and one carriage until well down the incline, when the engine hand brake was used, which brought the train to a dead stop. The conditions were practically the same as in the other trials —80 lbs. in main reservoir at the start, 70 lbs. in small reservoirs. At the finish the pressure in small reservoirs was reduced to 25 lbs., while that in the main reservoir remained almost constant, never being below 75 lbs., donkey going full speed.

FOURTH TRIAL.—TRAIN STANDING.

Time taken to fill the five (5) small reservoirs with air at 70 lbs. pressure, the main reservoir being full and its gauge showing 73 lbs. at start and 71 lbs. at finish; donkey going full speed, and 137 lbs. of steam on locomotive gauges.

1st half-minute pressure rose to	...	35 lbs.
2nd " " "	...	48½ "

but it took four minutes to rise from 48½ to 68½ lbs.*

From the above it will be seen that about 50 lbs. per square inch can be forced into the reservoirs in 60 seconds, but after that the pressure rises very slowly.†

FIFTH TRIAL.—TRAIN STANDING.

Time taken to fill one small reservoir next tender, all the others shut off; donkey going full speed. Pressure in main reservoir 70 lbs.

1st half-minute pressure rose to	...	35 lbs.
2nd " " "	...	60 "
3rd " " "	...	67 "

SIXTH TRIAL.—TRAIN STANDING.

Main reservoir showing 80 lbs.; donkey going full speed; 139 lbs. of steam; thirteen applications of the brake; and in two (2) minutes all the three reservoirs were practically exhausted from 70 lbs. to 5 lbs.

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* NOTE.—All the small reservoirs were empty at the start.

† SPECIAL NOTE.—We cannot understand this, as with a constant pressure in main reservoir it should (except for the increased friction) fill five in the same time as it takes to fill one.

SEVENTH TRIAL.—(Under same conditions).

80 lbs. in main reservoir; exhausted all the air from small reservoirs in 1 min. 50 sec.; eleven applications of the brake. At the finish there was about 60 lbs. in main reservoir.

This concluded the trials.

What you have just heard is a fair and straight statement of what we actually saw, and although the time and figures may not be absolutely correct, we have no hesitation in vouching for their approximate accuracy.

It is also desirable to mention that the officers in charge of the experiments were willing and anxious to carry out all the practical suggestions which, in our opinion, tended to enhance the value of the tests.

At the conclusion of the trials we *felt anything but satisfied under certain conditions*. We had seen the air exhausted without difficulty. This was done in various ways, and in a very short space of time; but being of a practical turn of mind, and pleading guilty to having a large amount of mechanical scepticism in our composition, we wanted to know how and by what means this sudden exhaustion came about.

In answer to enquiries, the officers intimated their willingness to supply any information regarding sizes, proportions and capacities of the various parts of the Westinghouse brake, and also sent us a triple valve (in sections), which is now before you.

We are free to confess that before seeing this valve we had a very hazy idea of its action, and it was only after spending a considerable time in patiently studying its design and construction that we began to see and appreciate the rare ingenuity and admirable skill displayed, and which, as a mechanical appliance, is worthy of all praise.

In connection with this valve it is desirable to refer to Mr. Shellshear's remarks concerning it. He describes it as a very simple affair, so much so that, to use his own words, "any apprentice boy would have no difficulty in understanding it." Well, this may be so. We respectfully, but decidedly differ from him; in fact, we don't feel very sure of knowing all about it now; but we have mastered it sufficiently to feel quite content to know that our want of perception and dulness of comprehension requires so much development.

Even Mr. Campbell himself never even hinted that the Westinghouse people ever claimed anything for its simplicity. On the contrary, he freely admits its complexity of parts ; but what he did say was something like this, that although to those who do not understand or are prejudiced this triple valve may appear very complicated ; it is so beautifully made, the proportion and construction of its parts so accurately arranged, that its liability to go wrong is reduced to the lowest possible minimum, and that, looking at its practical working, it is justly entitled to the public confidence.

We believe Mr. Campbell has fair justification in making that statement, and the fact that thousands of these valves are in daily use all over the world, doing good work, is very conclusive evidence of its truth. Mr. Campbell evidently looks upon the triple valve as an intimate relation of a clock or a watch, which, with all their complications, we put down as of no use unless they keep accurate time for years, and we expect them to do so without much examination or repairs. Speaking personally, I wish to say that, with respect to complications in mechanical appliances, I have received some wholesome lessons, and although I admire and appreciate simplicity in machinery as much as any man, still we should hesitate and make quite sure of our ground before we condemn any appliance because of the number of its parts. In proof of this let me point out that when the compound engine was introduced, a large percentage of engineers (myself included) raised the cry that the complexity of parts and the increase of pressure would, in the long run, cost more than could be gained by economy in coal, yet it has steadily made its way, and judging from what I see, there is little doubt that the triple and quadruple engines, with even more complications and much higher pressures, will do the same.

There are many gentlemen in the room who are connected with marine engineering, and they know as well as I do that our modern machinery has reduced the cost of repairs in a very material degree. Not many years ago hundreds of mechanics were constantly and profitably employed in repairing the machinery of the numerous steamers trading to Sydney, but now such is the improvement in the soundness of design, the efficiency of construction, and the excellence of our tools, that, notwithstanding increased complications, the machinery runs from year's end to year's end at a fraction of the expense incurred in the old days, and although it may appear a strange thing to say, I have no hesitation in stating that it is the high degree of efficiency which has been reached in complicated machinery which has caused and is now causing such a depression in Sydney.

It was only the other day, when examining the machinery of one of the Orient steamers, the chief engineer informed me that the vessel had steamed from the old country to Sydney, and there was nothing required but what the engine-room staff could do themselves. This was with 160 lbs. of steam, and complications enough in all conscience.

This is a suggestive fact, and is mentioned to show that in examining or criticising any mechanical appliance, complication does not always justify condemnation.

Returning now to the triple valve, we find in it is contained the whole principle of the Westinghouse brake, and which, with your permission, I will try to explain in a simple manner.

Take our first trial. We started with 80 lbs. in the main reservoir, 70 lbs. in the brake pipe and small reservoirs, and in less than three minutes the whole of the small reservoirs were practically empty, although the pressure in main reservoir remained steady at 75 lbs.

Now here we have a train whose brake power has been purposely dissipated, and yet the driver of that train has practically the same pressure on his guage when the small reservoirs are empty as when they were full. He has plenty of power in his main reservoir, yet his brakes are useless.

To explain this we must go to the triple valve. Anyone looking at its construction and understanding its action must be struck with the fact that it is not necessary to go on to a running train to be convinced that the air in small reservoirs can be exhausted without difficulty, for they have only to realise that the hole through which all the air must pass to charge or recharge the small reservoirs is so many times smaller than the passage for letting it out that it requires a very simple calculation to know how many full applications of the brake will practically exhaust them.

The size of the admission hole is equal to the area of a circle scarcely $\frac{1}{8}$-inch in diameter cut in two—that is, all the air has to pass through a semi-circular groove $\frac{1}{8}$-inch in diameter. The area of an $\frac{1}{8}$-inch circle is ·0121, and dividing this by 2 we have the actual area of the air passage, viz., ·0061. The diameter of the holes (smallest) from small reservoirs to brake cylinder is $\frac{5}{16}$-inch, the area of which is ·0769; then dividing area of hole through which the air passes to put the brakes on by the area of hole through which all the air has to pass to recharge small reservoirs we have $\because : \frac{\cdot 0769}{\cdot 0061} = 12\cdot 57$, which tells us the hole from brake pipe to small reservoirs is $12\frac{1}{2}$ times smaller than the passage from the reservoirs to brake cylinder, and this is irrespective of friction, which in this case would vary approximately, as follows :—

Directly as the length of passage,
Directly as the square of the speed,
Directly as the density or weight, and
Inversely as the diameter.

Taking the Westinghouse book of instructions, we find, in pages 20 and 21, that "a reduction of 20 per cent. in the brake pipe pressure causes the triple valve pistons to move down and set the brakes at full force by means of the air in small reservoirs." And, again, "to set the brakes with full force takes an average of $1\frac{1}{4}$ seconds, and to open the release ports about the same time. To restore the pressure in small reservoirs requires from 15 to 30 seconds after a full application." This shows very conclusively that, taking the average time given—$15 + 30 = 45 \div 2 = 22\cdot 5$ seconds—that it takes a great deal longer time to put the air into the reservoirs than to let it out; besides, it says nothing about any particular pressure that may be in the reservoirs, and it certainly does not agree with the results we obtained on the 3rd September, where in the 4th trial, which was for the express purpose of finding what time it took to fill the five small reservoirs (they being empty at the start and train standing), we found it took one minute to get the pressure up to 50 lbs., but it took much longer to raise the pressure from 50 to 70 lbs. Going back to the small admission hole again; and remember that if they attempted to enlarge this hole the triple valve would be useless, in fact it would not work at all; because then the air in small reservoirs would come out so fast, and the pressure fall to such a degree as would certainly destroy the efficiency of the brake.

Assume a case, and suppose there is 70 lbs. in brake pipe and 70 lbs. in reservoirs, and we want to put the brakes on with full force, we, in accordance with instructions, reduce the brake pipe pressure 20 per cent., bringing it down to 54 lbs.; we have then 20 per cent. more pressure on top of triple valve piston than we have on the bottom; this acts on the piston and brings it down; but, remember, the air is *leaking past it all the time through the admission hole, but it can't get out quick enough to prevent the excess of pressure from acting, because it is so small.* When the piston has travelled $\frac{5}{16}$, the admission port is shut; it is then all right.

The size of the exhaust hole, or passage, is $\frac{3}{16}$-inch in diameter, and, comparing it with the admission hole, it is $4\frac{1}{2}$ times larger; its area is ·0276, and dividing the one by the other we have: $\frac{.0276}{.0061} = 4\frac{1}{2}$.

It may be urged that as all the air has to pass through the exhaust its diameter should be taken instead of the passage from reservoir to brake cylinder, but it should be remembered that the pressure is always much less in the brake cylinder than reservoir, that when released it has only to contend with the atmospheric pressure, and also that the exhaust port on the valve face is nearly twice as large as the exhaust passage, thereby allowing it to remain longer open, whereas the air from brake pipe has to be forced through a very small hole against whatever pressure may be in reservoir, besides the immense friction to be overcome, and is all in favour of getting rid of your power much faster than it can be supplied.

GRADUATING THE PRESSURE.

This has been a much disputed point, and, without prejudice, am of opinion it can and is graduated every day. It is true the driver can't see the graduation, but there seems to me no difficulty in educating the hand to control any train. This means of graduating the brake pressure is a very clever contrivance, and appears to perform the same function for Westinghouse as the small injector does for the Vacuum brake, but it must not be forgotten that the Westinghouse can only be graduated one way—that is, when it is being applied to put the brakes on. There is no possibility of graduating the release, as every particle of air must be discharged into the atmosphere and the brakes taken completely off before another application of the brake is possible.

There is another point in connection with the Westinghouse which, I think, has escaped notice. It is this: Mr. Campbell, when speaking against the Vacuum brake, brought it prominently forward that the injector used a very large amount of steam.

No doubt it does; but let us look at the Westinghouse from an economical point of view, and see how it stands. For every full application of the brake you have to actually waste 20 per cent. of the brake pipe pressure, and taking their own figures, for a train of fifteen carriages you have to throw away 1,000 cubic inches of air, at a pressure of from 60 to 80 lbs., before the triple valve pistons can move their full stroke. Now this has to be done many hundred times every day, and as it takes a considerable amount of power to compress air to a high pressure, it appears to me that if the total quantity of air which is and must be wasted on applying the brakes was calculated, I feel pretty sure that the truth of a very old adage would be very fully realised, viz., "Those who live in glass houses should not throw stones."

Referring to Mr. Granlund's statement that the brake power on the New South Wales railways was only one half of what was fitted on the Victorian lines, and that for every 10 tons of brake power here they had 20 tons. This, coming from such an authority, is no doubt correct; at the same time, let me direct your attention to No. 3 trial, where, in careful hands, the great efficiency of the Westinghouse brake was clearly demonstrated, for on that occasion a train weighing 164 tons came down a grade of 1 in 45 at a speed of over thirty miles an hour, the air being applied on the tender and one carriage only, the cock being shut off, and couplings being disconnected behind the first carriage.

This goes to show that although the brake power on the New South Wales lines may, in the opinion of some, be limited in amount, still there is, even in cases of emergency, quite sufficient left to control the train.

Looking at the Westinghouse brake as a whole, it appears to me that its weak point lies in the fact that, by careless handling and injudicious management, the stored power in small reservoirs may (under exceptional circumstances) be exhausted, which means that the driver may have a large quantity of power in his main reservoir, and yet the small reservoirs be practically empty, and on heavy down grades a little carelessness, inattention, and want of judgment may result in his losing control of his train.

This, I think, might be remedied to some extent by fitting another pressure gauge on every tender, which would always give him a fair idea of the amount of power at his disposal for putting on the brakes.

On the other hand, this brake is, in careful hands, a safe and reliable contrivance, and until Mr. Selfe or somebody else shows us something very much better, it will continue to merit the public confidence.

Referring to the large amount of correspondence which has taken place in the public press in arguing about the relative merits of the brakes, one thing stands prominently forward, viz., the extreme difficulty of sinking personal interests when discussing this question, and many of the statements made are to be regretted.

Where the Westinghouse people made the mistake was in claiming too much for it. Like any other human machine, it has its good qualities and its faults, which may, and no doubt will be, improved.

Let us, therefore, hope that, as in this age of progression we cannot stand still, the present discussion may be the means of making railway brakes more economical and reliable than at the present time.

It was my intention to have said something about the relative merits of the Vacuum and Hanscom brakes, but time has compelled me to confine myself to the above.

Mr. Henry Davies said this discussion was appropriate to the intentions and designs of the Engineering Association. He also considered that the debate had been of considerable value to all, because the good as well as the bad points of many of the brakes had been indicated. The speaker then proceeded to refer to the sudden and uncomfortable stoppages which occurred on the suburban stations between Sydney and Parramatta, and said that many peeple complained of this, and said it was to be attributed to the action of the Westinghouse brake. Now he did not think the sudden stoppages were due to the action of this brake, but they were the result of other causes connected with the condition of portions of the rolling stock. He thought the defects complained of would be got rid of in time; it was not the fault of the Railway Department that they had not been got rid of before. He objected to this defect being attributed to the Westinghouse brake.

Mr. G. A. Key then made a brief reference to what he considered to be some of the faults of the Hanscom brake, after which Mr. R. B. Campbell read the following statement :—

"I regret that discussion on the cause of the late accident at Peate's Ferry has been forbidden, as circumstances connected with that disaster, undoubtedly form a large part of the paper now before us, and I think it would have been more satisfactory if this portion of Mr. Selfe's paper had been thoroughly gone into, but in deference to the opinion of our President, I will content myself with drawing your attention to this duplicate of the piping and tap, which was found closed after the accident. It will be seen, that from the manner in which this metallic connection of the hose pipe is made, it would be impossible for the overriding of the carriages, during telescoping to wipe this handle parallel with the pipe;