used in the Burlington brake trials was exhibited by Mr. Norman Selfe.

The President called upon Mr. A. D. Nelson, who proposed the adjournment of the discussion, to open the debate.

Mr. A. D. Nelson said he found that he had been placed in a rather false position from the simple fact that, when at the previous meeting he moved the adjournment of the debate, he did so on behalf of the President. Therefore he hardly thought it fair that Mr. Cruickshank should call upon him. However, with the permission of the gentlemen present, he would proceed to deal with a few matters worth touching upon. He then referred at some length to the position the members who might wish to speak were placed in by the request of the President, which was in effect that they were to abstain from touching upon the recent accident at Peat's Ferry. He then proceeded to show the difficulties the members laboured under in attempting to discuss the question of the railway brakes, when the main feature in connection therewith was debarred from discussion. There could be no denying the fact that the great interest taken in this