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VICTORIA.

WOODS' CONTINUOUS AUTOMATIC BRAKE.

RETURN to an Order of the *Legislative Assembly*,
Dated 7th June 1881, *for*—

A COPY of the Report on the Woods Continuous Automatic Brake.

(*Mr. Mason.*)

Ordered by the Legislative Assembly *to be printed*, 22*nd June* 1881.

REPORT ON THE WOODS' CONTINUOUS AUTOMATIC BRAKE.

Department of Public Works, Railway Branch,
Locomotive Engineer's Office,
31 May 1880.

THE advisability of making a more extended application of Continuous-brakes to our passenger trains, to which you have from time to time directed attention, having rendered of first importance the settlement of the form of brake most suitable for general adoption on our railways, I have, in accordance with instructions, made a careful examination into the working of the Woods brake on the Victorian Railways, to enable a comparison of its efficiency to be made with that of the Westinghouse brake, which has been under trial on our Western trains for sometime past, and I have now the honor to submit the following report.

The Woods brake is, as is probably already understood, a hydro-pneumatic brake, water being used to accumulate and distribute the required pressure in combination with air, which latter occupies the upper portion of each receiver or accumulator on the engine and carriages, and acts as a spring or cushion in directing and softening the action of the water.

This brake, like the Westinghouse pneumatic brake, is capable of being used either automatically or non-automatically, as may be desired.

The action of the essential parts of these two brakes is in many respects similar, although the parts differ very materially in details.

One important difference consists in this, that whereas the Westinghouse system, owing to the use of air as the medium for transmitting the brake-power along the train, requires an air-pump specially constructed and fitted to the engine for the purpose, the Woods system, by using water, is enabled to make use of the ordinary boiler-pump, or, if need be, of the injector.

As a medium for transmitting high pressures, water, on account of its greater density, possesses these two important advantages over air, viz., that the joints of the pipes and machinery used can be more easily and securely made and maintained, while the slightest leakage is at once made evident by the drip.

Water has also the power of washing and freeing from impediment the parts through which it passes more readily than air, while the subtilty and penetrating power of air necessitates a very careful and nice adjustment of the working parts of the apparatus, thereby increasing the risk of derangement and failure.

On the other hand, water has two disadvantages compared with air; one in respect of its corrosive tendency, which necessitates the use of brass or copper where otherwise iron would suffice, which, of course, enhances to some extent the first cost, although, in estimating the cost, the making of the working parts of brass or copper has been allowed for. The other is in respect of its liability to freeze; but in the warm climate of Australia this objection, so far as I can learn of the severest cold in winter, does not apply.

As regards the practical working of the Woods brake, the result of my frequent and careful observation of its behaviour, on the suburban, as well as on the main line trains of the Victorian Railways, has been to confirm the favourable expectation which I had formed of its capabilities from an examination of the fittings shown at the recent Sydney International Exhibition.

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Its action is, like the Westinghouse, practically instantaneous, and, owing to its capability of being worked, if need be, at the boiler pressure of 120 or 140 lbs. to the square inch, it possesses ample power.

As regards the actual distance in which it can stop a train travelling at any given speed, this is, as I have explained in the Appendix, a matter simply of proportion of the parts, which may be adjusted to produce either slow or rapid reduction of speed as may be required.

In estimating the first cost of each system, I have assumed a train to consist of one engine and *eight* carriages, which is the *full* average number usually worked per train.

The cost of each, as will be seen in the Appendix, may be stated as follows, including royalty in both cases :—

Westinghouse	Engine, £88.	Eight carriages, £192.
Woods	Engine, £24.	Eight carriages, £288.

This shows the cost with eight carriages to be somewhat in favour of the Westinghouse, giving £280 per train, as against £312 for the Woods brake, or £35 and £39 respectively per carriage ; the difference being due to the fact that the Westinghouse fittings are manufactured and supplied at English prices (including freight and all other charges), while, in the case of the Woods brake, the manufacture being in the hands of colonial firms, the fittings are tendered for at colonial prices.

If the fittings of the Woods system were made under the same conditions as to wages, &c., the first cost would be in its favour.

Even as it is, with trains of *five* carriages (which number many of our trains with long carriages do not exceed) in place of eight, the cost is somewhat in favour of the Woods brake, being in that case as follows :—

Westinghouse	£208 per train,	or £41 10s. per carriage.
Woods	£204 „	or £41 „

In coming to a decision on the practical question whether or not it is desirable to introduce on our railways the Woods brake, the matter must, I think, be settled by a consideration of these two points, viz. :—

1st. The amount already invested in the Westinghouse system, and

2nd. Whether, in view of that expenditure, any advantage (as regards reliability or otherwise) which the Woods brake is believed to possess over the other would warrant the sacrifice of that expenditure ; a course which must necessarily result on the adoption of any new system. The impossibilty of satisfactorily working a railway with *two* systems of Continuous-brakes, except in a purely experimental way, is self-evident.

I.—In the first place, the amount already invested in Westinghouse fittings fixed to vehicles is about £6,300, and the amount expended in fittings now being applied, or in store, is about £1,500 more, making a total of about £7,800. Of this sum, fittings (such as engine air-holders, pipes, flexible hose, and cocks, not being peculiar to the *patents* in either case) to the value of about £1,300 would be serviceable for the Woods system, and the market value of the superseded fittings would be about (say) £1,000 more, depending on the then demand for Westinghouse fittings, giving a total credit of (say) £2,300, and leaving a net loss of about £4,000.

If the Woods fittings were applied, and confined, in the first instance, to the Northern line, the sacrifice might be postponed for some years, until the junction between the Northern and Southern lines was made ; but, with a change ultimately in view, the application to Southern and Western trains of the present form of Continuous-brake, in excess of the fittings now in stock, would be undesirable, as incurring expenditure which must, to a great extent at all events, be ultimately thrown away by the adoption of the new system on the union of the Northern and Southern lines.

II.—In the second place, as regards the reliability and ease in maintaining the two systems in every-day working order, I have no hesitation in saying, for the reasons given in the Appendix, it would be found to be materially in favour of the Woods brake.

As serious accidents are likely to arise from misplaced confidence in the brake power of a train fitted with any brake which is difficult to maintain in proper working order, the importance of determining which of any two or more systems is the more reliable, and for adopting that which experience may prove to be the best, cannot be overstated. The substitution of another system which may in the meantime have been proved to be more reliable, and therefore the more likely to be in working order when required to prevent an accident, would, I think, justify the sacrifice of a considerable sum, the sum thus sacrificed being probably far more than covered by the avoidance of even a single serious accident.

In order therefore to establish beyond question the only point which, as it seems to me, can possibly be raised as not being established with exactness between the Westinghouse and Woods systems, viz., the greater reliability of the latter over the former, I would recommend—more especially if it be considered essential to continue the use of *automatic* brakes on our railways—that the trains of the Northern lines, where no Continuous-brake has yet been generally adopted, *be fitted with the Woods brake.*

Further, that the application of the Westinghouse brake be confined in the meantime, to the Western and Southern "through," and the Sydney "suburban" (American) trains, and that when the relative reliability of the two systems has been conclusively established, the least efficient be abandoned in favour of the other.

In conclusion, there is one point more which is deserving of special notice in connection with the use of Continuous-brakes, and which applies equally to the Woods and the Westinghouse systems, and, indeed, to all powerful brakes ; it is this, viz. :—That there cannot be a *rapid* reduction in the speed of a train without its being very sensibly felt by the passengers ; not only when the brake is first applied, but more especially at the moment when the train comes to a stand. This is due to the fact that the upper portion of the body of each vehicle, as well as that of each passenger, tends to continue its onward course at a uniform speed, while the lower portion is being pulled back, in the case of the carriage by its skidding (or nearly skidding) wheels, and in the case of the passenger by his feet, through their contact with the floor of the vehicle. By these contending forces every fibre of the carriage is put under strain ; while each passenger resists the forces acting on his body by powerful, though *unconscious*, muscular action ; and, if he be in a standing position, he leans his head and shoulders backwards to resist their tendency to go faster than his feet. When the train comes to rest this leaning atttitude has to be promptly recovered from, otherwise a fall backwards must result. To persons unaccustomed to use trains brought rapidly to rest by the application of Continuous-brakes, the need for at once resuming an erect position has to be learned, and they are apt, in the meantime, to attribute the stagger they experience, and the recoil in the fibres of the vehicles, to some *improper* action of the brake.

Passengers generally, and ladies more especially (unless they are experienced travellers with trains with powerful brakes), should therefore retain their seats until the train has come *perfectly* to rest.

I have in the Appendix added a few general remarks on the use and working of Continuous-brakes, which may serve to render clearer the points to which I have mainly directed my attention in comparing the construction and working of the Woods and Westinghouse systems.

ROBT. H. BURNETT,
Locomotive Engineer.

Appendix to the Locomotive Engineer's Report on the construction and working of the Woods Continuous-brake, of 31st May, 1881.

The following general remarks, on the use and working of Continuous-brakes, may serve to make clear the points to which attention has been mainly directed in considering the construction and working of the Woods Continuous-brake.

In the first place, it is important to bear in mind that the fittings which combine to make up a complete Continuous-brake consist of two *entirely distinct* portions. First, those parts which accumulate and distribute the brake force throughout the train—which form the subject of the several patented brake apparatus in use on various railways ; and, secondly, those parts (such as the blocks, hangers, cross-shafts, pulling rods, levers, &c., &c.) which are common to, but not included in, any of the patents, and which merely serve to transmit the brake force from the Continuous-brake apparatus, proper, to the wheels.

With the former *only* have we to deal in comparing the relative merits of different systems of Continuous-brakes.

In the next place, as is well known, the force or momentum to be overcome in bringing a train to rest is proportional to its weight and speed ; but as the force available for stopping the train—viz., the friction between the wheels and rails—is also proportional to the weight, the distance a train will travel after the application of a theoretically effective Continuous-brake will be the same, for any given speed, whether the train weighs 50 or 500 tons.

The maximum force available for stopping a train being determined by the amount of friction between the wheels and rails, when the wheels are skidding (or are on the point of being skidded) is of course variable, depending as it does on the weather and the state of the rails. It varies from (say) $\frac{1}{5}$th of the weight on the rails in dry weather, to $\frac{1}{10}$th in wet, slippery weather.

The maximum retarding force will therefore vary from 448 lbs. (or $\frac{2240}{5}$) per ton in fine weather, to 224 lbs. (or $\frac{2240}{10}$) in bad weather.

The friction between the wheels and rails in slippery weather may of course be increased by the well-known practice of using sand ; but as it is necessary, in considering the effect of brakes on trains, to allow for the *worst* case—when sand may not be available—not more than $\frac{1}{10}$th of the insistent weight must be taken as the utmost on which reliance can at *all times* be placed.

The following table shows, in foot lbs. per ton, the momentum which has to be destroyed in bringing a train to rest, at speeds varying from 60 to 10 miles per hour ; together with the distance the train will travel, in each case, after the application of the brake, under the most favourable and the least favourable conditions respectively :—

Speed.		Momentum per ton of train in foot lbs.	Brake power per ton, in lbs. per foot travelled.		Distance travelled before the train is brought to rest.	
In miles, per hour.	In feet, per second.		Friction taken at—		Friction taken at—	
			1-5th.	1-10th.	1-5th.	1-10th.
					yards	yards
60	88	269,000	448	224	200	400
50	73½	187,000	”	”	138	276
40	58⅔	120,000	”	”	88	176
30	44	67,000	”	”	50	100
20	29⅓	30,000	”	”	22	44
10	14⅔	7,500	”	”	5½	11

From this it will be seen that a train travelling at 60 miles an hour cannot by any brake, however perfect, be brought to rest in a less distance than 200 yards in the most favourable weather, or in less than 400 yards in slippery weather. At the slower speeds the distance that would be travelled after the application of the brake is proportionately less.

At the same time, although a train travelling at 60 miles per hour could, with a theoretically perfect brake, be brought to rest in a distance of 200 yards, or a train travelling at 10 miles per hour, in $5\frac{1}{2}$ yards, it should be borne in mind that such a rapid reduction of speed would not only bring an injurious strain on the rolling stock and permanent way, but would be attended with very unpleasant if not injurious shock to the passengers, and therefore a rate of stoppage considerably short of what *might* be accomplished by the forces at command must be resorted to in practice.

The extent to which the forces available are brought into play in actual practice, and consequently the distance a train will actually run after the application of the brake (at any given speed), depends entirely upon the number of wheels fitted with brake-blocks, and the amount of pressure applied to each block.

As the pressure which can be applied to a brake-block depends simply on the relative proportions of the levers or other intermediate parts which transmit the force from the brake apparatus proper to the blocks (whether it be by the Westinghouse, the Woods, the Smith, or any other system), it is evident that the distance which will actually be travelled by a train after the blocks have been applied is not a matter of *first* importance in determining the relative merits of different systems of Continuous-brakes.

The most inefficient brake—inefficient in the sense of being costly to make, difficult of application, uncertain in its action, and expensive to maintain, but with its intermediate parts proportioned to force with great and even injurious pressure on the wheels—may bring a train to rest in half the distance that an infinitely better brake, under precisely similar conditions as regards speed and weight of train, might accomplish it, simply because in the latter case the length of some intermediate crank or lever was advisedly proportioned so as to keep the force on the blocks *more within the skidding point.*

If the actual distance travelled by a train in motion, after the application of the brake, be not the chief measure of the efficiency of a brake, what then are the special features or considerations by which its merits are to be determined?

The first and most important consideration for any brake and under all circumstances is its—

(1) ***Reliability.*** The next two, which are closely allied to it, are—
(2) ***Simplicity,*** and
(3) ***Durability.*** The fourth is—
(4) ***Promptitude in action.*** The fifth—
(5) ***Facility of application*** to existing stock, and the last—
(6) ***Moderation in first cost.***

Comparing the number and character of the fittings in the Woods and Westinghouse brakes, ***especially*** if worked ***automatically,*** I have no hesitation in saying that the former would be found considerably more reliable than the Westinghouse; and although the comparison would be less unfavourable to the latter if both systems were worked *non*-automatically—thereby getting rid of the triple valve in the Westinghouse brake, which is more liable to get out of order than the corresponding part of the Woods brake—still, the balance as regards reliability would, I think, rest even then with the Woods system, owing to there being no special pump in the Woods brake to get out of order, coupled with the greater ease with which any leak with water can be discovered and the joints and couplings maintained.

The number of moving parts of each system is as follows:—

	Engine.	*Each carriage.*
Westinghouse	24 ...	17
Woods	4 ...	15

and as the ***whole*** of the brakes would be thrown out of work by the failure of any of the engine's parts, the greater risk of failure with the Westinghouse in comparison with the Woods system is evident.

I look forward to the general application to our trains of the Westinghouse system, in the event of its being decided to adopt it ***universally*** (especially in its ***automatic*** form) with considerable misgiving as to the practicability of maintaining it at all times in satisfactory working condition. So far, it has given, on the whole, satisfaction; but it should be noted that our longest experience of it has been as a ***non***-automatic brake, the use of it ***automatically*** being limited to about three months.

Further, its application has been limited to comparatively few trains, in an experimental way, and as the carriages have worked to and from Sydney as one of the terminal stations, they have had the opportunity of being looked after, and any defects repaired, in an exceptional way, which could not be counted upon when the vehicles became more scattered by the opening of distant extensions.

The recent returns of the Board of Trade for the United Kingdom show that its more extended use on those lines where it is applied—more especially as an ***automatic*** brake—is attended with considerable and frequent inconvenience.

The Westinghouse couplings are especially liable to suffer by exposure to the sun and weather in this climate, and the slightest defect in any of the couplings of (say) horse-boxes or other vehicles, taken on an emergency from a siding where they may have been standing for weeks and months together, would be almost certain to prove fatal to the working of the brake throughout the whole train. The unions of the Woods brake, being of metal, are much less liable to injury from the above cause.

As regards ***durability,*** this, in the Woods system, is quite equal to that of the Westinghouse, when the working parts are made of gun-metal and copper, as has been provided for in the designs and estimates.

In ***promptitude*** the Woods brake is equal to any other, its action, like that of the Westinghouse, being practically instantaneous throughout the train.

In ***facility of application to existing stock,*** it is, as regards the carriages, equal to any other, and, as regards the engines, it excels the Westinghouse in not requiring the fixing of a special pump.

The ***first cost,*** as will be seen from the foregoing report, is about the same in each case, under the conditions on which the parts are manufactured and supplied.

The following are the amounts in detail :—

WESTINGHOUSE.

Engines.

Pump	£60
Fixing pump with pipes ...	10
3-way cock	3
Air-holder and fittings ...	15
	£88

Carriages.

8 sets of fittings, including couplings, air-holders, triple valves and cylinders, at £21 each	£168
Fixing ditto at £3 each ...	24
	£192

Total £280, or £35 per carriage.

WOODS.

Engines.

3-way cock	£3	5	0
Air-holder with pipes and fittings ...	20	15	0
	£24	0	0

Carriages.

8 sets of fittings, including couplings, air-holders, triple valves and cylinders, at £33 each	£264
Fixing ditto at £3 each ...	24
	£288

Total £312, or £39 per carriage.

NOTE.—This does not include, in either case, the cost of the brake gear—such as blocks, hangers, compensating levers or rods—which are not covered by the patent apparatus in either case, and are common to each system.

With the Woods brake, worked automatically, after a vehicle has been cut off from a train, there remains a store of energy in the apparatus which allows of the brake being put on and off several times before the force is expended, which cannot fail to be found of use in shunting the vehicle.

The air-vessels require to be re-filled from time to time, at longer or shorter intervals (varying from about three days to three weeks), according to the number of applications per mile run, but this can be readily and quickly done by the opening (and closing after a few minutes) of a small cock attached to the lower end of each air-holder.

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