Western Australia.
1946

Report of the Royal Commission

appointed to inquire into

Australian Standard Garratt Locomotive

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ROYAL COMMISSION

WESTERN AUSTRALIA, TO WIT.
JAMES MITCHELL, Lieutenant-Governor.
[L.S.]

By His Excellency Sir James Mitchell, K.C.M.G., Lieutenant-Governor in and over the State of Western Australia and its Dependencies in the Commonwealth of Australia.

To the Honourable Albert Asher Wolff, Puisne Judge of the Supreme Court of Western Australia.

Greeting—

I the said Lieutenant-Governor acting with the advice and consent of the Executive Council, do hereby appoint you the Honourable Albert Asher Wolff, Puisne Judge of the Supreme Court of Western Australia, to be a Royal Commission generally to examine and report upon all matters in dispute between the Commissioner of Railways and the Western Australian Locomotive Engine Drivers, Firemen and Cleaners' Union, with regard to the Australian Standard Garratt Locomotives; particularly to determine whether such locomotives fulfil all reasonable requirements from the point of view of safe, economical and satisfactory working, and, if not, to advise whether alterations and modifications are practicable to achieve such working, or whether such locomotives should be discontinued in use.

And I hereby declare that you shall, by virtue of this Commission, be a Royal Commission within the Royal Commissioners' Powers Act, 1902, as reprinted in the Appendix to the Sessional Volume of the Statutes for the year 1928, and that you shall have the powers of a Royal Commission or the chairman thereof under that Act.

And I hereby request you, as soon as reasonably may be, to report to me in writing the result of this your Commission.

Given under my hand and the Public Seal of the said State, at Perth, this 18th day of October, 1945.

By His Excellency's Command,

(Sgd.) F. J. S. WISE, Premier.

GOD SAVE THE KING ! ! !

ARRANGEMENT OF REPORT

Arrangement of Report—continued.

AUSTRALIAN STANDARD GARRATT LOCOMOTIVES

REPORT

BY THE

ROYAL COMMISSIONER

To His Excellency Sir James Mitchell, K.C.M.G., Lieutenant-Governor in and over the State of Western Australia and its Dependencies in the Commonwealth of Australia.

MAY IT PLEASE YOUR EXCELLENCY—

I have to report having carried out your Excellency's Commission of the 18th October, 1945, to examine and report upon all matters in dispute between the Commissioner of Railways and the Western Australian Locomotive Engine Drivers', Firemen's and Cleaners' Union with regard to the Australian Standard Garratt Locomotives ; particularly to determine whether such locomotives fulfil all reasonable requirements from the point of view of safe, economical and satisfactory working, and, if not, to advise whether alterations and modifications are practicable to achieve such working, or whether such locomotives should be discontinued in use.

Part I.

INTRODUCTION:

The use of the Garratt locomotive on the Western Australian Government Railways goes back to 1912, shortly after this type of engine was invented by the late Mr. H. W. Garratt, an English engineer. The patent was acquired from the inventer and developed by Messrs. Beyer Peacock & Co., Limited, Locomotive Engineers, of Manchester, who have had very wide experience in the design and manufacture of these locomotives. Of all types of articulated locomotive this type has proved the most popular and is extensively in use on narrow gauges in other parts of the world—on the Continent of Europe, in India, in Africa, and in South America. The Union of South Africa in particular has been running these locomotives, both in passenger and goods service, with marked success. The principle underlying the design is a central boiler slung on a frame with two engines, one pivoted fore and the other pivoted aft of the central cradle carrying the boiler. Each engine component has a water tank carried on its frame and the rear component also carries a bunker behind the cab, which is fixed to the rear end of the boiler unit. The design of the firebox and boiler is exceedingly simple and lends itself to a short but commodious firebox and a much shorter barrel than can be used in ordinary locomotive design. The design solves the problem which confronted engineers forty years ago—the problem of increasing tractive effort and yet keeping within the limits of rigid dimensions imposed by track conditions.

The Western Australian Government commenced construction of 10 locomotives of this type in 1928 (the earlier ones having been designed and manufactured by Messrs. Beyer Peacock & Co., Limited). Those built in 1928 followed closely the design of the locomotive which had been imported in 1912. The first Beyer-Garratt locomotive supplied by Messrs. Beyer Peacock & Co., Limited, was driven by saturated steam. Those of 1928 were superheated. In 1931 construction of a further 10 locomotives of this type, but heavier and with a greater tractive effort, was commenced at Midland Junction. These were also superheated. The first series was given the distinguishing letter "M," the next type in 1928 "MS," and the 1931 type "MSA." Some brief particulars of these locomotives are given :—

	M (1912–13).	MS (1928).	MSA (1931–32).
Weight	69 tons	70 tons	74 tons
Tractive effort at 80% B.P.	22,436 lbs.	24,488 lbs.	26,784 lbs.
Tons capable of hauling over ruling grade (1 in 45)	275	275	302

This Inquiry, of course, concerns the Australian Standard Garratt as distinguished from its predecessors of Garratt design used on the Western Australian Government Railways. But as some criticism was levelled at these older types I intend to deal shortly with them. The criticism voiced was faint and not sustained. There does appear to have been some justifiable complaint in regard to the degree of heat developed in the cab but that is a matter which could easily have been corrected. I have no hesitation in saying that whatever evidence there is points very favourably to these older types and to their design in general.

In the Commissioner of Railways' Annual Report for 1913–1914 it is recorded that—

> During the wheat season the Garratt engine was utilised with great advantage on light agricultural lines and proved most suitable for hauling the heavy loading then offering.

and in the Annual Report for the year 1931–1932 (page 11) the following appears :—

> The MSA Garratt locomotives, which were constructed in the Midland Junction Workshops, have been most useful on the branch lines in bringing in the wheat harvest, the high tractive power being most beneficial in hauling heavy loads on the light lines.

In 1912 a letter was written by the Union to the Chief Mechanical Engineer complaining that the locomotives were not suitable for long runs as they caused long hours on duty and consumed an excessive amount of coal. It was complained that an extra truck had to be pulled behind the engine in order that sufficient coal might be available for the journey. There was a request for extra preparing time and stabling time, which was granted on account of the larger size of the engine and the greater detail to be attended to. The request seems to have been reasonable and to have been reasonably received. The letter went on to say that the men found no fault with the engine. Presumably this related to the mechanical performance of the locomotive, *i.e.*, its steaming and pulling power. There may have been some initial difficulties when these locomotives were first introduced, but in the long run both the Union and the Commissioner seem to have accepted them as giving a satisfactory performance.

In Tasmania, the Tasmanian Government Railways commenced to use the same type of locomotive in 1912 and general satisfaction has been expressed with their performance. Here again there is evidence of some complaint regarding heat conditions in the cab, but this complaint does not appear to have been formally brought before the Administration. It was only in recent years that the Chief Mechanical Engineer of the Tasmanian Government Railways noticed the condition and took some remedial steps.

The Garratt type locomotives possess the feature of being able to run to intermediate stations and return for loading without the necessity of turning, owing to their double-headed construction. They have a marked advantage in haulage capacity over other heavy types in vogue at the time they were introduced.

Owing to the financial depression of the 1930's construction of locomotives of this type had to be discontinued. Since 1934 the history of locomotive stock on the Western Australian Government Railways has been a matter of "making do." The proportion of old locomotives to total stock has gradually increased. The economic life of a locomotive is generally accepted as 30 years, and when it is remembered that at the beginning of the recent war slightly over 84 per cent. of the locomotives had been 30 years or more in operation it will be seen how serious the situation was.

When war broke out in 1939 the Commonwealth Land Transport Board, a Commonwealth body formed for the organisation of land transport, came into being under National Security Regulations. With the entry of Japan into the war Australia's transport system has taxed to the extent of disorganisation. There was a Commonwealth-wide shortage of locomotive stock and the position was complicated by the different gauges in the States. The Commonwealth urgently called for 26 locomotives from this State for use in the Northern Territory and the State sold 26 shunting engines to the Commonwealth. The locomotive stock position of course became much worse than before.

In 1942 the Commonwealth Land Transport Board appointed Mr. J. A. Ellis, M.Inst.C.E., Commissioner of Railways in Western Australia, to go into the question of the carrying capacity of all the 3ft 6in. gauges in Australia and to consider the building or acquisition of locomotive stock for use on those gauges. The position was particularly acute in Queensland and Western Australia, the two States where the impact of war with Japan was most likely to be felt. It became necessary to consider what type of engine or engines would be best suited to do the work of transporting materials and troops to places where they might be required. In this State the amount of traffic over some of the lines had reached saturation point and the position in Queensland was equally as bad.

In considering the problem many factors had to be borne in mind. Some of the more important are—

The general design and construction of the tracks and bridges over which the engines would have to pass, the weight of rails, the nature of the ballast, and the curves likely to be encountered. Considerations of this nature limit the load which may be placed on a pair of wheels, and the concentration of loads on sets of wheels, a matter which in turn has a bearing on the distribution of the weight of the locomotive over the axle system and spacing of the wheels.

Any special regulations of the several States limiting the maximum distance between centres of coupled wheels, including limitations on rigid wheel base due to restrictions brought about by curves.

The maximum number of coupled wheels which engineering experience shows it is desirable to have.

The relation between the tractive effort and the frictional resistance between the wheels of the locomotive and the rails. Frictional resistance must in practice be greater than the tractive effort, otherwise the wheels simply slip on the rail and the effort is wasted. Experience shows that if the ratio of adhesive weight of the locomotive is less approximately than four times the tractive effort slipping is likely to occur.

The question of weight is of paramount importance. If a locomotive is designed with a distribution of weight so disposed that a greater weight is put on the wheels than the permanent way is intended to bear there is a danger of the track collapsing.

In Queensland the limit of rigid wheelbase is 12ft. 6in. Any design which conformed to this restriction and also limited the coupled wheels to this wheelbase would need to make provision for increased axle loading and that in turn might frustrate the designer's purpose because conditions in Queensland necessitated an axle load not exceeding 8½ tons. The first essential would therefore appear to be to spread the load over as many axles as possible in order to reduce the weight on each axle and yet keep within the limit of rigid wheelbase. In that State there are many lightly constructed bridges and any proposal to increase loads above what these bridges had been carrying had to be approached with caution.

The Australian Standard Garratt has a distance between coupled wheels of 13ft. 6in. This is one foot in excess of the maximum distance prescribed in Queensland. The leading coupled wheels are flangeless. The avowed object of making these wheels flangeless was to give the locomotive greater ease in riding around severe curves and comply with Queensland limitations regarding rigid wheelbase, because as the distance between centres of coupled wheels of each engine of the locomotive is 4ft. 6in. and the rear wheel and the wheel next to the leading unflanged wheel are both flanged, the rigid wheelbase is therefore 9ft. The details of the wheelbase will be discussed later. Then again, from an economic point of view it is desirable to concentrate in the one locomotive the greatest practicable tractive effort so as to be able to haul greater loads, thus reducing the number of trains over a particular line or lines in a given time.

The articulated engine provides the answer to the problem, for while possessing ample firebox and boiler dimensions sufficient to develop a high tractive effort, articulation enables the spreading of the load over the axles and permits the locomotive to negotiate curves and operate on heavy grades and over a wide variety of tracks both heavy and light.

There were further problems to be considered in designing a locomotive or locomotives for use in the various States having the 3ft. 6in. gauge. For example, maximum drawbar load, difference in coupling designs, braking equipment on the trains, tyre profile, and system of rail laying ; the 3ft. 6in. gauges in Queensland and in Central Australia do not have their rails canted inward as is the case with the 3ft. 6in. gauges in Western Australia and Tasmania.

After consideration, Mr. Ellis recommended the building of three types of locomotives on the Garratt principle—a heavy, a medium, and a light type, but eventually the Commonwealth Land Transport Board decided on the building of the lightest of the three types, to be designed for an axle load of 8½ tons, which would conform to Queensland conditions. The tractive effort was to be about 34,000 lbs. The purpose was to build a locomotive to work on any 3ft. 6in. gauge in Australia. It was an ambitious project and the first of its kind to be undertaken in Australia. It would be hard to find a case where so many complications have entered into the hurried production of a locomotive. Had a locomotive been built specially to meet the needs of Western Australia a much greater axle load could usefully have been provided, viz., approximately 11¾ tons, and this in its turn would have permitted an increased tractive effort approximating 46,000lbs. and a total weight of the locomotive of 186 tons.

The locomotive which was designed and built has many radical features about it, which will presently be discussed. The locomotive built to the design which was adopted has a sufficiently low axle load to permit it to travel on almost any part of the railway system in Western Australia. This is a special virtue which has been claimed for it, although I cannot help feeling that there are a great many stretches of line where it cannot be usefully and economically employed and that the heavier axle load would have been a far better proposition in this State.

Before it was decided to build the locomotive in Australia to an Australian design an approach was made to Messrs. Beyer Peacock to ascertain whether that company could produce the locomotive. Cabled communications took place from April to July of 1942, but nothing eventuated. Messrs. Beyer Peacock offered to build locomotives to two designs, one at £20,000, and the other (the Kenya type) at £26,000, English currency. This offer was refused as the price was thought to be too high. Messrs. Beyer Peacock were asked in June, 1942, to quote for a set of working drawings for the Kenya type and in reply they offered to supply drawings in from four to six weeks at a price of £5,000 sterling London with order, and a fee of three English pounds per ton, empty weight manufacture. They urged that whatever was done they should have control of design and drawings. Messrs. Beyer Peacock's offer to supply working drawings was not accepted, and on the 31st July, 1942, the Commonwealth Land Transport Board recommended to the War Cabinet that it undertake the design and building of 30 locomotives of the type which had been decided on. At this time materials were in short supply ; neither materials nor locomotives could be got from America on lend-lease as America was allotting priority to centres of war where help was more urgently needed.

From all appearances an outline drawing (of a type of locomotive numbered 120328) which had been supplied by Messrs. Beyer Peacock some years previously to an Australian Railway Administration, was the basis for the locomotive design which was eventually adopted. I do not want to be misunderstood here, because the only indication the designer (Mr. Mills, the Chief Mechanical Engineer of Western Australia) had was the outline drawing and there is no evidence that any particular features of design of this type of locomotive went into the design of the Australian Standard Garratt. Mr. Mills, who was appointed Designing and Constructing Engineer of the Commonwealth Land Transport Board and Controller of Rolling Stock, was entirely responsible for the design.

On the 12th August, 1942, the War Cabinet approved of the construction of the locomotive on condition that the Commonwealth Land Transport Board should be responsible for design and inspection and the Ministry of Munitions should be responsible for construction.

The States of Queensland and Tasmania and the Commonwealth Railways did not accept the proposal with any enthusiasm.

It has been said that the decision to build an Australian Standard Garratt locomotive was in reality the individual decision of the Chairman of the Commonwealth Land Transport Board (Sir Harold Clapp) (see the evidence of Mr. Wills, Commissioner of Railways in Queensland). Mr. Wills avers that the decision was only nominally the decision of the Board. But I am interested only in so far as the matter affects my inquiry. At the same time it is noteworthy that Mr. Wills, who all along maintained an active opposition to the Australian Standard Garratt, stated that before it was decided to build the locomotive a decision had been reached at a conference of Mechanical Engineers constituting a sub-committee of the Commonwealth Land Transport Board, that a number of C17 locomotives—a proved type in Queensland—should be built for the Queensland railways, but this decision was not adopted by the Board. Mr. Wills's argument was that the proposed ASG was experimental, that it was intended as a war engine, and that it would have no utility value after the war. He considered that the proposal to build so many locomotives to a design which was complicated by many unusual features was a reversal of sound practice.

One feature of the design of the ASG which is of paramount importance is the designer's method of dealing with the problem of weight distribution. The total weight planned was approximately 119 tons —much the same weight as the Beyer-Garratt type 120328. It was necessary however to make more ample provision for the carrying of additional supplies of coal and water over the Central Australia railway, where coaling and water facilities are infrequent. To do this the designer added a more commodious bunker and larger water tanks. These, as I have explained, are carried on top of the engine frame. The firebox was increased in size and the barrel of the boiler was also enlarged, thus adding further weight. The total additional weights thus added to the upper structure amounted to about 9½ tons and this weight had to be got rid of by reducing the weight of the under structure and the movement. For example, the thickness of the plates used for frame stays was reduced, holes were cut in the sides of the boiler cradle frame, holes were cut in the main plates of the engine frames, and some of the control rods were made hollow instead of solid. The reduction accomplished by this means is, according to engineering standards, a radical departure from orthodox design, not so much from the point of view of the methods employed or as regards a mere reduction in weight, but more importantly from the aspect of the large aggregate of reduced weight.

On the 30th November, 1942, it was decided to increase the number of ASG locomotives to be built to a total of 65. Difficulties arose in connection with the manufacture and assembly. Ultimately the manufacture of various components was spread over no less than 105 different shops in the Commonwealth. Assembly points were arranged at the railway workshops at Newport, Victoria ; Islington, South Australia ; Midland Junction, Western Australia ; and the Clyde Engineering Works in Sydney, New South Wales. Normally when an engine is designed only one of the type is produced and it is put into traffic for perhaps several years before others are manufactured. In this time it is studied and an opportunity is gained to correct defects which show up. A locomotive is so much a matter of compromise in design, and different designs are so prone to show individual idiosyncrasies, that it would be foolish to endeavour to mass produce a type under a new design. There was, however, no time to follow the normal procedure if the locomotives were to serve their purpose.

Again, in ordinary circumstances, it is advisable that as much of the locomotive and its components as possible should be made by the one manufacturer, otherwise there will be inevitable differences notwithstanding that the design is allegedly uniform for all.

The first locomotive of the series was in steam within 12 months of starting the design. It was put into service in Queensland in September, 1943, but by that time the peak loading in Queensland and in Western Australia had been reached.

When giving his evidence Mr. Mills, the designer, stated that Queensland would give no assistance either in connection with the design or the construction of the locomotive, but that Tasmania had agreed that certain locomotives that were being built to its order with the Clyde Engineering Company of Sydney should be set aside. Mr. Mills could not have known the true facts when he made this statement. It is quite clear from records which I saw that the Tasmanian Government was compelled to accept the position. The facts are that the Tasmanian Government had placed an order with the Clyde Engineering Company for the building of four Q locomotives at £18,690, delivery F.O.B. Launceston. The contract was made in February, 1940, and the Tasmanian Railways anticipated getting delivery, two in May, 1941, and the other two in September 1941. War conditions and high priority work compelled the company to put aside the work of construction of these locomotives. Subsequently, in September, 1941, after pressure from the Tasmanian Government, the Tasmanian Railways got priority for material required in the construction of the locomotives, but still delivery was delayed. In March, 1942, the Premier of Tasmania took the matter up with the Minister for Munitions, but he was advised that although the Tasmanian Government had a defence priority for material it had none for construction. In March, 1943, delivery was still delayed, it being found impossible to get any progress with the work unless the contract was placed on the same basis as munitions work, that is to say, on a cost plus basis. The Transport Commission of Tasmania then agreed with the company to vary the contract to provide for the price being based on cost plus. That, the Commission states, was very much against the grain but it was all that could be done, yet despite the arrangement, in September, 1943, progress was still unsatisfactory because of the continual setting aside of the work in favour of the ASG's which were being constructed at the Clyde Company's works. After consideration the Commission instructed the General Manager of Railways in Tasmania to examine the position to see whether the uncompleted locomotives could be taken over and completed in the Tasmanian Government Railway Workshops. The first two uncompleted locomotives arrived in Tasmania in November, 1943. At the same time arrangements were made between the Commissioner of Transport in Tasmania and the Commissioner of Railways in New South Wales for eight locomotive fitters to be made available from the New South Wales Railway Workshops to the Clyde Engineering Company to assist in completion of the other two locomotives. The Ministry of Munitions, however, directed that these men should be transferred to the building of the Australian Standard Garratts. The additional two locomotives were delivered to Tasmania in an incomplete condition between March and December, 1944.

It will thus be seen how little there was of agreement on the part of the Tasmanian Government. The result has been, as regards the cost of the Q locomotives, that the Tasmanian Government has been involved in a claim by the Clyde Company for £32,000 for each engine, and with a further considerable sum to complete construction in its own shops. The probabilities are that the price of each of these locomotives to the Tasmanian Government when ultimately completed will be approximately £34,000, and in addition to that the Government is faced with the obligation to pay interest on the additional loan moneys which will be used in financing the purchase.

The Commonwealth Railways, which were to be given 30 of these locomotives, were also disinclined to take them. In actual fact they never did take any as they had handled the peak loading before the ASG's became available.

At this stage it will be convenient to give a short description of some of the principal features of the ASG locomotive. The outline drawing in Appendix I. shows the general dimensions. It will be seen that there are two sets of four-coupled wheels on each engine. The boiler unit is slung on a cradle with the cab and controls at the rear end. The two engines are shown in outline, one at the front of the boiler and the other at the rear. The rear component carries the bunker and a water tank behind the bunker, and the forward component carries a water tank of larger dimensions. All the principal dimensions are shown on the outline drawing. The driving wheels of each engine are four feet in diameter and are 4ft. 6in. between centres. The first and third sets of coupled wheels, counting from either end, are flangeless. The distance between the coupled wheels is therefore 13ft. 6in., but the rigid wheelbase, it will be seen, is 9ft. At the forward end of each set of coupled wheels is a bogie unit, which is swivelled at the end of the boiler cradle by means of a pivot. The bogie is a four-wheeled bogie. At the rear of each set of driving wheels are two pony wheels. The arrangement of wheels is therefore 4–8–2–2–8–4.

In Appendix II. is a general arrangement drawing of the locomotive. In Appendix III. there is a photograph of the locomotive. In the drawing in Appnedix II. and in the photograph in Appendix III., the equipment for Westinghouse brake is shown. That feature is not applicable in Western Australia, where the vacuum brake is used on the train.

Appendix IV. is a diagram of the ASG locomotive standing on a four-chain curve. The pivot centres which are designed to allow, first the forward engine, then the boiler and cab, and then the rear engine to work freely around the curve are shown. The bogie at either end is designed to act as a guiding medium when the locomotive is rounding a curve. When going round a curve, severe forces are exerted by the flanges of the driving wheels against the outer rail of the curve and the tendency of the forces developed is to throw the locomotive centrifugally outward. If all the wheels of each engine component were fixed to one rigid frame it could not negotiate sharp curves, so the bogie serves the purpose of carrying portion of the weight of the engine, and by a swivelling device at the centre of the bogie which permits it to turn on its own axis, the engine is enabled to ride around curves. But the bogie also serves to counteract the tangential forces developed by the rigid unit it assists to carry. The weight and strength of the bogie frame and the means adopted to counteract any tendency by the flanges of the coupled wheels to side-thrust against the outer rail of the curve must be considered. In some cases the bogie is designed so that as the flanged wheels of the rigid unit exert their side-thrust on the outer rail of the curve, so the counter force exerted by the bogie increases. There is another type of bogie in which the resistance remains constant and this seems to be more favoured in the other Australian States. I think that the better opinion prefers the constant resistance type. The variable resistance type is fitted on the Australian Standard Garratt. The resistance is controlled by left and right springs enclosed in slides which operate transversely at either side of the bogie centre. When sufficient force is exerted by the rigid component behind the bogie to the right the spring on the righthand side is gradually depressed, and vice versa when the force is exerted on the left the spring on the lefthand side is gradually depressed, and so in theory, at any rate, the bogie should counterbalance the tangential force developed at the flanges of the flanged wheels. The success of this design depends largely on the effective behaviour of the spring and slide and as both are out of sight, and difficult of access, the design is open to serious objection.

To get proper results from the bogie, whatever the type, care must be practised in designing the frame, to give it the requisite weight and strength and effective resistance at its centre.

The bogie on the ASG was designed for a maximum throw-over of four and three-eighth inches on either side. That throw-over was to accommodate curves in Queensland. Had the bogie been intended for use in Western Australia, a much less displacement could have been provided. The sharpest curve the locomotive would be called upon to negotiate in Western Australia has a radius of five chains, with a maximum widening to guage of three-quarters of an inch. In these circumstances, three and a half inches of side movement at the centre of the bogie would have been sufficient provision.

The pivot centres are arranged with the female portion underneath and the male portion on top. When these two portions are put together it is not expected that they should need attention for some years. Provision is made for the insertion of oil in the lower portion of the pivot. A felt liner is provided between the two portions for the purpose of making an oil-tight joint. The theory is that the lubricating oil should not become contaminated and that it should work effectively until the time of major overhaul, which means really that the oil should do its work and the pivot should not need inspection for about three years.

There were many features of economy in the design and construction of this locomotive. I list some of them :—

- Cast iron box pistons ;
- Separate cast iron horn blocks in lieu of the heavy monobloc steel castings frequently used ;
- No axle box wedges ;
- Springing not compensated—a most unusual feature with a locomotive of this size ;
- Crank pin bearings with solid bushes and without means of adjustment ;
- Rigid firebox stays and crown stays ;
- Cast iron pivot centres ;
- Cast iron bogie centres ;
- I have already referred to the use of steel plates in the frame and the measures adopted to curtail weight.

The outline drawing in Appendix I. indicates that the bunker and water tanks are placed relatively high and something more will be said with regard to this feature later.

The maximum speed which this locomotive should be able to attain, free of any special restrictions brought about by track limitations or conditions of loading, is 45 miles per hour.

I have already mentioned that the first locomotive came out of Shops in September, 1943. By about November, 1943, the locomotives were in steam in Queensland, Tasmania and Western Australia. As early as July, 1944, complaints arose in regard to various features of the locomotive involving major details of design, including the strength of structure as well as mechanical matters. These were discussed at a meeting of a sub-committee of Mechanical Engineers of the Commonwealth Land Transport Board held in Melbourne on the 28th July, 1944, at which the designer, Mr. Mills, was present. The resolutions passed at this meeting are set out in Appendix V.

By November, 1944, the several States mentioned had had more experience of their performance. The Queensland attitude towards the locomotives was definitely hostile. Tasmania was unwilling to take any more until modifications had been made to the structures. The various complaints in general were voiced at a special meeting of the Commonwealth Land Transport Board held in Canberra on the 7th November, 1944. The meeting was dealing primarily with the completion of the programme of construction of the locomotives. It also discussed what modifications should be made in the design of locomotives already in service and in those yet to be completed. The Chief Transport Officers of the various Australian systems were represented. A number of the locomotives had not been commenced, but it was thought that it would be cheaper to have them built than to pay compensation moneys to contractors. I have reason to believe that the Commonwealth then had the locomotives in the market for sale and efforts were made to sell them abroad as well as within the Commonwealth. There were apparently no buyers abroad and the States were pressed to purchase. Up to this time the locomotives had been leased by the State systems from the Commonwealth. But, as already pointed out, they came too late to serve their purpose.

Against the hostile attitude of Queensland and the lukewarm attitude of Tasmania, a Western Australian representative at this conference declared that the locomotives had given satisfaction in Western Australia and that no difficulties had been experienced there. There is ample evidence that difficulties and objections had been raised in Western Australia and I cannot understand how such a statement could have been made.

At this time the Commissioner of Railways of Western Australia had recommended to the Government the purchase of ten ASG locomotives which were then in service under lease from the Commonwealth, and shortly afterwards he made a recommendation that fifteen additional locomotives should be bought. It is clear that the Chief Mechanical Engineer (Mr. Mills, the designer of the locomotive) and the Chief Traffic Manager of the Western Australian Government Railways (Mr. Evans), had no hesitation in supporting the recommendation. The Commonwealth at that time was asking approximately £18,000 for each locomotive and these two officials thought that by comparison the with S class locomotive, one of the newest and most powerful engines on the State system—which cost £16,000—the ASG locomotive was good buying. Subsequently, it seems, by the use of various arguments, the purchase of the locomotives was arranged at £12,000 each. The Chief Traffic Manager stated in evidence that he was so satisfied wtih the locomotive that on the 27th July, 1945, in a joint report with the Chief Mechanical Engineer he recommended the purchase of an additional five. Up to date the State has acquired twenty-five from the Commonwealth and the purchase of the additional five is in abeyance.

From the time of the introduction of these ASG locomotives into the Western Australian railway system difficulties and complaints arose. Much the same complaints had arisen in Queensland and these were known to the Western Australian Railway Administration.

On the industrial side the Union from time to time voiced complaints regarding the inefficiency of the locomotive and the inconvenience of the various appliances. The whole matter forms the subject of lengthy correspondence between the Commissioner of Railways and the Union and the Minister for Railways and the Union, and several deputations to the Commissioner and to the Minister. Certain incidents conduced to bring matters to a head. One related to the death of Fireman Whitmore at Karrakatta on the 12th September, 1944. There is no distinct evidence as to how this fireman was killed but it appears more than likely that he was struck by an open door of a carriage of a train coming in the opposite direction, when he was leaning out of the cab of an ASG locomotive. The second cause of industrial trouble arose in regard to the taking of the ASG locomotives through the Swan View tunnel. This tunnel was constructed many years ago and provides very little clearance for a modern locomotive. In the case of the ASG the distance between the sides and top of the locomotive and the structure of the tunnel is a matter of inches. There had already been cases with smaller locomotives (some fatal) of carbon monoxide poisoning due to the inhalation of fumes by engine crews. The danger of poisoning became accentuated with the introduction of the ASG locomotive, and as the Department was insistent that the engine should be worked through the tunnel, a stoppage of work resulted, and further trouble was averted only by building a deviation. In the meantime traffic of all ASG locomotives through the tunnel in the " down " direction (*i.e.*, away from the port) ceased.

These cases will serve to illustrate some of the more serious incidents that led up to the present dispute. The contention of the Commissioner of Railways is that the real motive of the Union in taking objection in various forms to the design and behaviour of the locomotive is a rooted opposition to the working of a big and powerful locomotive which will inevitably have the effect of displacing labour. That contention deserves some examination and at the conclusion of this report I shall deal with it.

The ambit of my inquiry really embraces everything in connection with the structural and mechanical efficiency of the locomotives and their operation and safe-working. Put briefly, the Union as a body complains that the locomotives are large and unwieldy to work, that they are uneconomical in operation, and just before this dispute crystallised, a definite allegation took shape that they were unsafe, principally by reason of the fact, so the Union contends, that the leading flangeless wheels have a tendency to derail both on straights and on curves, even at slow speeds. This allegation of unsafety was developed on other lines as well, one being that the locomotive was too wide, another that visibility from the cab was restricted, more especially by a tendency to steam blows from steam pipes, etc., and there is a further contention that the brake is faulty.

Part II.

CONDUCT OF INQUIRY.

Before entering on this Inquiry I asked the Commissioner of Railways and the Union to furnish me with a statement of their respective contentions, much in the same form as issues take in a court of law, so that I could have a guide as to what was in dispute. Although the inquiry which I have conducted has been principally along these lines, I have at no time lost sight of the fact that it was an inquisitorial proceeding and not an action at law, so that in fact the burden of proof must not be regarded as being on either the Commissioner or the Union. It is true that in view of the allegations having been made by the Union I requested the Union to have available in the first place all evidence which it desired to bring before me so that the Commissioner might have an opportunity of answering, and generally the inquiry proceeded along these lines. As the matter is of a technical nature I intimated that I did not desire counsel to assist me, but I did permit lay advocates to propound the views of the Commissioner of Railways and of the Union.

The issues formulated are as follows :—

Union's Contention.	Department's Answer.
Firstly—THE ENGINE IS *UNSAFE* FOR THE FOLLOWING REASONS AND OTHERS :—	
1. The steam brake is unreliable in an emergency, owing to condensation in pipes and brake cylinders.	1. The steam brake is efficient and reliable—special action is being taken to minimise condensation.
2. The steam brake power decreases with decrease in boiler steam pressure. (*See* 11.)	2. This is admitted, but safety is not impaired.
3. The leading driving wheels are flangeless, making the engine liable to leave the rails.	3. The fact that the leading driving wheels are flangeless does not render the engine liable to leave the rails.
4. The excessive length of the wheel base, plus the heavy wieght of the engine, causes much stress on rails on curves, damaging the road.	4. This is contrary to actual experience.
5. The excessive width of the engine is a danger when passing other trains or bridges or shed doors, etc.	5. The width of the engine is within the loading gauge and therefore is not dangerous.
9. The reversing gear, upon which a driver often has to depend to stop an engine in an emergency, is unwieldy.	6. There is gross exaggeration in the statement that a driver has often to depend upon the reversing gear to stop an engine. Though the Department does not regard the reversing gear as unwieldy, an engine has been fitted with a special reversing screw which requires only half the number turns. Extension of this modification to other engines has been prevented by the Union.
7. The regulator cannot be regulated, except with difficulty. This means that sometimes less steam is admitted to cylinders than intended and sometimes more. This is dangerous during shunting operations and at other times.	7. This is denied.
8. Steam blows, inherent in Garratt type locomotives, interfere seriously with crew's visibility.	8. The statement that steam blows are inherent in Garratt type locomotives has no foundation in fact and is an unwarranted aspersion on locomotives not known by the Union. The Department admits that there has been cause for some complaint due to steam blows on ASG engines but has taken special remedial action and asserts that satisfactory results are being obtained.
9. The bulk of the engine, when engine is moving forward, restricts the crew's view of the road directly ahead. When moving backward, the coal tender restricts view.	9. Visibility is not restricted.
10. The difficulty of sensitively manipulating the regulator causes jerks to train, with the possibility of injuring passengers and guard.	10. This appears to be repetition of No. 7 and the con tention is denied.
11. The unpredictability of the behaviour of the steam brake, combined with the vacuum when stopping train, also causes bumps to train, with the possibility of injuring passengers and guard.	11. Brake operation has proved satisfactory.
12. When train is rolling (*i.e.*, regulator closed) upon undulating road the weight of the engine causes alternatingly excessive strain and retardation on couplings causing jerks and bumps.	12. The weight of the engine is not responsible for jerks and bumps.
Secondly—THE ENGINE IS UNWIELDY AND IRKSOME TO OPERATE.	
Besides the unwieldiness of the various parts of the engine being a danger, it also greatly adds to the labour of the crew. It causes irritability, fatigue, and nerves. The engine and its parts are unwieldy and irksome in so many ways it is hardly possible to separate and enumerate them. It can be said that the levers operated perhaps 100 times a day by both the driver and fireman almost all require exertion of strength and the use of two hands and sometimes a foot. The engine is a double engine, therefore the driver has practically double the worry over the various parts. He has a double number of oiling points and of moving parts which can run hot or become defective. The fireman has to maintain steam and water for two engines therefore he has to work excessively. About half way through his shift, when he is beginning to tire, the coal has become out of reach, therefore he has to get into bunker and shovel it down—meaning he has to shovel it twice. To get into bunker he has to wait until engine is stationary, then get down on to ground, then climb a ladder and *vice versa* to get back into cab, then put his fire on and be ready to go. It is all tiring. And while he is doing this shovelling the driver's and the guard's watch are checking his time, so he works frantically.	This is no more than a general statement of opinion with which the Department does not agree. The work required of enginemen on ASG engines is no more exacting or laborious than on other engines.

UNION'S CONTENTION.	DEPARTMENT'S ANSWER.
Thirdly—THE ENGINE IS UNECONOMICAL.	
1. The engine weighs 119 tons, therefore it has always 119 tons to haul before it couples up to its train which, of course, reflects itself in the coal and water consumption.	1. The weight of any engine is necessarily in proportion to its tractive effort. Extra tractive effort compensates for extra coal and water consumption.
2. The engine, by far more often than not, runs with only a part of a load because :—1st—Full load is not always available ; 2nd—Sixty-two in length constitutes the maximum train length allowed in these railways, and when the vehicles are empty or light loaded the train could be hauled by a much smaller engine ; 3rd—Eight hundred and fifty tons constitutes the maximum drawgear load allowed in these railways ; 4—Bunker does not carry sufficient coal to enable a full load always to be hauled.	2. 1st—This applies to all classes of engines. 2nd—Empty haulage is inseparable from railway operation. There are many sections where no other engine than an ASG can haul 62 vehicles. 3rd—There are few sections of the railway where even an ASG can haul 850 tons. 4th—The bunker capacity is sufficient for normal operation.
3. Though the locomotive has only one boiler and firebox it is a double engine, *i.e.*, it has four cylinders instead of the usual two, therefore it is generally using more steam, which reflects itself in the coal and water consumption.	3. The use of one boiler and firebox in place of two is an obvious economy.
4. It is a superheated locomotive but the steam pipes to front and back engines are so long that the steam has lost much of its temperature by the time it reaches the cylinders, therefore it is not as expansive as superheated steam should be, therefore more steam is required to operate the engine, which reflects itself in coal and water consumption.	4. This is merely a statement of opinion and is disagreed with.
5. The engine parts so frequently break or become defective that mechanics are constantly in demand to effect repairs, which must be extremely costly.	5. Breaks of or defects in engine parts due to fair wear and tear are not excessive and maintenance is not excessive.
6. The engine steams poorly, causing excessive use of blower and so of coal and water.	6. This is denied.
7. Delays due to breakdowns and defects are probably the costliest feature of this engine. It is impossible to calculate the loss to consignors, consignees, passengers, and the community generally, of railway delays. It is not even possible to calculate the more closely related costs of a delay, such as the added wages to be paid to the train crew, because one train running late will probably block or otherwise cause other trains, perhaps many, to be late.	7. This is a repetition and expansion of Item 5 and is similarly answered.
8. The ASG engine uses at least twice as much oil as any other.	8. Oil requirements are not excessive.
9. Driver and fireman are allowed 30 minutes extra to prepare and 15 minutes extra to stable this engine than most other types, which adds to wages costs.	9. Despite the impost, which applies to all Garratts in this State and which the Department does not concede as being reasonable, the ASG locomotive is economical in operation.
10. The unwieldiness of this engine has caused bumps and damage to other engines and vehicles which have had to be repaired, adding to costs.	10. Damage has not been caused by the engine itself but by incorrect operation of it.

The foregoing is a brief summary of the Union's case against ASG engines.

In addition to the grounds we have outlined, we say that no railway system which tries to give efficient service should tolerate an engine so generally unsatisfactory as this. The delays these engines cause must frequently throw the delicate railway mechanism out of gear. A delay to a train in one part of the railway system can possibly cause delays to other trains in any part of the State's 4,000 miles of railway. The locomotive is the vital part of the mechanism and reliability should be the locomotive's acid test. It is the considered opinion of the members of this Union that the outstanding characteristic of the ASG is its unreliability. We have no suggestions now to offer whereby these engines might be kept in service. They are inherently a failure. All that can be done to obviate their costs being a complete loss is to utilise as many of their parts as possible in the building of single engines.	This is general comment. The Department maintains that the engine is safe, satisfactory, and economical.

It will be noticed that in the allegations made by the Union it is stated that on account of various specified matters " and other matters " the engines are unwieldy, dangerous and uneconomical to work. This " et cetera " ground was not developed in any specific way, and the whole inquiry in Western Australia turned on the specific allegations already enumerated, although I wish it to be borne in mind that I have not tied myself down to these items, but have taken into consideration evidence which I obtained from all over Australia and any matters which developed as a result of my investigations, and these will be found mentioned and elaborated in this report.

In addition to calling evidence it early became obvious that certain tests and inspections would necessarily have to take place. I made inspections and running tests of the Australian Standard Garratt locomotive, both alone and in conjunction with older locomotives. These comparative tests were made because the Union contended that older locomotives which the ASG displaced were giving a better performance. Some of the most recent locomotives apart fr m the ASG were also tested and the weight and importance od these tests will be noticed later when I come to deal with this aspect in more detail.

I have had the advantage of hearing, and formulating a judgment on, the evidence of foremost locomotive engineers in Australia. I have been personally present at inspections and on some of the tests of a more general nature in order to gain first-hand knowledge of the locomotive. I have also driven one of the locomotives under the supervision of a driver, in order to get a better idea of the efficiency of the various appliances.

I took evidence—

At Perth, between the 5th November, 1945, and the 20th December, 1945 ;
At Bunbury on the 11th December, 1945 ;
At Melbourne on the 14th February, and on the 1st and 2nd April, 1946 ;
At Brisbane on the 22nd February, 1946 ;
At Ipswich (Queensland) on the 25th February, 1946 ;
At Rockhampton on the 1st March and 2nd March, 1946 ;
At Sydney on the 12th March, 1946 ;
At Hobart on the 15th March, 1946 ;
At Launceston on the 22nd March, 1946 ;
At Adelaide on the 12th and 15th April, 1946.

The following witnesses were called by me in Perth, at the instance of the Union—

Alexander Ross Davies, General President of the Union ;
William Lot Theodore Yeoman, Packer and Trimmer, East Perth Running Sheds ;
George Ponsonby Napier, Fireman, East Perth ;
Robert Leonard Innes, Washout man, East Perth ;
Robert Roy Dunn, Driver, Perth-Brunswick ;
John William Rickaby, Shed Driver, East Perth ;
Ernest Melville Renner, Driver, East Perth ;
Maurice Galvin, Driver, South-West ;
Leslie Maskew, Driver, Midland Junction ;
Joseph Edward Mildern, Driver, Midland Junction ;
Joseph Walter Leslie Matthew, Driver, Bunbury ;
Thomas John Charles Mezger, Driver, Narrogin ;
William Hosford McAuliffe, Guard, Perth ;
Arnold David Flanders, Driver, Northam ;
Theophilus Kissick, Queensland Government Railways ;
Samuel Charles Sharpe, Driver, Northam ;
Mervyn Frederick James Doig, Fireman, Pinjarra ;
Thomas Priestman, Driver, Midland Junction ;
George Bolton, Driver, Kalgoorlie ;
Francis Brady, Driver, South-West ;
Robert Sylvester George Price, Driver, Narrogin ;
Walter John Kirk, Driver, Bridgetown ;

and the following were called by me at the instance of the Commissioner of Railways—

Royston Macauley Evans, Chief Traffic Manager, Western Australian Government Railways ;
Frederick Mills, M.I.E.A., M.I.Loco.E., Chief Mechanical Engineer, W.A.G.R. ;
Tom Marsland, M.I.E.A., M.I.Loco.E., Assistant C.M.E. and Chief Draftsman, W.A.G.R. ;
Samuel James Hood, A.M.I.E. (Aust.), Chief Civil Engineer, W.A.G.R. ;
Ernest William Morris, A.M.I.E. (Aust.), District Engineer, Kalgoorlie ;
James Henry Shaw, A.M.I.E. (Aust.), District Engineer, Narrogin ;
Herbert Johnson Bromilow, District Engineer, Bunbury ;
Joseph Pickup Heweston, Special Footplate Inspector, Traffic Branch, W.A.G.R. ;
John Mervyn Thomas, M.I.Loco.E., Mechanical Inspector, W.A.G.R. ;
John Arthur Stanley Giles, District Loco. Superintendent, Northam ;
James Johnson Hunter, Chief Boiler Inspector, W.A.G.R. ;
William Raynes, A.M.I.Loco.E. (Eng.), Works Manager, W.A.G.R. Workshops, Midland Junction ;
Joseph Arthur Ellis, M.Inst.C.E., Commissioner of Railways in Western Australia ;
Percy Tudor Banks, Ganger, Bridgetown ;
Amos Edward Scott, Inspector Permanent Way, W.A.G.R.

I also had the following witnesses called at Bunbury—

Herbert John Eastcott, Driver, Bunbury ;
Charles William James Hills, Fireman, Bunbury.

In addition, I myself got in touch with various experts and persons in the other States, having a knowledge of the design of the locomotive or of its working, and as a result I took evidence from the following—

At Melbourne on the 14th February, 1946—

Andrew Campbell Ahlston, A.M.I.E. (Aust.), Diploma of Associate of Mechanical Engineering, Melbourne Technical College, Chief Mechanical Engineer, Victorian Railways.

Again on the 1st April, 1946, from—

Andrew Campbell Ahlston (recalled) ;
Edgar Henry Brownbill, M.Mech.E., B.El.E., A.M.I.E. (Aust.), Assistant Chief Mechanical Engineer, Victorian Railways ;
George Alfred Gahan, Commissioner of Commonwealth Railways ;
Charles James Kirkbride, Engineer, Commonwealth Railways.

Again on the 26th and 27th July, 1946—

Andrew Campbell Ahlston recalled.

At Brisbane on the 22nd February, 1946—

Percy Robert Turner Wills, Commissioner of Railways, Queensland ;
Theophilus Kissick, Engine Driver (already called in Western Australia), President of the A.F.U.L.E., Queensland ;
James Fraser, Engine Driver ;
Harold Llewellyn Edmonds, Fireman ;
Richard Rootes, Fireman ;
Stanley Robinson, Fireman ;
Thomas Shaw, Fireman ;
Norman Thomas Smith, Fireman ;
Allan Henry Kingston, Fireman ;
William Ewart Gladstone McHugh, Driver.

At Ipswich on the 25th February, 1946—

Vincent Hall, A.M.I.E. (Aust.), Chief Mechnaical Engineer and Workshops Superintendent, Queensland Railways.

At Rockhampton on the 1st March, 1946—

William Sidney Lievesley Forrest, Fireman ;
Colin Hector McTaggart, Driver ;
Maurice Clohessy, Driver ;
Percival Patrick Kaine, Acting Driver ;
John Macoun, Driver ;
Thomas Wilkins, Former Driver, now Shed man ;
Frederick William Parker, Driver ;
Victor Harvey Morris, Driver ;
George Bradley Wilkinson, Driver ;
James Sullivan, Driver ;
Ellis Harvey Skyring, A.M.I.E. (Aust.), Loco. Engineer, Central Division, Rockhampton.

At Rockhampton on the 2nd March, 1946—

George Thomas Harris McBryde, Driver.

At Sydney on 12th March, 1946—

Harold Young, M.I.M.E. (Eng.), M.I.Loco.E. (Aust.), A.M.I.E. (Aust.), Chief Mechanical Engineer, New South Wales Railways.

At Hobart on the 15th March, 1946—

Eldred Hobart Connor, General Manager, Railway Branch, Transport Department, Tasmania;
Alexander Keith Reid, Secretary, Transport Department (this witness was recalled on the 18th March) ;
Cyril St. Clair Barnard, Associate Commissioner, Transport Department.

At Launceston on 22nd March, 1946—

Walter Matthew Cowie, Guard, Tasmanian Railways ;
Vaudrey Arthur Robert Heathcote, Fireman ;
Gordon Gilmorris Mitchell, Driver (President of the A.F.U.L.E., Tasmania) ;
John Wilfred Dennis, Driver ;
George Edward Mullins (Diploma in Mechanical and Electrical Engineering, South Australian School of Mines), Chief Mechanical Engineer, Railways Branch, Tasmanian Transport Commission.

At Adelaide on the 12th April, 1946—

Eric Adam, B.E., A.M.I.Loco.E., A.M.I.E. (Aust.), Chief Mechanical Engineer, Commonwealth Railways, Port Augusta.

On the 15th April, 1946—

Frank Hugh Harrison, M.I.E. (America), Chief Mechanical Engineer, South Australian Railways.

John Adrian Fargher, M.C.E. (Melb.), Acting Assistant Chief Engineer, South Australian Railways.

I now proceed to deal with the various matters arising in the course of my Inquiry, and to consider whether this Australian Standard Garratt Locomotive as designed and constructed is safe to use on the railways of this State for the haulage of both passengers and goods ; whether its performance is satisfactory in the economic sense ; and how far it offers reasonable standards of ease of operation for the engineman.

Part III.

SAFETY OF THE LOCOMOTIVE.

DERAILMENTS.

General.

This is the most important aspect of this inquiry as it concerns the safety of the locomotives. The first main line derailment of an ASG in Western Australia, occurred in April, 1945. In Queensland the first main line derailment occurred in January, 1945. There has been no case of a derailment when an engine was "new." By "new" I mean an engine which is just issued from shops and which has done comparatively little running in traffic.

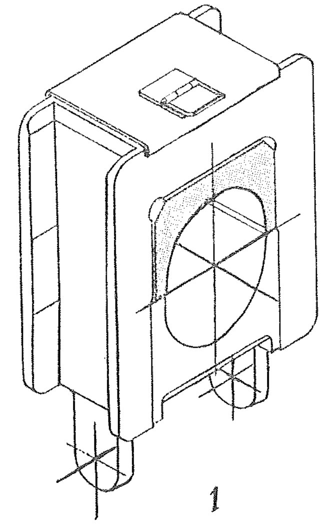
In Western Australia, since April, 1945, there has been a number of cases of derailment of the leading flangeless wheels. The Union points to these happenings as indicating that the locomotive is dangerous in operation. The Union does not suggest any cause of the derailments. There is in every case a denial that the driver was exceeding the maximum speed and I am asked to draw the inference that the mere happening is sufficient evidence of the unsafe nature of the locomotive. If no explanation can be found it would be reasonable to treat the circumstances as speaking for themselves and to make a finding that the locomotive is unsafe.

Except in one case which will be referred to, the Railway Department has been emphatic in attributing main line derailments in Western Australia to the locomotive being driven at an excessive speed around a curve. Mr. Mills, the designer, stated in evidence that when the locomotives issued from shops the boxes of the engines had the brasses adjusted so as to give a maximum sideplay between the brasses and the wheel hubs of one-eighth of an inch. The limit of tolerance to be allowed, he said, and which would arise through wear, was three-eighths of an inch. His opinion was that the brasses should not give any trouble for about 40,000 miles and that a rigid system of workshop inspection would ensure in practice that this limit would not be reached, because, he stated, when the wear got near the limit the locomotives would be brought in for attention. Experience shows that derailments of the flangeless wheels have occurred after the locomotives have done between 20,000 and 45,000 miles of running. In Queensland data collected shows that the brasses have been allowed to wear beyond the limit. In Western Australia there was one case where a derailment of the flangeless wheels occurred and the amount of play was within the limit, but, despite the assertion of Mr. Mills that brasses would not be allowed to wear beyond the limit, cases have occurred where excessive wear has been established. There is no room for doubt that, if the brasses are allowed to wear and excessive side-play to develop, there is a danger of the leading flangeless wheels derailing.

The original design of the box and the bearing surface of the brass which is intended to take the hub of the wheel as it oscillates when revolving did not allow sufficient bearing surface to reduce frictional wear set up by the hub face. In consequence, very rapid and excessive wear of the brasses took place. In order to rectify this trouble steps were taken to increase the bearing surface for the wheel hub by welding a metal plate to the box. White metal inserts were also provided at the bearing where it rests on the journal, and where the bearing surface which came into contact with the hub was worn it was built up with white metal. A marked improvement resulted. These steps were taken in Queensland and in Tasmania. Mr. Mills, the designer, stated that in Western Australia, in view of the fact that coupled axle boxes might be expected to give 40,000 miles of service before removal and that hub liners had not been found necessary, nothing would be done until the locomotives were in shops for general overhaul, when hub liners would be fitted for the purpose of extending the period of service already anticipated. Hereunder are two perspective sketches showing an exterior aspect of an axle box bearing in the horns provided at the frame. The first sketch shows the bearing in the box before provision was made for the alterations, and the other sketch shows the effect of the alterations which were made. It will be noted how small was the bearing surface originally provided and the substantial increase which was made by the alterations.

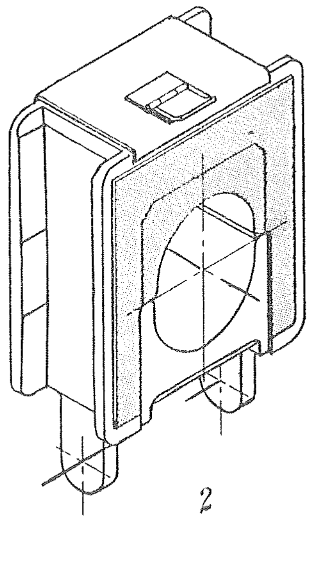
PERSPECTIVE SKETCHES OF AXLE BOXES AND BEARINGS PRIOR TO AND AFTER ALTERATIONS.

SKETCH No. 1.—Prior to alterations.



1

SKETCH No. 2.—After alterations.



2

Recently there was a case of an ASG (No. 48) derailing near Toodyay, and when the pivot centres were subsequently examined it was found that the oil which had been put in the pivot centres had been lost. Examination, however, showed that there was no material wear of the pivot centres but there was no information to show how long they had been devoid of oil.

Notwithstanding any wear which may occur at the pivot centres, I do not think that they can be a contributing factor to the derailment of the leading flangeless wheels. Wear which might take place at the pivot centres could conceivably lead to the several units swaying excessively from side to side and affect the stability of the whole locomotive. At this juncture nothing more need be said on this phase of the matter.

The question may be asked what bearing has the speed of a locomotive on its liability to derail. Taken by itself, the speed has no great significance. The state of the track, the weight of the rails, and other features, such as ballasting, are important. Assuming the track to be in good condition, speed will become important if the locomotive is driven so fast that a horizontal oscillation is set up between the front and the rear engine so that it tends to "gallop." At this stage the wheels of the locomotive are striking the rails with a series of hammer blows, tending to dent them and the speed will be so great that if the locomotive itself derails, some of the train which it is pulling will also be likely to derail. When a locomotive is rounding a curve extra care is called for because of the centrifugal forces set up between the flanges of the wheels and the rails.

I think the way is now clear for a critical analysis of the principal facts as adduced in evidence relating to all main line derailments. In this report I have discarded all derailments which were the result of locomotives crossing over split points or crossing over points which were defective. Later I shall be pointing to certain peculiarities in the design of the locomotive in the development of a theory which it will be important to consider as a further conducing factor in connection with derailments of the leading flangeless wheels.

ANALYSIS OF DERAILMENTS WESTERN AUSTRALIA.

The first Hester derailment.—This incident happened on the 25th April, 1945, the locomotive involved being ASG No. 27, which at that time had done between 17,000 and 18,000 miles. The locomotive, travelling chimney first, was pulling No. 32 Goods train, which stops for roadside traffic at all stations. The train stopped at Hester, which is at the top of a grade. The train then commenced its journey to the next siding—Catterick. From Hester to Catterick is a long and heavy downhill grade, and according to the driver he proceeded downhill, with regulator shut off, at a speed of 15 to 18 miles an hour, and on the last quarter of a mile down the bank he increased to about what he termed "the maximum," which would mean about 30 miles an hour. At this juncture the fireman noticed a hot box on his side of the engine. The driver says that on being told of the hot box he pulled up the train in a few hundred yards, and after examining the box decided to set the train for roadside to attend to it at the siding ; he then became aware of marks on the leading flangeless wheel. The wheel at that time was on the rail. His evidence is that he had no inkling that it had been off the rail at any time during the run from Hester to where it stopped. On stabling the locomotive at Bunbury the driver drew the attention of the shed driver to the marks, and booked the locomotive for examination. The locomotive was examined on the afternoon of the 25th April by the District Locomotive Superintendent and the District Engineer. There were some marks on the outside of the left-hand leading flangeless driving wheel and marks on the inside of the right-hand leading flangeless driving wheel. These marks consisted of a bright ring on the face and near the rim of the wheel indicating that the wheels had been off the road and rubbing against the side of the rail. There were marks on the corner of the balance weight on the left-hand leading flanged driving wheel. There were corresponding marks on the inner face of the long connecting rod showing where it had brushed against the balance weight. On examination of the track on the following day it was quite obvious that the right-hand leading flangeless wheel had been off the road for three and a-half miles. It had first dropped off on the outside of a nine-chain right-hand curve in the direction of travel. While the wheels were off the road they rubbed along the sides of the rails, marking fish plates and fish bolts and kinking the rails for a considerable distance. The derailed wheels had run through a crossing, smashing the wood of the crossing, which was in bad condition, and then ran on a further distance of one mile 41 chains to another crossing, where the timbers were in good condition. This resulted in the wheels being lifted up to rail level, where they re-railed.

I have gone into this incident with some particularity in order to give a typical instance of what happens when the leading flangeless wheels derail.

There was a conflict between two professional officers as to the condition of the track. They both consider that the driver of the locomotive must have been exceeding the speed limit for it to become derailed and damage the track to the extent it did, but the District Locomotive Superintendent said that the joint between the rails on the high leg at the entrance to the curve on which the leading wheels of the locomotive derailed was defective as the end of one rail was lapped slightly in from the true line which the rail should have taken, while the District Engineer, who is responsible for the track, is emphatic that no such defect was there.

Derailment between Greenbushes and Balingup.—On the 8th December, 1945, the same locomotive (ASG No. 27) was involved in a further derailment. At this date it had done about 25,000 miles and on this occasion it was the other pair of leading flangeless wheels which was derailed. The locomotive was running bunker first and after running down grade on a series of compensated curves for a considerable distance, the locomotive negotiated successfully an eight-chain right-hand curve and then proceeded to a 10-chain left-hand curve. Just beyond the point where the leading flangeless wheels entered the curve there were marks on the high leg which showed that the left-hand leader had dropped off on the outside of the rail, and some distance farther on the other wheel of the pair dropped off on the inside of the other rail. The locomotive ran for some distance before it was stopped with the flangeless wheels off the road, and when it entered the straight leading from the curve where it had derailed the derailed wheels marked fish plates and fish bolts and crippled a number of rails in the straight. The driver states that prior to entering the curve where the wheels derailed his fireman had drawn his attention to the flangeless wheels, stating that they were showing a tendency to leave the rails. He looked on his side, saw the wheel on his side ride over towards the inner margin of the rail and then ride back on to the rail. He then looked up and the fireman called out that the flangeless wheel was off the road. The train was pulled up and by using a block of wood the flangeless wheels were lifted and re-railed.

After this derailment I inspected ASG 27 in the Loco. Shed at Bunbury. Nothing had been done to it since the derailment. An inspection of the right-hand leading flangeless wheel, bunker first, showed a bright mark about half-an-inch wide all the way round the rim of the tyre on the exterior face, and a dullish mark about three-quarters of an inch in breadth all the way round the same face of the tyre from where the bright mark ceased. On the inner side of the face of the tyre on the same wheel there was another bright mark extending round about half-an-inch in breadth, but no significance was attached to this mark, which most probably had been caused by an overhanging lip from the brake shoe. On the other flangeless wheel of the same pair there was a bright ring around the inner face of the tyre about half-an-inch broad, and some scratchings and scorings appeared on this face. These marks were consistent with the wheel having been derailed and rubbing on the outside face of a rail. The dullish mark on the right leading wheel would probably have been caused by the ballast, and the bright mark by the wheel coming into contact with the side of the rail. The intermediate flanged wheels were then checked for clearance by means of a wooden wedge at the axle boxes, and it was found that the clearance was 9/32nds of an inch, which was within the limit of tolerance allowed for side-play. There were marks on the balance weight of the intermediate flanged wheel on the left-hand side where the long connecting rod had been brushing against it.

Suspected derailment of ASG 27.—This locomotive was worked on the 2nd July, 1945, on the No. 3 Passenger train to Bridgetown. About a week later the District Locomotive Superintendent drew the driver's attention to the right leading flangeless wheel of the locomotive, which he considered had been off the road. There was a mark on the outside of the wheel. It was a scrape mark which might have been caused by an overhanging lip of the brake. The wheel affected was one of the wheels which had derailed in the previous April derailment, but in that derailment the engine was running chimney first, whereas on the 2nd July, 1945, the wheel would be trailing, as the locomotive was running bunker first. The permanent way was inspected and no damage could be found. There is no evidence in this case to support an affirmative conclusion either way, but it is more feasible, in view of the fact that the wheel was trailing and that no damage to the permanent way could be found, that the mark on the wheel was caused by an overhanging lip of a brake shoe.

Clackline-Toodyay derailment.—This incident concerns ASG 48, which was derailed twice on the 4th February, 1946, first when the locomotive was drawing a load from Toodyay to Clackline, near the 52-mile post close to Lawnswood ; and later while running light over the points at the eastern end of Clackline station. The first derailment occurred after a long down grade run and it was on a reverse left-hand curve of 10 chains radius with a 1 in 45 down grade towards Clackline. The fish plates, bolts, and rails were characteristically marked for a distance of about 19 chains and it appeared that the left-hand side leading flangeless wheel had derailed first, followed by the right-hand side wheel of the same pair about four feet farther on. The bolt, plate, and rail marks continued for some chains to a point where the locomotive was stopped and the flangeless wheels were re-railed by means of old sleepers. The wheel marks were very pronounced on the Toodyay side of the rail joint and indicated that after hitting the first bolt the wheels had bounced or lifted, striking the next bolt of each joint to a much lesser degree, which showed the direction in which the locomotive was travelling. In some cases the wheels had dropped right down on to the bottom of the rails and in others had struck the head of the rail and almost re-railed.

After this incident the locomotive was brought into the Clackline yard and while working slowly in the yard and running light over the points at the eastern end of the Clackline siding, the leading flangeless wheels again derailed. In both cases the locomotive was running chimney first.

This engine was inspected by me not far from the scene of the second derailment and the leading flangeless wheels running chimney first were again on the point of derailing. A check showed that there was excessive movement of the bogie. The bogie frame was very close to the crosshead on the right-hand side and hard up against the bogie stop on the same side. The play between the flangeless wheel and the bearing surface in the axle box was measured and found to be three-eighths of an inch, according to one officer, and five-sixteenths according to another. The left-hand pony wheel of the front engine travelling chimney first showed evidence of rubbing against the side of the frame. The mileage done by this locomotive at the date of these derailments was 25,981 miles, which is comparatively small.

A subsequent inspection of this locomotive at the Midland Junction Workshops showed that the permanent oiling system in the pivot centres was not functioning, but I cannot relate this in any way to the derailment. At the same time the bogie centres were inspected, and here again the oiling system was apparently a failure. An examination of the leading engine bogie showed a total lack of lubrication. There was rust and grit in the centre, and the female casting was badly cracked. There was evidence of wear in that portion of the casting which rides on the slides at that part, but on the other side the brass slides showed a coating of oil. The fact that this bogie centre could have got into this condition, which could only be discovered by measures appropriate to a major overhaul, serves to illustrate my remarks at the beginning of this report about the shortcomings of this type of bogie. There is no doubt that the defective bogie in this case was a contributing factor, although I do not think it was the only factor, in causing this derailment.

Derailment of ASG 57 on Toodyay-Clackline section, near Lloyd's Crossing.—The appearance of a track irregularity on this section led to some inquiry. The irregularity is alleged to have been first discovered on Wednesday, 9th January, 1946, at 11 a.m., when it was found that the high rails on a 12-chain left-hand curve were damaged, although there had been no report from any driver of any derailment or irregularity. There were no signs of a wheel having been derailed on the low leg of the curve. ASG No. 57 worked several trains over the section between 4 p.m. on Tuesday the 8th and 11 a.m. on Wednesday the 9th January, 1946. The rails in this case showed the same characteristic markings. There were abrasions on the outside of the head of the high rail and some of the nuts of the fish bolts were heavily marked. There was also a mark apparently caused by a wheel re-mounting the rail. These marks extended for about nine chains. On examination of the engine of the trailing unit, which in this case would have been leading, it was found that the maximum allowable sideplay existed between the wheel hubs and the axle brasses of the leading coupled flangeless wheels. There were no markings on the sides of the tyres, but on the rim of the right leading flangeless wheel looking towards the bunker there were some indentations which could have been caused by the wheel striking fish plates and fish bolts. The position of the marks just referred to indicated that the locomotive had run some distance down a long and fairly steep grade and derailed when negotiating a curve. From the records of traffic movements there is no doubt that this locomotive was the one involved in the derailment.

Suspected derailment of ASG 48 near Lloyd's Crossing, Toodyay, on the 2nd December, 1945.—This locomotive, which was derailed twice on the 4th February, 1946 (see p. 19) was also probably derailed on the 2nd December, 1945. On this occasion about 11 lengths of rail on the high leg of a 12-chain left-hand curve were crippled, one rail being broken. The outside face of the rail and the fish plates and bolts on the outside of the rail were marked as in other cases. ASG 48 was the only locomotive working the section and, although it was examined and no markings found on the wheels indicating derailment, I strongly suspect that this locomotive caused the damage and that one or both of the flangeless leaders were responsible. The absence of markings on the wheels leaves the matter inconclusive. The marks may have been rubbed off by the lip of the brake shoe.

Narrogin Yard derailment.—ASG No. 49 was involved in this incident, which happened at the Narrogin loco. yards. The locomotive collided with a truck of timber which was being shunted and which was fouling the neck of a Y. When putting the locomotive on to the road, after crossing the points the driver applied the brake but failed to stop and so collided with the truck, which was fully laden. The buffer beam of the engine lifted the truck off its wheels and the chassis of the truck rode on top of the steam chest and cylinder and developed a lean of about 40 degrees to the permanent way. According to a report furnished by the sub-foreman fitter of the Narrogin depot the engine bogie wheels nearest the truck just lifted clear of the rail, due to the wedging of the two vehicles, but the driver asserts that the leading bogie wheels were on the road. The flangeless wheels dropped off clear of the rails. The sub-foreman fitter states that they dropped off about two inches clear of the rail. I think two inches is probably a mistake and the actual clearance would be much less. He goes on to say that the engine involved in the collision developed a lean of about 10 degrees to the permanent way. It was found on inspection that neither vehicle was damaged. The wheels were trammelled and found correct. In order to get the engine back on the rails the truck was jacked up and as the weight was taken off the buffer beam the leading flangeless wheels sprang back into position on the rail.

The width of the leading flangeless wheel is $5\frac{3}{4}$ inches, so it is obvious that if the facts given me are correct there must have been a fair amount of give either in the engine or the rails, or both, for these wheels to have got in the position they did. Nothing was done to the track where the engine derailed as it was found to be in order, but the road under the truck was distorted. Mr. Mills, the designer, advances the opinion that the spring of the rail could permit the dropping over of the flangeless wheels. I do not think that the possible deflection in the frame of the engine could account in any material measure for this happening. The condition of the boxes could have been a vital factor in the cause of this peculiar incident, but there is no evidence on this point. The position is that in the vague and sketchy outline of what took place I find it impossible to arrive at any definite conclusion, or to find that there is, in all the circumstances, any evidence which points definitely to a defect in the locomotive design.

The Yellowdine Triangle.—An instance was related by a driver of an incident which happened on the triangle at Yellowdine. No date was given by the driver and no report was made by him of the occurrence. This is open to comment because any derailment is a matter of importance and should be reported at the first opportunity so that the cause may be investigated.

The driver stated that he was driving the engine up one side of the triangle in order to make way for another engine which required coal. The engine he was driving had about 100lbs. of steam. It stalled on the curve. The driver got down to examine the brake blocks to see if they were sticking on the wheels and found that they were free but that one wheel of the pony truck was skidding and another was about five inches above the rail. He did not examine the road. Three or four weeks later, he says, he told the Chief Footplate Inspector of the happening. He gives his speed at the time when his locomotive stalled at about five miles an hour. These pony truck wheels are separate from the coupled wheels. They are attached to the frame by means of a yoke. The axle which joins the wheels can tilt or move sideways in relation to the rest of the locomotive without disturbing any other part of the locomotive. Here again, the evidence is too vague to reach a conclusion. Assuming the witness's account of the facts is accurate, the lifting of the wheel could have been due to some defect in the locomotive or to some defect in the road, or possibly both.

This concludes the account of derailments in Western Australia. I have not appended any diagrams showing the line sections as that seems unnecessary. Diagrams were supplied in the case of the derailments of ASG's 27 and 48. They exhibit the same characteristics of travel down a long and fairly steep grade, and derailment first occurring on the high leg of a curve at or near the bottom of the grade.

QUEENSLAND.

In Queensland I made inquiries as to derailments which had taken place there. Here it was said that experience had shown that the locomotives were derailing both on straights and on curves, even at slow speeds. While it is true that there is evidence that flangeless wheels have derailed in Queensland on a straight (in one case), this proposition cannot be accepted and the closest examination has shown that all main line derailments bear similar characteristics to the main line derailments in Western Australia. In the only proved case of leading flangeless wheels leaving the road on a straight it will be seen that that happening occurred after the locomotive had run down a long descending grade and derailed on a straight after just emerging from a curve.

I shall have occasion after setting out full lists and analyses of derailments in Queensland to make particular reference to what appears to be an extraordinary happening in which the whole rear engine component of an ASG was derailed when the locomotive was crossing the points leading to a diamond crossing.

In order to get a full statement relating to derailments in Queensland I prepared a form of questionnaire, and this form is set out in Appendix VI. The general trend of information relating to all locomotives which suffered derailment shows conclusively that in Queensland, owing to abnormally heavy traffic conditions during the war, excessive wear was allowed to develop in the brasses in the axle boxes. But it is also apparent that that excessive wear took place altogether more rapidly than ought to have been the case and it will be pertinent to inquire the reason for that rapid wear in the course of formulating a theory as to the cause of the derailment of the leading flangeless wheels.

The country in which these locomotives were operating for the most part was difficult, with continuous grades and curves, imposing stresses on the locomotives and calculated to show up any weaknesses.

I submit hereunder a list of all derailments which have been proved to have occurred in Queensland :—

Date.	Engine No.	Weight of rail.	Which wheels derailed.	Extent of wear in brasses.	Load hauled.	Record of mileage.	Short description of happening.
3-1-45	G.15	42 lbs.	Two pairs trailing engine wheels	Not known and not material	Not material	Under 26,000	Two driving wheels on each side of the trailing unit became derailed while the locomotive was being worked around a curve of three chain radius. The wheels were packed up and rerailed but again derailed on the curve. This curve was not a regular crossing loop, the locomotive and train having been placed there in order to allow other traffic to cross. The curve was far too sharp for the locomotive. Rail at point of derailment broken in three places on the left-hand side in a length of 2 ft. 6 in. The section of the rail which fractured was in crytallised condition.
31-1-45	G.15	60 lbs.	Leading coupled flangeless wheels	Not known ...	Light engine	26,000	Engine running light in easy country where 615 tons is a train load. Driver says derailment occurred on straight but all reports and examination show that it was on start of 15 chain curve on a 1 in 66 down grade after a long distance of compensating running. Driver says regulator shut off.
6-7-45	G.5	60 lbs.	Leading coupled flangeless wheels	Excessive ...	Light engine	43,000	Derailment on straight just after leaving 15 chain curve on a level stretch, but this was approached by a long descending grade of nearly one and a half miles.
28-7-45	G.52	60 lbs.	Left leading flangeless wheel	Excessive ...	317 tons	34,000	This was a fruit train, *i.e.*, a fast goods. Derailment occurred entering a curve on a 1 in 66 down grade, a couple of chains in a left-hand curve after one and a half miles of descending grade.

Date.	Engine No.	Weight of rail.	Which wheels derailed.	Extent of wear in brasses.	Load hauled.	Record of mileage.	Short description of happening.
25-8-45	G.21	60 lbs.	Leading coupled flangeless wheels	Excessive ...	513 tons	47,000	This was a goods train. Derailment three chains inside a curve on up grade of 1 in 90 and 11 chains on the up grade, but train approached this point on a long down grade of at least a mile of 1 in 80 and 1 in 50. After derailment, train continued on curved and undulating road for 61 chains.
5-9-45	G.25	60 lbs.	Leading coupled flangeless wheels	Excessive ...	486 tons	43,000	Goods train. Derailment seven chains inside an eight chain curve. After emerging from the curve, engine came on to a four chain straight, rerailed inside next curve reverse direction. All this on a 1 in 90 up grade, but the approach is approximately a mile of heavy down grade, then a mile practically level, then half a mile of 1 in 82 down grade.
11-9-45	G.19	41¼ lbs.	Leading flangeless wheel on right-hand side of hind engine (which was leading at the time)	Leading flangeless ¼ in. ; intermediate, $\frac{7}{16}$ in. ; intermediate flangeless, $\frac{7}{16}$ in.; trailers, ⅜ in.	Light engine	77,720	The engine derailed while turning on a triangle and while passing through the points leading from the leg of the triangle (radius five chains) on to straight dead end siding. The grade is level on the curve and also on the siding.
14-9-45	G.5	61 lbs.	Radial bogie and four pairs engine wheels of the engine which was trailing	Excessive in trailing bogies	Light engine	43,732	The locomotive was running bunker first and proceeding from loco. shed to pick up load. Travelling about eight miles per hour. When running up a grade of about 1 in 35 the locomotive passed over the points at the end of a straight and then proceeded to round a left-hand curve equipped with a guard rail. There was evidence that the radial bogie of the unit which was trailing had ground hard up against the guard rail. The locomotive then proceeded to cross over another line by means of a diamond crossing. The leading unit and boiler successfully negotiated the crossing but the radial bogie and four sets of driving wheels of the engine which was trailing became derailed. There was a distance of 58 feet from the centre of the guard rail to the radial bogie.

Three cases in this list call for special comment. They are the cases of the derailments of G. 15 on the 3rd January, 1945, G. 19 on the 11th September, 1945, and G. 5 on the 14th September, 1945.

The derailment of G. 15 on the 3rd January, 1945, was obviously due to the sharp curvature of the track. Examination of the circumstances relating to the derailment of G. 19 on the 11th September, 1945, shows that the derailment of the right leading flangeless wheel occurred on a 5-chain curve and that both sets of intermediate coupled wheels behind the flangeless leaders were beyond the limit of tolerance and the rear coupled wheels were up to that limit.

While I do not doubt the sincerity of Driver Fraser, who gave evidence as to the derailment of G. 5 on the 14th September, 1945, his explanation is, on the face of it, extraordinary and incompatible with any rational mechanical theory. He states that he was running bunker first from the loco. shed at Gympie at about 8 m.p.h. up a grade out of the shed approximately 1 in 33 when the locomotive gave a violent lurch and stopped. He got down and examined the engine and found the rear end derailed, *i.e.*, the radial bogie and the four sets of coupled wheels of the engine which was trailing derailed ; the four-wheel trailing bogie did not derail. He said he examined the road but could find no defect. He considered the incident was due to the pivot being too stiff, which would mean that the hind unit would have to be lifted or jerked over the rails. When one considers the enormous forces which would have to be exerted at the pivot centre to balance the leverage which would be exerted by the trailing unit, and then bears in mind that the male section is at the top of the casting, this theory is untenable. The locomotives have now run many thousands of miles and there is no evidence of wheels other than the leading flangeless wheels being derailed without the cause of derailment being ascertained. In my opinion, in cases bearing any similarity to this one the cause can be assigned to some defect in the rails, including the points, or to excessive slog in the axle and bogie boxes.

The departmental records indicate that this locomotive was taking a curve when the derailment took place. There was excessive wear in the boxes of the bogie that was trailing. A sketch made from notes taken by the Department at the time indicates that the locomotive had passed over the points at the end of a straight and then proceeded to go around a lefthand curve (equipped with a guard rail). The radial bogie of the unit which was trailing had ground hard up against the guard rail. The locomotive then proceeded to crosss over another line by means of a diamond crossing. The leading unit and boiler successfully negotiated the crossing but the radial bogie and four sets of driving wheels of the engine which was trailing became derailed. Running light, the tendency to excessive lateral oscillation due to excessive wear in the trailing bogie boxes would be accentuated.

TASMANIA.

In Tasmania there has been no case of a derailment of any ASG. This has been ascribed largely to the fact that many years ago a Beyer-Garratt locomotive was run at great speed down what is called the Campania Bank. The engine toppled over at the foot of the bank with fatal results and this has had a psychological deterrent effect on enginemen. Moreover, the curves on tracks are more frequent, and this has the effect of keeping down speed.

The same rapid wear of the brasses was epxerienced and steps had to be taken to rectify this matter by means of a white metal insertion and a facing on the axle box which seems to have given tolerably good service.

THEORY OF DERAILMENT.

The following results may now be summarised in regard to all these derailments :—

1. With the exception of the one case (ASG 48—Clackline Railway Yard), all main line derailments have taken place when the engine was either just rounding a curve or emerging from a curve after running on a down grade.

2. In all main line derailments the leading flangeless wheels of the engine, which at the time is the forward unit, have been the wheels derailed.

3. The flangeless wheel on the high leg is the one which leaves the rail first. The other flangeless wheel has in some cases subsequently just dropped down or ridden near the inside edge of the bearing surface of the other rail.

4. Kinking and distortion of the rail on the high leg, and sometimes on the low leg, and damaged fish bolts and marked fish plates are observable in all cases where an engine has derailed and run any distance. This damage is most marked at the rail joints. The bearing surface of the rail generally shows a mark where the wheel first leaves the rail.

5. The wheel of the locomotive which drops off on the high leg will be found brightly ringed around the exterior margin of the face which rubs against the side of the rail. Where the other wheel drops off it is similarly marked with a bright ring on the exterior margin of the face which rubs against the side of the rail. It does not follow that because one wheel drops off the rail the other wheel will derail. This can be illustrated diagramatically.

   In Appendix VIII. is shown a number of diagrams which illustrate this theory. The evidence shows that in some cases one wheel left the rail before the other derailed, and in other cases only one wheel derailed. These sketches show the cross sections of light rails as used in Western Australia. Sketch No. 1 shows the flangeless wheels in a central position on a straight track, the head of the rail in this case being shown as 2 in. wide. Sketch No. 2 shows one leading flangeless wheel with a bearing on the same type of rail, the actual bearing being 7/8ths of an inch, while the other leading flangeless wheel is line and line with the outside edge of the other rail. In this case the rails are shown definitely to gauge, *i.e.*, 3 ft. 6 in. In other words, this diagram shows that on a 3 ft. 6 in. straight, when one wheel has a bearing of 7/8ths of an inch the other would derail. *These conditions are given for new rails and in ideal circumstances, but with the normal wear which takes place, the tendency for the wheel (which in the diagram is shown with a 7/8ths overlap) to derail would be increased.*

   Sketch No. 3 illustrates a similar set of conditions but with a railhead of 1·9 inches. Here the seating is 31/32nds of an inch when the other wheel is line and line with the outside edge of the other rail. Sketch No. 4 is intended as an illustration of the bearing surface which one wheel has on the low leg of a five-chain curve which is widened in accordance with standard practice in Western Australia. This shows that when the wheel on the low leg has a bearing of 3/8ths of an inch the other wheel is line and line with the outer edge of the other rail. In this case the railhead is two inches in section. Sketch No. 5 shows that under similar conditions, but with a railhead of 1·9 inches, when the wheel on the low leg has a bearing of 15/32nds of an inch the other wheel is line and line with the outer edge of the other rail.

6. In the absence of direct evidence the direction in which the locomotive is travelling at the time of derailment can be ascertained circumstantially by the markings on the fish bolt heads and on the fish plates. Each set of fish bolts and fish plates will be found more heavily marked where the wheel first strikes the bolts or plate. It then bounces and subsequent marks on bolts and plates are lighter.

7. When the wheels derail they are prevented from dropping right down on to the ballast due to the axle dropping on to the horn stays.

8. With the exception of ASG 27, in all cases where the extent of side play is recorded there is evidence of excessive wear in the axle box bearings at mileages well under the figure at which the Chief Mechanical Engineer estimated they would need attention, and there is evidence that the engines are being allowed in service in a condition in which, according to the Chief Mechanical Engineer, the axle box bearings have worn to an extent which renders the flangeless wheels liable to derail.

9. There is no direct evidence of any untoward noise after the flangeless wheel has derailed and is pressing heavily against the side of the rail. Despite what one might expect to the contrary, the enginemen concerned have all definitely stated that there was no squealing or grinding noise and that their attention was drawn to the mishap simply by reason of looking at, or having pointed out to them, the position of the flangeless wheel.

10. In each case, with the exception of the derailment in the Clackline yard, the Department has attributed the derailment to speed. In no case, in my opinion, has the evidence been conclusive, although there is reason to suspect that speed was a contributing factor in some cases, both in W.A. and in Queensland. The locomotive is smooth riding and does not give the same indications of speed as one which rides roughly.

11. There is no evidence of the flangeless leading coupled wheels of the M, MS, or the MSA, or of the FS behaving in the same way as the flangeless leading coupled wheels of the ASG. The evidence is affirmatively the other way. The FS in particular has a rigid wheelbase comparable with the ASG.

12. It is safe to say that in all the years in which these other locomotives have been in operation on the State system, some drivers must have driven them at speeds exceeding the limits laid down by the Railway Department as safe working speeds.

13. The evidence shows affirmatively that in all cases of derailment of the ASG in normal main line running no other wheels, except one or both of the leading flangeless coupled wheels of the engine then running forward, have been derailed. There is evidence that no vehicle drawn by an ASG which derails is at the same time derailed.

14. Except in the case of the first main line derailment on the Hester-Catterick section, the evidence shows that the track was in order. In the Hester-Catterick case there is a doubt, but even if I accept the District Locomotive Superintendent's statement that there was a bad joint at the beginning of the curve, the track was still in reasonably safe condition.

15. All these facts lead to the conclusion that some other factor or factors besides that of speed must be looked for as the main cause contributing to these derailments. I put forward several theories for examination.

AXLE-BOX BEARINGS.

I have already made some reference to this question. Here again, it would be safe to assume that if axle-box bearings are allowed to wear beyond the limits of tolerance prescribed by the Department, axle-box bearings on other locomotives such as the M, MS, and MSA have also been allowed to go beyond the limit of tolerance permitted. There is no direct evidence specifically directed to these locomotives, but there is evidence of a general nature that wheels of all kinds of locomotives on occasions rub against frames through (amongst other causes) excessive wear in the bearings. So again it would appear that while excessive wear in the bearings may be a conducing factor there is something in regard to the ASG which compels further inquiry.

DESIGN AND CONSTRUCTION OF THE FRAME OF THE LOCOMOTIVE.

Further consideration will be given to this matter on dealing with the strength of the main frame, but here it is of importance only in regard to the amount of whip or bending or deflection that might take place in the frame. If the frame were liable to any excessive whip, etc., that in turn should be transmitted down the horns and thence to the wheels. Although the main frame plates are only 7/8ths of an inch thick they seem to be very well braced, with the result that the frame is exceedingly rigid. Calculations of the maximum lateral frame deflection at the flangeless wheel have been made by the Chief Civil Engineer. For the purpose of making calculations lateral loads at the flanged wheels equal to one-half of the vertical loads on the axles were assumed. The calculation is of the lateral deflection of the frame at the leading flangeless wheel measured from the production of the chord joining the centre line of the frame at the second and fourth drivers (*i.e.*, the flanged drivers). There is an unbalanced moment of 1,500 tons inches about the pivot.

It was necessary to make two calculations.

The first calculation assumes this moment balanced by a moment about the pivot in which case the resultant calculated lateral deflection is ·22 inches.

The second calculation assumes that no moment is transmitted by the pivot and the lateral load on the trailing driver is increased in order to obtain equilibrium. In this case the resultant calculated lateral deflection is ·024 inches.

The Chief Civil Engineer is of the opinion that the actual condition of deflection falls between these two extremes.

In making these calculations no allowance has been made for stiffening by the superstructure over the frame and the supports of the superstructure or by the wheels, axles and motion. In other words, the calculation has been made in reference to the bare frame and the cross members which belong to the frame. The resultant calculated lateral deflection is so small that it may be disregarded for all practical purposes. The general opinion of engineers is that this engine frame is particularly stiff and that deflection would be of no account.

STABILITY OF BOGIES ; STRENGTH OF BOGIE FRAMES, BOGIE CENTRES, AND BOGIE SPRINGS.

There is evidence that the female centre casting of the leading bogie of ASG 48 was in a broken condition on the 4th February, 1946, and that there is premature and excessive wear in the axle brasses of this bogie. ASG 48 is the only locomotive remaining with bogie centres in cast iron, all others having been replaced by cast steel. The mileage at the date of the derailment which led to a subsequent examination of the bogie centres of this locomotive was only 25,981. Bogie wheel boxes in general on the ASG have shown a tendency to run hot which has been largely ascribed by the Administration to their letting in water in wet weather, but this is not, in my opinion, the explanation. No fault has been found with weight distribution. The result of every inquiry which I have made has negatived any defect in this regard. The rapid wear of brasses in the axle boxes of the driving wheels and in the bogie boxes is something which requires special examination. In general no fault has been found with the quality of the metal used in these brasses, although there are some individual cases where it is not up to standard. The bogie should act as a stabilising influence. If the weight distribution is faulty or the bogie shows a tendency to hunt its effect on the engine components as a guider and stabiliser will be the reverse. Inquiry revealed the following :—Despite the C.M.E's. definite statement that the bogie on the ASG was free from hunting, I believe that experience has proved the reverse. Here then is one of the factors conducing to the derailments. The natural lateral oscillation of the engine components is not sufficiently controlled by the bogie, which permits the flangeless wheels behind it to move from side to side on the bearing surface of the rail. The engines of the Australian Standard Garratt locomotive have a longer wheelbase than the older M, MS, and MSA Garratts in use by the Department. It follows that the longer the rigid wheelbase the greater will be the tendency to lateral oscillation of the leading flangeless wheels which must be controlled and kept in hand by the bogie. In Appendix VII. there is a diagram of profiles of rails of 45 and 60 lb. types. The rails are shown with a 1 in 20 inward cant according to the practice in Western Australia and Tasmania. The flangeless wheel is shown riding on the bearing surface of the rail. With a 45 lb. rail the dimension from the inside line of contact of the flangeless wheel to the commencemet of the radius at the outside edge of the rail is 13/16ths of an inch and the corresponding dimension for the 60 lb. rail is 29/32nds of an inch. These calculations are based on a curve of five-chain radius and maximum permissible oscillation. No allowance is made for play between the hubs of the wheels and the boxes, the boxes in the horns, or anywhere on the journals. Any tendency to lateral oscillation, through a defect in the bogie—and there is, in my opinion, such a tendency in this locomotive—would set up the excessive wear in the bearings in the axle-boxes which has been experienced. This wear, coupled with the very small bearing surface which the leading flangeless wheel has on a curve, more particularly a five-chain curve, is, in my opinion, a major factor in the derailment of the leading flangeless coupled wheels.

In South Africa, where the South African Railways have had a long and successful experience with Beyer Garratts, and very fast and powerful locomotives of this type are used, leading flangeless coupled wheels have been discarded for over 15 years. Prior to that, locomotives operating on one in 30 grades and around five chain curves, had leading flangeless wheels. Some had thin intermediate types of flangeless wheels and a small number had two flangeless wheels. While there were no derailments of flangeless wheels on curves, flangeless wheels which became worn tended to damage points and after a few months' running, excessive lateral movement increased maintenance costs. The South African Railways then tried all wheels with full tyres and flanges and this has remained standard practice on all mountain type and double mountain Garratts built during the last ten years. These mountain type Garratts, and also ordinary type Garrats were designed for 275 feet radius curves with three-quarters of an inch widening to gauge, but in fact they operate on five chain curves.

While the locomotives were under construction at Newport, attention was drawn to the matter of the flangeless wheels. The Chairman of the Mechanical Engineers' sub-committee queried the design in this respect and stated that, assuming flangeless wheels were employed, it would be preferable to reconsider the coupled group for increased lateral stability. No effect was given to this suggestion.

In modern locomotive design the general consensus (and I think the better opinion) is against leading flangeless wheels. There is no need for flangeless leading wheels in the case of the ASG locomotive ; on the contrary, it would be an advantage if the locomotive had flanged leaders. The tendency to lateral oscillation would be checked, there would be less wear on curves, and the bogie could more easily perform its work of guiding and stabilising the locomotive in curving.

I find that there is no need for these wheels to be unflanged. I recommend—

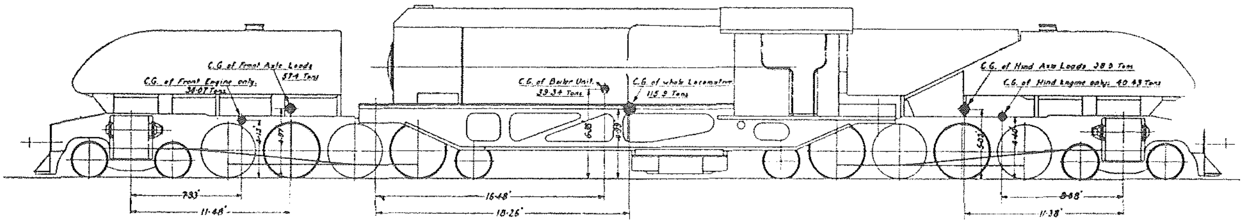
That the leading flangeless coupled wheels of all Australian Standard Garratt locomotives in Western Australia be fitted with flanges and that the intermediate flangeless wheels be fitted with thin flanges; that an entirely new design of bogie of the swing-link type with roller bearings be substituted for that at present in use. The form of bogie in use in Western Australia does not find favour on other systems for reasons which I have already given.

STABILITY OF THE LOCOMOTIVE AND ITS UNITS.

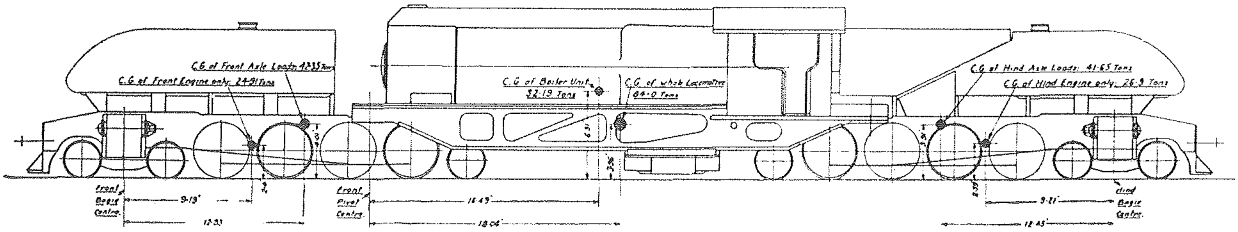
This matter will also be touched on when considering the subject of frame structures and strength.

The high pitch of the tanks will be noticed from the outline drawing. They were placed high above and bolted to the frame in the original design in order to give the greatest possible accessibility to working parts beneath them, but as will be shown presently the plates of the tanks showed a tendency to crack under stress. As the bolts which held the tanks on the frames worked loose in service they were replaced by rivets and the idea of accessibility has lost a good deal of its force. Hereunder are diagrams showing the longitudinal centres of gravity of the whole locomotive fully loaded with coal and water, and also in an empty condition. The centre of gravity is also shown for each separate component.

DIAGRAM SHOWING THE CENTRES OF GRAVITY.



LOCOMOTIVE IN ROADWORTHY CONDITION



LOCOMOTIVE EMPTY—84·0 TONS
TANKS, BUNKER, BOILER & GRATE EMPTY

As the locomotive is for all practical purposes symmetrical about the longitudinal centre line all of the centres of gravity shown on the two drawings are to be regarded as positioned on the longitudinal axis of the locomotive.

It will be noted that in each drawing the position of the centre of gravity of the whole locomotive is shown, and close to this position will be seen the centre of gravity of the boiler unit. Next will be seen two centres of gravity for each engine unit, which of course includes the bogies and radial truck. These two centres are shown because it will be remembered that the end of the boiler frame is attached by a pivot to the engine at either end, so that each engine frame carries portion of the weight of the boiler and its components.

It has been thought desirable to give the two sets of conditions, *i.e.*, roadworthy and empty, asgiving some conception of the extremes which may occur in the position of the centre of gravity with the locomotive in a static condition. The centre of gravity for the whole locomotive is lowered approximately one foot by removal of all coal and water, which are carried above the centre of gravity for the whole locomotive, but there is little change in the longitudinal position as the loads are nearly in balance about that position. The centre of gravity of each engine is lowered considerably by removal of the water in the case of the front engine and by the removal of the coal and water in the case of the hind engine, but in each case the longitudinal position is affected to a much less extent.

The general tendency when moving from full to empty condition is to bring the centre of gravity for each group of axle loads nearer to the centre of the coupled wheelbase, thus showing a tendency to maintain coupled axle loads and the factor of adhesion.

When moving—particularly at speed—the movement of the water in the water tanks must affect the centre of gravity and baffles are provided to keep this variable within limits.

The weight of evidence points to the stability of the locomotive and its several units. The boiler unit is particularly stable. Whatever side-sway has been observed is seen in the engines but even here the sway is not excessive. The behaviour of the locomotive in collisions and after derailment of the flangeless leaders also suggests that there is no danger from lack of stability. Nevertheless, the tanks should be placed lower than they are and the factor of stability will be considerably increased, and the surging in the tanks kept more under control.

Closely allied to the question of stability of the locomotive as influenced by the tanks is the force exerted on the pivots under the general influence of oscillation set up by the engines, and more particularly by the forces operating when the locomotive is rounding a curve. When the locomotive is rounding a curve, severe forces are set up at the pivots and when considering the question of strength of the frame, I shall have occasion to mention some structural defects which early manifested themselves and which were noticed and discussed at the conference of engineers held in Melbourne in July, 1944. There are no side bearers on the frame to check any tendency to side sway and reduce wear at the pivot. These are standard practice on Beyer Garratts and should be fitted to all ASG locomotives. I do not think there is any immediate danger that the locomotive will turn over. Although pivot wear, and side sway, due to excessive pivot wear, must be considered in relation to any tendency to overturn, there is no connection between this and the inherent tendency already discussed of the leading flangeless wheels to leave the rails.

ALLEGED TENDENCY TO DISPLACE CURVES.

Two witnesses deposed that the ASG locomotive had a tendency to displace curves. One witness mentioned that he had actually seen a curve move when the locomotive was working slowly around it, but stated that he had not seen such an occurrence before or since. The other stated that he had seen the sleepers moving about two inches on sharp curves when the locomotive was passing over them. Neither of these men, who were firemen, made a report on a matter concerning the safety of lives and property. Assuming they stated correctly what they saw, there is no more warrant for laying the blame with the locomotive than there is for holding the occurrences against the track. Indeed there is evidence from the Chief Civil Engineer, that the track on the Hotham Valley Branch where these men were operating was not in the best order. No permanent way man was called to support the theory that this locomotive had a greater tendency than others to displace curves. There was affirmative evidence from the Civil Engineering staff that the ASG was not heavy on the track. There was no instance cited of any similar occurrence in either Queensland or Tasmania where these locomotives have now travelled hundreds of thousands of miles. Apart from the particular cases due to the derailment of flangeless wheels, I find on the evidence that the ASG locomotive is economical as regards track wear.

STEAM BRAKE.

Perhaps no equipment on the ASG has given rise to more dissatisfaction than the steam brake. In locomotive design, the steam brake is quite common and if properly designed and constructed, should be very effective.

On the ASG, the brake is so designed that the vacuum brake of the train can be controlled from the engine and means are provided whereby on the application of the vacuum brake, the steam brake should automatically apply, thus doing away with the necessity of operating two levers. The vacuum brake is operated by using the steam from the engines to clear the air from a pipe going the length of the train, thus creating a vacuum which in turn permits a number of pistons in cylinders on the vehicles to rise in the cylinders owing to the outside atmospheric pressure. By means of rigging, these pistons communicate with brake shoes near the wheels and the brakes may be put on or off according as the vacuum is destroyed or created. Provision is made whereby the vacuum steam ejector, which is the part of the vacuum brake instrument used to clear the air from the train pipes, can also be used for putting steam into the steam brake pipe in the application of the steam brake. The Union's case is—" the steam brake is unreliable in an emergency owing to condensation in pipes and brake cylinders." The Commissioner's reply to this allegation is " the steam brake is efficient and reliable. Special action is being taken to minimise condensation."

It will be seen that this is an equivocal reply. There is a denial with a half-hearted admission. The position is that for twelve months or more, enginemen have been complaining about the steam brake and the Department has consistently reiterated that it is efficient. Enginemen have been either directly or tacitly blamed for accidents which have resulted when the brake has failed to give an efficient performance. In the evidence of Mr. Heweston, Chief Footplate Inspector, and of Mr. Thomas, Chief Mechanical Inspector will be found a reiteration of the view that the brake is and always has been effective. At the same time, Mr. Heweston admits that there is a tendency to condensation in the brake cylinder which retards its effectiveness. This condensation must be removed before the brake becomes effective. To do this, Mr. Heweston advocates a few momentary applications of the brake lever in order to clear out the condensation. This, to me, is an expedient which should not have to be used with any instrument which is effective. Emergencies present themselves more or less suddenly, and there is not time in the severest emergency, if such manoeuvres have to be resorted to, to check the speed of the engine sufficiently to avert a serious accident.

Furthermore, the fact that such manoeuvres are necessary is apt to destroy the confidence which enginemen ought to have in the appliances at their disposal.

Another indication of the attitude of the Department in regard to the brake is the instruction given to the shed staff as to the minimum boiler pressure to be maintained when these locomotives are being moved in the shed. The instruction given is that the minimum pressure is to be 100 lb. This was ordered as a precaution against the carelessness of some of the shed staff. It is said that at the speed at which they were operated the locomotives could be easily braked with a much lower minimum steam pressure but because of mishandling it was thought advisable to have this precaution. But it seems to me that the instruction only serves to indicate a particular shortcoming in regard to the brake.

Besides the condensation defect there are other features of importance which affect the efficiency of the steam brake. The steam valve, which is operated by steam from the vacuum steam ejector, has been found not to seat properly, thus robbing the brake of some efficiency. It was found that the metal of the seating was faulty and that continual operation resulted in rapid wear.

There is evidence of lack of harmony between the vacuum brake and the steam brake. Owing to the inter-relation of the two instruments a certain degree of vacuum is necessary where both brakes are applied simultaneously for the valve on the steam brake to lift and permit the steam brake to release. According to English standards (this valve is a proprietary fitting and manufactured in England) the valve is designed to lift with a vacuum from 15 to 20 inches. But trains in this State are allowed to depart with a vacuum equal to 15 inches and it has been found in practice that the spring load of this valve is too great for the leverage which has been applied on the brake lever at the air sub-piston for the purpose of lifting it and consequently something needs to be done to accommodate the design of the valve to the lower vacuum which is permissible in this State ; or an alteration must be made in the leverage. Time and again there have been complaints from enginemen that they have got the steam brake on only to find it securely locked against the wheels when they have put the steam brake lever in the release position and the services of a fitter have had to be obtained in order to release the blocks. Cases were cited where the two brakes had been applied simultaneously and on the release of the steam brake the vacuum brake could not be got off the train. It should be possible to use either of these two brakes independently but often, when the steam brake is used independently, the vacuum will show a tendency to apply. Mr. Mills, the designer, and Mr. Marsland (Assistant C.M.E., W.A.G.R.) both stated they could not understand how such a thing could happen, but Mr. Heweston, Chief Footplate Inspector, did furnish a clue to the explanation of this defect. It is true that some of the trouble may be due to air leaks past the rings and pistons in the brake drums attached to the vehicles behind the engine and to leaks either in the pipes or in the pipe joints of the vacuum pipe on the train, but the escape of steam to the ejector is definitely the main cause of the trouble. Examination of the design of the vacuum ejector in relation to the steam brake instrument indicates that there is a tendency for the escape of exhaust and live steam from the steam brake into the small vacuum ejector, thus interfering with its action, and this is the cause of the trouble.

The design of the steam brake consists of a vacuum controlled steam valve admitting steam to the brake cylinder through a 1 in. bore pipe which serves as both *supply and exhaust* pipe, the exhaust steam being discharged through the discharge pipe of the small ejector and not through the cones.

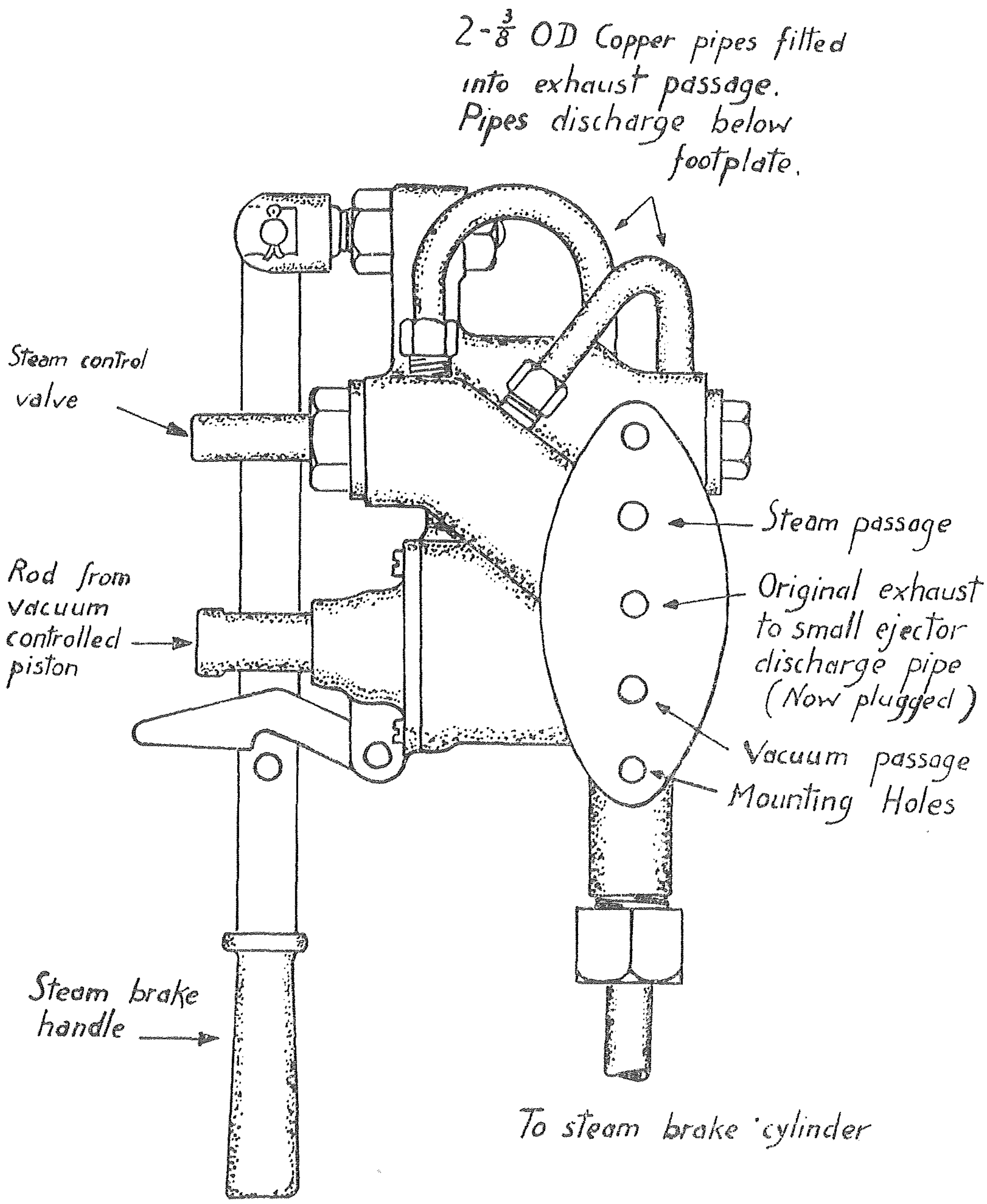
On application of the vacuum brake the automatic application of the steam brake occurs satisfactorily, but when the ejector handle is returned to the running position the steam brake begins to release, allowing exhaust steam to flow through the discharge pipe of the small ejector, impeding its action and preventing the formation of sufficient vacuum to release the train brakes completely and close the steam brake valve. In the half closed position of the steam brake valve a small amount of live steam is admitted to the brake pipe, supplementing the exhaust steam from the brake cylinder and further impeding the small ejector.

In order to obtain release of the train brakes it is often necessary for the driver to close the steam brake valve by hand and frequently to use the large ejector to restore vacuum.

In Tasmania, in an effort to overcome this difficulty, small spring loaded release valves were fitted about two feet from each brake cylinder to deal with the exhaust steam, but that resulted in only slight improvement. The position of the relief valves was later altered to the under side of the head end of the brake cylinder. Next an exhaust to atmosphere was fitted to the steam brake mounting. This consisted of two three-eighths inch O.D. copper pipes running from the mounting and discharging below the footplate. This arrangement gave satisfactory working of the steam brake with fairly rapid and automatic release. The exhaust hole on the brake mounting through which the exhaust steam was discharged to the small ejector, for discharge through the small ejector discharge pipe, was plugged.

The last two ASG locomotives delivered to the Tasmanian Government Railways are fitted with an automatic steam brake mounting similar to those previously fitted but the steam brake exhaust is discharged direct to atmosphere through a 1 in. O.D. copper pipe. Results with this mounting are said to be satisfactory, release of the steam brake being complete by the time a normal operating vacuum has been restored to the train pipe. The restoration of the vacuum is not interfered with by the steam brake exhaust. The proprietary fitting has now been designed with an improved mounting for the ASG locomotives, intended to overcome the difficulty just discussed.

The sketch hereunder shows the steam brake mounting. The hole through which the exhaust steam was discharged to the small ejector pipe is shown as well as the two copper pipes which were fitted by the Tasmanian Government Railways to the exhaust passages in the steam brake mounting.



Reference has been made to the expedient suggested by the railway officers of making several short applications of the brake before a full application. The purpose was to clear the brake cylinder of condensate which robbed the steam of its efficiency and impeded the application of the brake. The design is definitely faulty in not providing for a release cock to discharge the water when the brake mechanism is applied. In no instance where I have inquired have brake cylinders of steam brakes been designed without this provision. The design has been used for many years in accordance with this practice. In Tasmania, not only has provision been made for ready drainage from the cylinder by means of a drain cock, but similar provision has been made to take away condensation in the steam brake pipe.

I think the Department's attitude in regard to the steam brake has been irritating and has increased the dissension which existed between the Union and itself. This is illustrated in some correspondence concerning collisions between the ASG locomotives and other vehicles in shed driving. The Department stated that a very efficient hand brake is fitted and should be used for the unavoidable shed shunting when steam pressure is dropping back. The hand brake would in my opinion be particularly awkward to use in shed shunting and it is a poor way out to suggest the use of the hand brake as a substitute for the inefficient steam brake, which can and should be made to operate efficiently.

SHUNTING AND STEAM BLOWS.

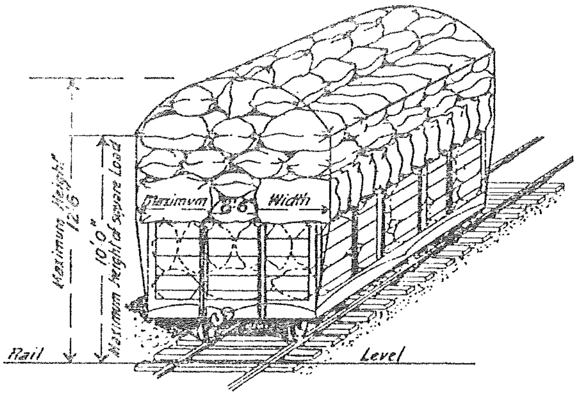
The Department admits that the Australian Standard Garratt locomotive is not a suitable engine for shunting and that shunting should be kept down to a minimum. In my opinion it is not the size of the locomotive which militates against its being used for that purpose because modern controls of large machines can be so delicately adjusted that they should be manoeuvrable with the same ease as a small machine. The real difficulty in relation to shunting has been brought about by steam blows, and the awkwardness of the reversing gear. It has been found that in summer time these blows are of little consequence and do not obscure visibility, but in winter when the air is clear rapid steam condensation takes place if steam escapes to atmosphere from steam joints and packing and is a real nuisance and danger in shunting operations, more particularly with a locomotive which is driven by double engines so that steam may be escaping both from the front and rear ends at the one time. It is possible that a small escape of steam on a clear winter morning may almost wholly envelop the front or back of the engine and obscure the driver's vision. In my opinion all steam blows which have been experienced with the locomotives are remediable, and a little more attention to the idiosyncrasies of design and better workshop supervision would lead to greater satisfaction both to the Administration and the operatives.

Trouble has chiefly been experienced with the piston gland packing, the main steam ball joint, the main steam expansion joint, the steam snifters, and the steam brake. I would like it to be understood that all engines, no matter what make or design, develop steam blows, and the only thing that can be said as regards the ASG is that it needs a little more attention (and this applies to articulated locomotives in general) to the main steam pipes, which must be designed to provide for curvature of the pipe, which is essential when the locomotive is rounding curves. The packing in the main steam ball joint will need further consideration as regards design. It is very inaccessible and everybody knows that if a part is inaccessible it is likely to be neglected. I agree with the proposal made by Mr. Marsland, the Assistant Chief Mechanical Engineer, that a casting Y should be placed in a convenient position so that the shed staff can get at it more easily to take out the gland and insert new packing as required. The piston rod packing, too, needs to be considered with a view to stopping blows. In the large Beyer Garratts which I saw at Burnie, Tasmania, on the Emu Bay Railway Company's line, steam blows have not been a nuisance. The piston glands are in a white metal packing and the first engine did 22,000 miles before the first packing blew out. The main steam expansion joint calls for regular maintenance attention. In winter time it is packed once every six weeks, which would amount to about once every 2,000 miles. I do not consider this any detraction for large and powerful locomotives which give highly efficient service. The Emu Bay Company is entirely satisfied with these Beyer Garratts which operate under very severe conditions.

ROLLING STOCK OUTLINE AND LOADING GAUGE.

One of the objections urged against the Australian Standard Garratt by the Union is that its dimensions are outside what was called the "loading gauge." "Loading gauge" is a term loosely used. It is nowhere defined, but at page 254 of the General Appendix to the Railway Regulations there is a perspective sketch of a truck loaded with bagged material. It is obvious that the intention of the sketch is to show that the maximum width of a truck so loaded shall not exceed 8ft. 6in. In the case of a vehicle loaded with firewood there are other sketches which show the method of loading. The evidence is that with this class of load the maximum width is not to exceed 7ft. 3in. A special regulation provides that a boiler or tank may be loaded up to a width of 9ft. provided it is securely chained down. In the case of firewood it is obvious that the restricted width is laid down on account of the tendency of wood to shift in transit. A lot is left to be worked out, but it appears from the evidence which I heard from both the Administration and the Union that the sketches convey a definite concept to railway men which would be just as well more specifically defined in the regulations. However, it is clear, I think, that as a general rule the load placed on any truck or wagon must not exceed 8ft. 6in. in width with a maximum projection of 4ft. 3in. on either side of the centre of the track. The sketches are shown hereunder.

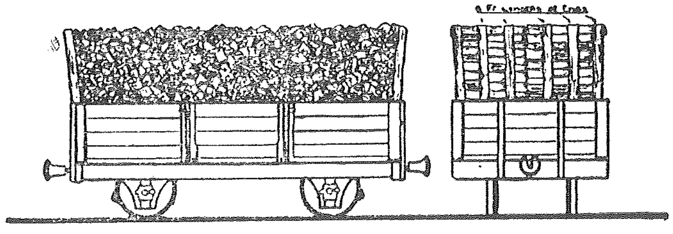
SKETCHES SHOWING LOADING GAUGE.



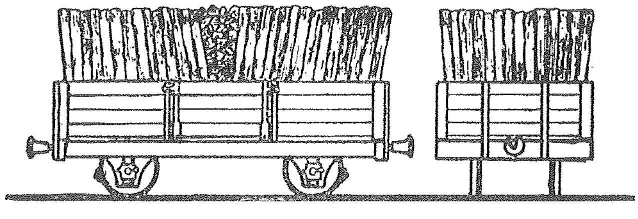
The above represents a fully loaded, sheeted truck. The load as per measurements shewn above is not to be exceeded in any case.

Diagram showing method of loading Firewood.

3 Ft. Lengths



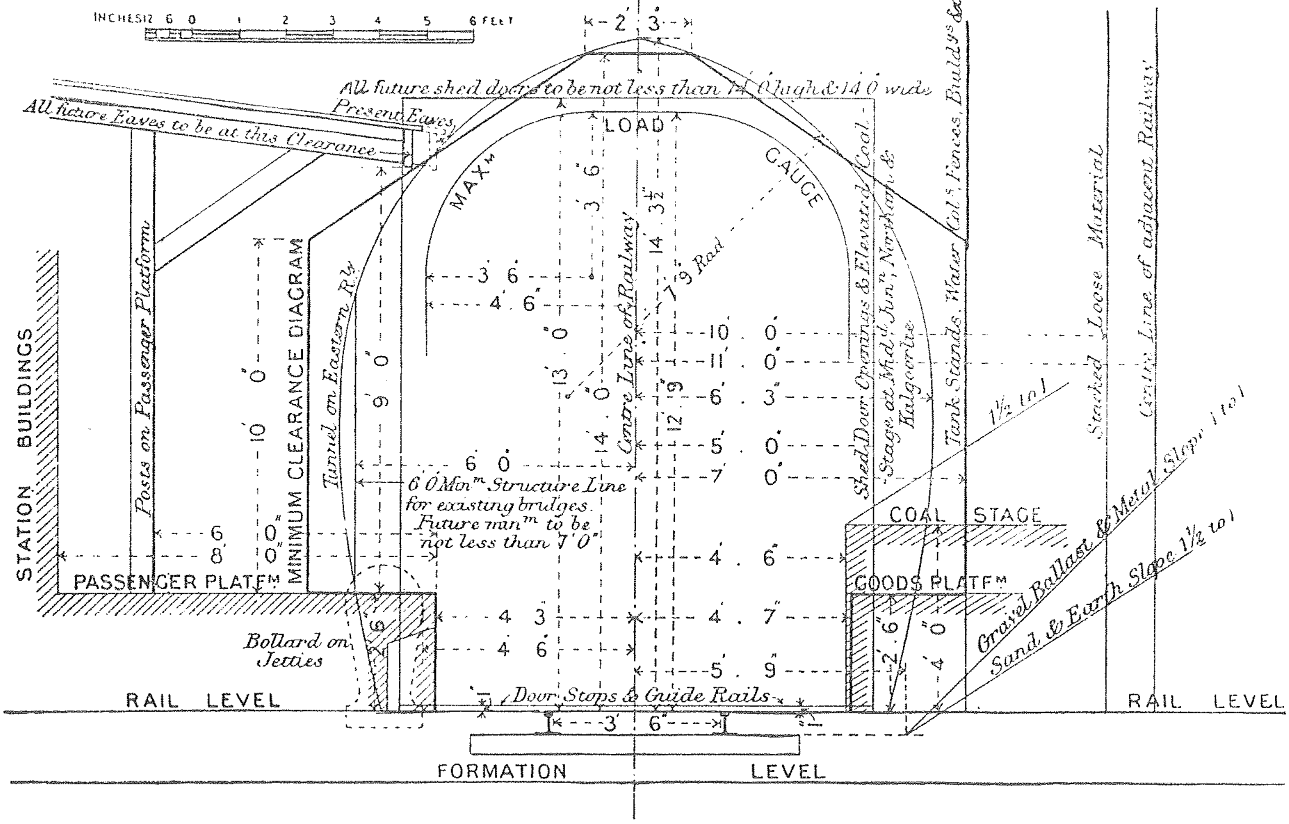
6 Ft. Lengths.



On page 253 of the General Appendix there is a "Diagram of Clearances." This diagram is intended to give the clearances between moving vehicles and their loads and fixed structures. As a matter of inference rather than strict definition one is left to gather that the maximum permitted width of a vehicle on the track is 9ft. The following is the sketch:—

DIAGRAM
OF
CLEARANCES

Scale



It is argued, rather speciously by the Union, that the dimensions of the locomotive exceed the loading gauge. The maximum width of the locomotive, measured from the extreme projection on either side, is 8ft. 11½in. What is meant really is that the width is outside the *maximum rolling stock outline*, which is a different proposition. There is no definition of this to be found in any Railway regulation or order, though it is generally recognised that there must be a limit to the width of a vehicle on a track, both from the point of view of stability and the avoidance of hitting or brushing up against other vehicles or fixed structures. The rolling stock outline and the loading gauge are determined with similar objects in view, but there seems to be a need for further definition in both cases. In Western Australia the maximum width between track centres on double lines is fixed at 11ft. and the maximum rolling stock outline (width) is recognised as 9ft. overall, which leaves 2ft. between moving vehicles of maximum outline passing on double lines. So that when it is said that the dimensions of the ASG exceed the loading gauge, what it is intended to say is that the dimensions are in excess of the width recognised for the maximum rolling stock outline. The argument fails. No reason is given for the difference between the maximum in either case of the width of the rolling stock outline and the width of the loading outline, but it seems clear that the distinction is as between the vehicle and a load which is likely to shift or move in transit.

I therefore find that the overall width of the ASG is within the standard recognised by the Railways.

But I agree that no rule which is laid down will necessarily make a thing safe or unsafe. Nor, if a thing is unsafe, can any argument be used in favour of its continuance. For example, in this particular case, if locomotives 9ft. in width are unsafe and to discard them would mean the end of progress on our railways, they should nevertheless be laid aside unless some safe working conditions can be brought about But one must have regard to the fact that rules are laid down in pursuance of what are regarded as objective standards—standards which common experience shows as being reasonably safe. No degree of human care can avoid all accidents. No absolute standard can be reasonably laid down, but a rule of caution which is well recognised and practised in this and other parts of the world may well come to be regarded as a test of the measure which common prudence demands. It has been shown in evidence that the rolling stock outline in this State is more liberal as regards clearance between outlines of other vehicles and their loads on adjoining tracks than is the case in other parts of Australia or in Great Britain. While in Western Australia the minimum clearance between outlines of vehicles on adjoining tracks is 2ft., in Great Britain it is 1ft. 6in., and it is the same in New South Wales.

Because some careless person throws a bottle out of a carriage window and the bottle hits a passenger in a passing train, or because some person leans out of a carriage and is struck by a passing vehicle, or by a piece of timber badly loaded on a truck and projecting beyond the loading gauge outline, that is no argument for altering the loading gauge or the maximum outlines of the vehicles, or for making a rule that tracks must be put farther apart. And that is what the argument really comes down to here. It is my belief that the argument advanced by the Union was conceived as the result of dissension in regard to other matters concerning the locomotive. When men are dissatisfied it is not unusual to find them advancing all kinds of reasons—some good and some bad—in support of their objective. In my opening remarks I made some reference to Fireman Whitmore's death at Karrakatta on 21st September, 1944. It is a theory that he was struck by a passing door negligently opened or left open by someone, but there is no direct proof. It is a fact that the distance between the edge of an open door of certain types of carriages and the limit of the outline of the ASG is 5½ inches. To argue that because some careless person leaves a door open in such circumstances the ASG locomotive is dangerous is unreasonable. As I have shown, there could be no limit to the contingencies which might happen and which would be further grounds for placing tracks farther and farther apart. The Coroner who took the inquest added a rider to his verdict as follows :—

> " I consider that it would be advisable for special safety measures to be prescribed in relation to the use of Garratt (presumably Australian Standard Garratt) locomotives where other trains are likely to be passed, on account of the unusual width of the Garratt engine."

There is nothing unusual about the width of this locomotive in a general sense. It is of course new to Western Australia, but only slightly wider than the P class engine (8ft. 3in.) and a half-inch narrower than the S class, which is the full 9ft. permitted by the rolling stock outline.

Following on this rider the Coroner suggested a form of notice to be placed in the cab of the ASG locomotives :—

> CAUTION.—Do not lean from cab when passing trains, when in sidings or on double lines. See that the line is clear when leaning out.

With all respect to the Coroner, this rider does not seem to credit the enginemen with any common sense or any experience of general driving conditions. To warn a driver or a fireman not to put his head out when other trains are likely to be passed is hardly necessary. Every man becomes accustomed, or should become accustomed, to his job and an engineman can reasonably be expected, before he puts his head out of the cab, to make sure that the way is clear. It is true that we are all caught off guard sometimes and some of us must suffer for it.

The argument which I have discussed at such length was not even mentioned in Queensland or Tasmania. It is entirely untenable. In developing it, it got some curious twists, namely that the engineman must be considered " a part " of the engine, which would have the effect of extending the outline wherever an engineman's fancy might take him. It was even argued that certain rules (173, 174, 177) require the engineman to " look out " for signals, etc., as if to suggest that enginemen must physically expose their heads to danger. I cannot imagine their being so obedient as to do that even if the rule bears that construction ; but the real meaning of the rule is obvious, namely, that they are to be on the alert and keep a watchful eye for signals, etc. A prudent driver or fireman does not put his head out until he is reasonably sure of what is immediately ahead.

But the argument does succeed in regard to fixed structure outlines, such as posts, sheds, platforms and the like. It has been shown that the ASG has been required to go to places where there is little or no clearance between the moving locomotive and fixed structures. There is no excuse for tolerating or continuing this state of affairs. Proper clearances should be provided by shifting back limits of structures without delay so that the limits conform to the recognised safe clearances. It is probable that many thousands of pounds expenditure will be needed to provide these clearances. This cannot be helped and it is no argument against the using of larger and more powerful locomotives. If the State railway system is to develop properly and to meet opposition from other forms of transport, railway rolling stock must be kept up to date. In Tasmania the estimated expenditure on structures and modifications to station yards and turn tables amounts to £30,000. I have not gone into the amount of expenditure required in Western Australia. It will probably be a great deal more, and even if the expenditure is necessitated immediately by the ASG locomotive, it will serve its purpose prospectively for the larger and more powerful locomotives which the Railways will have to acquire if they are to survive.

From my previous remarks I think it is apparent that the case of the ASG locomotive has illustrated the need for definitions laying down the limits of the interrelation of structures, rolling stock, and loads.

STRENGTH OF DRAWBAR.
DRAWBAR SURGE ON UNDULATING ROADS AND WHEN ENGINE TAKING UP LOAD.

In Western Australia there is only the one centre coupling and the drawbar pull is transmitted through this coupling. The couplings are joined together with a chopper and a locking pin is inserted through one side of the bar and the head of the chopper. There is always slack in these couplings and the longer the train the greater the aggregate of slack. The ASG is able to pull longer trains than any other locomotive and this has led to complaints about the jerking which takes place when the locomotive is taking up its load or working on undulating roads. It has not been shown that the drawbar is unable to take the extra strain due to the increased length of the trains. The evidence is that the safety factor provides for a strength of drawbar which will take a breaking strain up to four times the maximum load it is called upon to bear. In my opinion there is nothing unsafe in the drawbar. It is at times unpleasant but this is due to the slackness in the coupling itself and, while this is the form of coupling used on our railways, it has always been a disadvantage and I do not see that the ASG, by reason of the fact that it pulls a longer train and that therefore the amount of surge is greater, should be condemned, or that it is much worse in this respect than other types of locomotives.

Although not strictly relevant to this subject, it will be appropriate here to mention a matter related to the length of the train which I noticed in the course of the inspections which I made. That concerns the poor visibility brought about by the neglect to clear obstructions, such as trees and suckers, from the edge of the line. In one particular instance, on the Collie Mines shunt (Collie-Stockton run) I could not help noticing that the trees obscured the guard's and the driver's views of each other. It is unreasonable to expect safe working in such conditions or to blame the engine for the resultant lack of visibility. It is essential that immediate steps be taken to rectify this condition.

VISIBILITY.

With a larger locomotive the point at which the driver sees the centre of the track must necessarily be farther away than with a smaller locomotive. In the case of the Australian Standard Garratt the track centre when the locomotive is running chimney first is visible a farther distance away than it is when the locomotive is running bunker first. This subject involves one of the arguments put forward by the Union that the locomotive is large and unwieldy, but of course to say that a locomotive is large is no argument against its use. There is a good view from the window of the cab on either side. When the tanks are lowered there will be some improvement in this position. This complaint of poor visibility on account of the bulk of the locomotive is not to be confused with a similar complaint which arises out of steam blows, which has been dealt with elsewhere in this Report.

A number of tests made with the ASG and other locomotives does not show up the ASG unfavourably considering its size. A table of these tests is set out below :—

VISIBILITY TESTS.

Engine Class.	Driver's Side.		Fireman's Side.		——
	Seated.	Standing.	Seated.	Standing.	
	ft. in.	ft. in.	ft. in.	ft. in.	
C 275	53 8	44 0	53 8	44 0	Chimney first.
D 370	99 4	61 1	99 4	61 0	Chimney first.
	No view	33 8	No view	33 8	Bunker first.
DM 588	70 11	45 9	70 11	45 9	Chimney first.
	40 1	19 1	40 1	19 1	Bunker first.
E 316	85 4	59 0	85 4	59 0	Chimney first.
F 286	65 11	52 2	65 11	52 2	Chimney first.
G 233	41 4	31 9	41 4	31 9	Chimney first.
	No view	72 10	No view	72 10	Bunker first (empty bunker).
K 193	58 4	44 7	58 4	44 7	Chimney first.
	No view	45 7	No view	69 5	Bunker first (empty bunker).
M 393	96 6	68 3	96 6	68 3	Chimney first.
	No view	66 4	No view	66 4	Bunker first (empty bunker).
MSA 466	127 9	39 6	127 9	39 6	Chimney first.
	30 3	28 4	30 3	28 4	Bunker first.
N 206	60 0	52 10½	87 11	51 4	Chimney first.
	No view	possible	No view	possible.	Bunker first.
O 218	54 8	39 0	54 8	37 5	Chimney first.
	No view	45 5	No view	45 5	Tender first (empty bunker).
PR 453	105 2	85 3	105 2	85 3	Chimney first.
S 542	174 0	131 3	159 9	131 3	Chimney first.
ASG 63	133 3	111 0	133 3	111 0	Bunker first.
	116 0	119 6	116 0	108 2	Chimney first.

Note.—All dimensions taken from the buffer face to the point at which the observed man is sighted on the centre of the track.

Part IV.

STRENGTH OF STRUCTURES OF MAIN FRAMES INCLUDING BOGIE FRAMES AND WORKING COMPONENTS.

MAIN FRAME.

With the exception of the bogie frames which, as originally designed, were weak and liable to severe fracture (and which, in my opinion, are still not strong enough), I am of the opinion that the engine frames and boiler cradle frames are sufficiently stiff and well braced. The bogie frames have been dealt with generally when considering the question of safety.

There is a sharp difference of opinion on the subject of whether the engine and boiler cradle frames will give the lasting service that should be expected. The cutting down of weights of these frames, and the superimposition of heavy weights by increasing the capacity of tanks, bunker, firebox, and boiler to a marked degree, would in itself be good reason for caution. The main frame plates are of 7/8ths inch thick steel and they are held rigidly by a longitudinal steel plate attached to the main frames by means of riveted angle iron. There are holes cut in this plate to reduce weight. There are also cross members between each set of coupled wheels. These cross members, which are steel plates, also have holes cut in them to reduce weight. The upper structure on the frame must also have the effect of considerably stiffening up the frame. The sketch on page 37 gives a perspective view of the engine frame.

This frame is a plate frame and it is of a type which has long fallen into desuetude in the United States of America, where the bar frame is in vogue, but on the other hand it is widely used in preference to the bar frame in Great Britain.

The designer, Mr. Mills, considers that it is a very strong frame and there is evidence that it has withstood severe collision. After collisions, the frame has been checked for distortion and the alignment has been found correct.

In Queensland it is considered that the frame is extremely rigid, but in Victoria the view was expressed that it would be a source of trouble in the future through cracking. I do not know whether the fact that the frame is very rigid necessarily implies that it is exceedingly strong, and for my purpose, I do not intend to decide which of the protagonists is right, but the point to be borne in mind is the lightness of the frame—a frame which cannot yet be judged by any prolonged running experience. The mileages put up by the locomotives are small in the light of what one would expect before being able to lay the basis for any sound opinion. It is a matter, however, of fair comment, that if this considerably lightened plate frame is sufficient to withstand the stresses and strains of hard and continuous running and the oscillation set up by engines fore and aft, without leading to heavy maintenance costs, then engineers for years past have been spending more money than necessary in constructing locomotives designed with frames heavier than is really warranted.

The Assistant Chief Mechanical Engineer of the W.A.G.R., Mr. Marsland, adopted the attitude of " wait and see " when I first questioned him on this subject—page 416 transcript, although he later said he thought the frame was sufficiently strong—page 417 transcript.

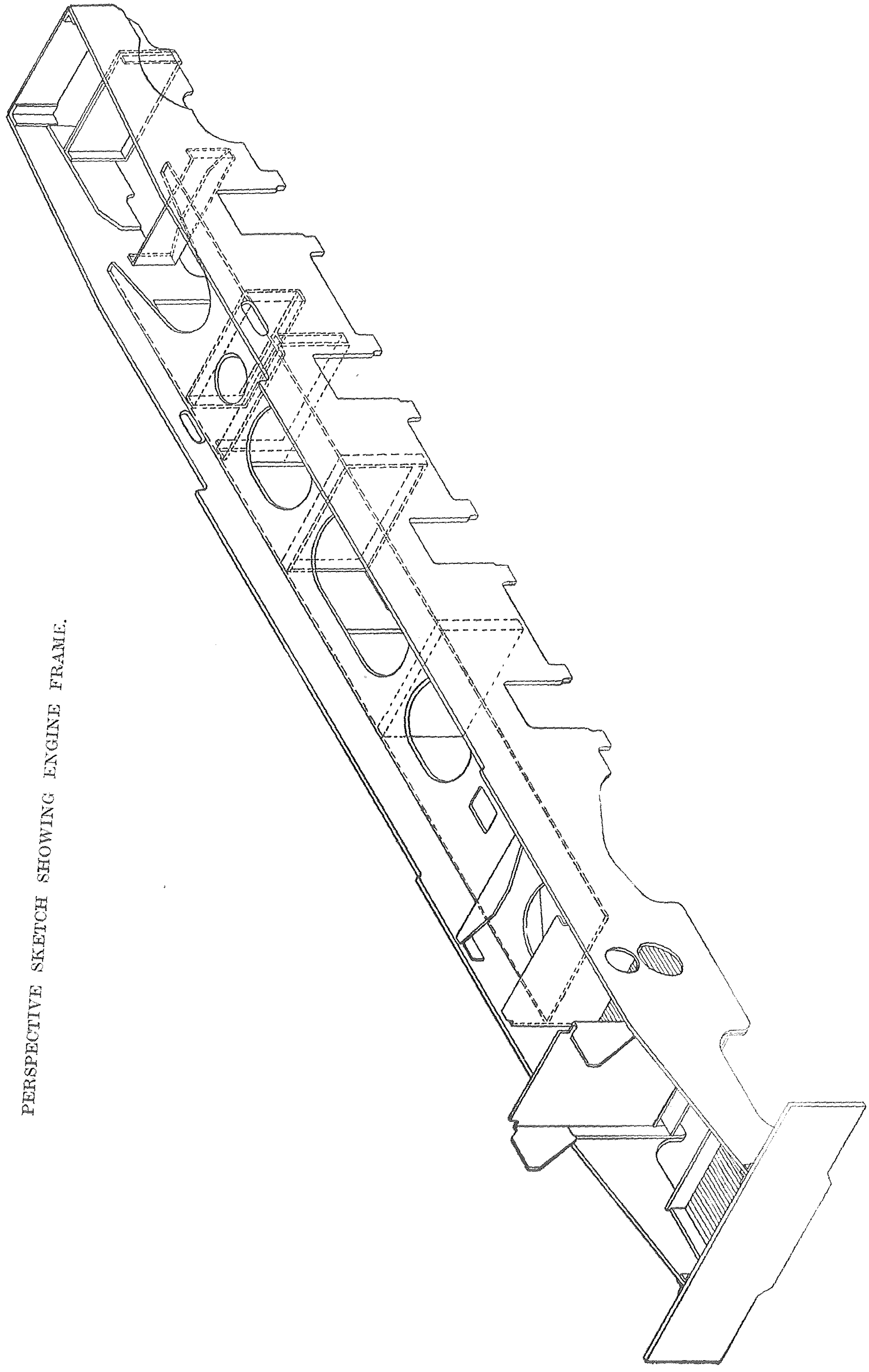
The Chief Mechanical Engineer of the Victorian Railways (Mr. A. C. Ahlston) was more critical. His prognosis was that the frame would not stand up to wear and tear of general running. Mr. Ahlston is a strong advocate of the bar frame. His point is that the plate frame is subiected to eccentric stresses. while the stress on the bar frame is direct. Instead of the centre of pressure being through the centre of the plate it is well to one side, and the same remark applies to the transfer of the load through the springs, which are normally attached to some sort of bracket fastened on the side. In the bar frame type, the frame consists of bars with vertical members, but instead of being 7/8ths or one inch thick, they may be up to three inches thick. With the bar frame the loading is symmetrical.

It is interesting to note another view expressed by the Chief Mechanical Engineer of the New South Wales Railways (Mr. H. Young), who considers that the best type is the integral casting type of frame (in which the whole of the frame and cross members, including the cylinder castings, are cast in one unit). In his opinion, there is nothing to choose between the bar frame, which is made up of a number of bars joined together, and the plate frame, but he does consider that a bar frame which is cast in one piece, or which is cut out of a solid casting, is preferable to the plate frame.

Dealing particularly with the ASG, one must not lose sight of the fact that in designing it, the designer had to meet war conditions and to consider how quickly the locomotive could be put into production. It would not have been practicable to design it with the bar frame. *At the same time, that is not my problem, which is to consider the locomotive as a buying proposition and whether it could be regarded as advantageous buying for our State Railways.*

In the boiler cradle frame design, the same principal of cutting down weight has been followed.

As in the case of the engine frames, where additional weights were added to the upper structure, additional weights were also added to the upper structure on the boiler cradle frame by increasing the size of the firebox and boiler.



PERSPECTIVE SKETCH SHOWING ENGINE FRAME.

Quite early, the cross members of the boiler cradle frame showed excessive deflection in service and it became necessary to strengthen these by inserting gussets and additional cross members to stiffen up the plate where the male section of the pivot is installed. These measures seem to have effected the required strengthening and no further deflection has been reported.

The first locomotives were issued from the shops with the pivot centres in cast iron and under the stress of the deflection at the plate where the male section was installed these pivot centres cracked. They were replaced by steel castings, and since the frame was stiffened there is no record of any further breakages.

If side bearers are fitted to check side sway—and I have already expressed the opinion that they should be—then consideration will have to be given to the question whether further stiffening will need to be provided at the frame where these side bearers are placed.

SPRINGING.

Each set of coupled wheels is independently sprung, an unusual feature for such a large locomotive which is used in general traffic. Compensated springing should be provided, thus distributing any road shocks suffered by any wheel or pair of wheels. If the state of the permanent way were ideal, then an argument might be made out for the independent springing, but the many different weights of rail and track conditions render it necessary to have compensated springing.

BOGIE FRAMES AND BOGIE CENTRES.

The design of the bogie was considered incidentally when discussing the function of the bogie as a guiding unit and the subject of derailments. The bogie as originally designed had a plate frame and insufficient provision was made for stiffening. Bogie centres, as in the case of pivot centres, were in cast iron, and experience showed that the cast iron would not stand up to the work of general running. The frames of the bogies were obviously too weak and had to be stiffened by the provision of cross members, which were welded from side to side of the frames. This resulted in some improvement. There is a case on record in Queensland where a bogie frame cracked completely through on either side and the section which broke turned over on the carrying wheels.

As I think that this bogie needs to be entirely re-designed, it is of little use pursuing the subject of its existing design at any length.

WATER TANKS.

There is a lack of strength in the structure of the tanks, mainly owing to the height at which they are set above the frames supporting them. The pitching of the water accentuates the strain to which they are subjected on curves. Various instances have occurred where the plates have proved too brittle and the tank has split under the strain. In Queensland, it became necessary to take urgent steps to strengthen the tanks to avoid wastage of large quantities of water. This trouble has been experienced also in Western Australia and Tasmania. Further baffles and internal stays are necessary and the tanks should be brought down approximately one foot. They should be set down as low as possible even to the extent of providing recesses where necessary.

LONG CONNECTING ROD.

This was designed in accordance with orthodox practice. In a letter under date the 25th April, 1946, Mr. F. H. Harrison, M.I.E. (America), the Chief Mechanical Engineer, South Australian Railways, stated as follows :—

> "The design . . . . . . has been carefully examined and I am of the opinion that although the direct stress at the least section of rod is rather high no trouble should be experienced. Calculations for—
>
> (1) transverse bending,
>
> (2) bending (column vertical),
>
> (3) bending (centrifugal force),
>
> (4) combined vertical bending (at diameter speed of 336 r.p.m.),
>
> show that they are all within the prescribed limits and have a factor of safety of at least six."

This report does not say to what limit of orthodox designing the rod was designed, that is to say, was it designed to the lowest limit or, if above the lowest limit, to what extent was it above. Mr. E. H. Brownbill, M.Mech.E. and B.E., A.M.I.E. (Aust.), the Assistant Chief Mechanical Engineer of the Victorian Railways, who had the supervision of the construction of the first ASG locomotives built at Newport, noticed the difficulty which the machinists were having in machining the rods. In machining the web, the rod showed a tendency to "chatter," which made machining extremely difficult. He considered this was due to the lightness of the web design and that the design of the rod had been cut down to the minimum of orthodox practice. No figures or computations were advanced in support of this opinion. Mr. Brownbill considered that in machining a rod such as this, small errors, such as taking out too much metal, might bring the rod under the margin of safety.

A marked lateral vibration has been observed in the long connecting rod when the locomotive is pulling heavily, which would indicate that the design calls for further consideration.

LEVERS.

There is room for further improvement in the strengthening of the sand levers and the cylinder release valve lever. In regard to the latter it sometimes exhibits a tendency to fall out of position. These matters are simple and can be easily corrected. They should not have been allowed to remain so long without correction.

ENGINE HEADSTOCK.

In Queensland and in Tasmania, where there is the side buffer the headstock has shown signs of deflection and has had to be strengthened, but this defect is revealed by reason of the double buffer and the shocks at the sides of the headstock in operating. In Western Australia where the buffer is a single buffer in the centre the trouble has not occurred.

Part V.

EFFICIENCY OF APPLIANCES AND EASE OF HANDLING.

STEAM BRAKE.

This was considered when dealing with the question of safety of the locomotive. Many of the comments which were made are relevant to a consideration of the efficiency of the appliance from the point of view of convenience of operation, and therefore there is no need for me to repeat here the remarks which I have already made.

REGULATOR.

This apparatus and its components are designed to regulate the flow of steam from the boiler to the steam chest and cylinders. The principal feature is a valve of mushroom type operated by a spindle controlled by a lever from the cab.

The main complaints about this important instrument are :—

That it is difficult to adjust to get the right flow of steam to the steam chests and cylinders, and that it is jerky in operation.

That it does not function at all until it is near the end of its travel, and even then in many cases it does not give a full head of steam to the cylinders.

That it requires physical effort to move, *i.e.*, two hands, which necessarily distracts the driver's attention when shunting.

Two distinct matters are involved in the complaints about the regulator. The first relates to the functioning of the valve and the second to the lever which operates it.

As regards the valve—in modern locomotive practice the valve is placed outside the boiler and not inside as formerly. The valve is therefore more accessible and by placing it outside the boiler the necessity for breaking boiler joints to get at it is obviated.

In the case of the ASG the valve is situated well forward on the right-hand side of the boiler near the chimney and is operated by a long rod in turn worked by a lever with a ratchet device on a quadrant in the cab. This lever is often referred to by enginemen as the regulator.

I have no doubt that all the complaints made are true. I have had experience of some of the difficulties myself. At the same time I do not think there is anything basically wrong with the design or construction of the regulator. It is probable that a slight alteration of the balancing piston by the fitting of a small hole in the balancing cavity may give a better performance.

A cover plate has been provided over a hole cut in the outside clothing of the boiler to provide easy access to the valve and its components. This was not a feature of the original design. At the time of taking evidence only nine of the engines had been fitted with this cover. It is very desirable that the remaining ones should have the same fitting and I understand that this alteration is scheduled for attention.

In the main, the matters complained of are matters arising out of lack of mechanical adjustment, and it seems that workshops supervision and maintenance are to blame in this case. There is no reason why the valve should not be got to work easily and satisfactorily. In the operating manual instructions are given for the adjustment of the valve should it be required, but it is not such an easy matter for the engine crew to make the adjustment on the track, nor should lack of workshop supervision and maintenance necessitate their having to do so.

Although it is not considered good practice to drive on the regulator, I have seen it used on the ASG with ease and effectiveness in the control of the motion of the locomotive, which proves that it can be adjusted for easy movement, and where the lever is stiff, or the valve does not lift properly a little mechanical attention should soon remedy matters.

REVERSING SCREW.

This screw is designed to operate a lever which in turn operates the reverse gear on the engine. But it also performs a wider function, because by using the screw when the lever is either in forward or reverse direction, a more delicate adjustment of steam flow to the cylinders can be obtained than by using the regulator. In orthodox driving the regulator should, when the engine is running along the main line, be kept wide open and the screw used to obtain whatever adjustment of steam is necessary to move the locomotive at the required speed. The reversing screw on the ASG locomotive has from 21 to 22 turns and in practice it has also been found to be too stiff. This is a very great handicap, particularly in shunting operations. The Department has in mind altering the pitch of the screw to provide for about 11 turns and an easier movement for the wheel operating the screw. While this will improve the position to what one might call normal operating conditions I consider that with a modern locomotive designed to develop the power which the ASG should develop, steam reverse should be provided. If the Railways are to move forward with the times locomotives introduced into the service should be provided with the latest appliances.

ASHPANS.

In Western Australia, and in Queensland and Tasmania, objection was voiced to the type of ashpan fitted to the ASG. In both Queensland and Tasmania the ashpan was removed and the hopper type substituted. The designer of the ASG, in my opinion, exhibited obstinacy in refusing to listen to any suggestion in regard to this item. When it was proposed that 30 of the locomotives should be put in service on the Central Australia line, the Commonwealth Railways drew attention to what they considered was the unsuitable type of ashpan. The design provides for side doors on either side of the locomotive. In order to clear the ashpan the fireman has to rake out the ashes through these doors. The Commonwealth Railways pointed out that they had obtained efficient service and easy emptying from a hopper type, details of which were submitted to the designer when the design was under consideration. The designer's reply was, in effect, a criticism of the details of the design which the Commonwealth Railways had submitted and also a criticism of the type in relation to its dimensions and fitting to the ASG. There was nothing said as to whether a type of hopper ashpan could be designed for the locomotive and whether if designed such a type could in principle be approved. In fact, that type of ashpan has been successfully used by the Commonwealth Railways and the South Australian Railways over dry and arid country for the last 20 years. In Western Australia the objection voiced against its use was that it would lead to the burning of sleepers. I do not think that this is any more likely with the hopper type than with the type at present in use on the ASG. The raking out of ashes through the side doors on to the track in proximity to the ends of the sleepers can still cause fires. Enginemen are instructed to empty the ashes at specified places and while there will always be occasions when careless enginemen will disobey their instructions such cases can be followed up and punishment imposed. In my opinion the hopper type of ashpan should be fitted. In the latest catalogues issued by Messrs. Beyer Peacock & Co. a Garratt locomotive, supplied to various systems in very hot climates, is fitted with a hopper type ashpan.

EXHAUST STEAM INJECTOR.

The purpose of this instrument is to utilise the exhaust steam of the locomotive in the feeding of the boiler with water from the tank. If the instrument works properly a saving of coal and water should result because the already warmed exhaust steam mixed with water from the tank is used again.

The instrument is connected to the water tank, the live steam pipe, and the exhaust steam pipe. In operation the water is turned on and a jet of live steam fed into the instrument. The effect of this is to create a vacuum in the water column and the water, relieved of atmospheric pressure, then flows freely from the instrument and up the pipe mixed with the steam and then into the boiler where less heat is required to vaporize the water because it is already heated in a measure by the steam with which it is mixed. Once the operation is started the live steam should, under running conditions, automatically shut off by means of a valve, and at this moment the exhaust steam should come into operation, mixing with the water in the mixing chamber, and passing along to the boiler. The apparatus provided is a proprietary line and the model used is a late one. It is said that some alleged improvements have interfered with its efficiency.

I am satisfied that it has been a failure and the source of a good deal of trouble and irritation. It is in a measure responsible for some of the patchy steaming performances by the locomotive. Instead of saving water and coal it has been the cause of wastage.

The water regulator spindle has suffered rapid corrosion. Efforts to move it with the long rod provided from the cab often prove futile. Mr. Mills suggests that a greater leverage should be provided, but if corrosion is there that would only have the effect of causing breakages of the spindle.

Corrosion also takes place at the bottom of the spindle and of a small renewable tip, which is part of the delivery cone.

The cone (exhaust steam cone) also fails to function. In this model the cone is wound round on the outside with asbestos fibre packing which renders it too stiff and leads to operational failures.

The combining cone (clapper valve or flap) should shut tight when the live steam has served its purpose and brought the water up, the idea being that the mixture of water and steam should then pass via the delivery pipe to the boiler. The valve, however, develops heavy wear on the face and fails to close tightly. If it does not seat tightly the instrument will not function effectively. Should this valve get into such a position that the clapper is not lying truly horizontally it will open—with the same result.

There is a flat choke valve (water valve) operated by a spring, which should close automatically when the injector comes into operation, shutting out the air and stopping the passage of water to atmosphere, but the design or material is unsatisfactory for local conditions and it fails to close, with the result that large quantities of water are wasted on the track.

There is a section of the casting of the injector into which the live steam is admitted from the boiler, and which has been subject to breakage and corrosion. This lies between the exhaust steam admission point and the water admission point. A number of castings have failed, in Queensland, through the water supply not coming through in sufficient quantity, and the failure of the live steam valve to close and the exhaust steam valve to open. That means that excessive pressures of live steam are exerted on the inner surface of the casting, leading to breakage and failure of the casting. The casting was weak and collapsed under the strain.

In my opinion, this exhaust steam injector has proved such a failure that it is advisable to discard it altogether and fit an additional live steam injector in its stead.

GAUGE GLASSES.

See under " Firing."

SAND BOXES.

One set is provided on either side at the front and back of the locomotive. The Union requested the provision of extra sand boxes at the rear end of each engine, but I do not think that any case was made out for this additional sand. The large Beyer Garratt which I saw on the Emu Bay Company's line in Burnie, Tasmania, is similarly equipped with sand boxes, only at either end of the locomotive. As the boxes are now placed on the ASG they are situate immediately in front of the leading coupled wheels of each engine and are formed in the structure which carries the slide bars. When the design was under consideration the attention of the designer was called to the fact that the boxeswere situate in such a position that the sand was likely to get wet through spillage from the tank. This was a well founded warning but it went unheeded, and events have shown that too often the sand is wet when it is wanted due to the fact that water has slopped over from the tank. These sand boxes have also exhibited a tendency to let in the rain. Further attention seems necessary to get over the difficulty.

TANK FILLER COVERS.

These covers are poorly designed and there is great wastage of water, particularly when the locomotive is ascending banks.

I recommend that the present cover be replaced by a more efficient type.

Part VI.

OPERATING AND GENERAL CONDITIONS IN THE CAB.

FIRING.

The Australian Standard Garratt locomotive has a grate area of thirty-five square feet. There is no locomotive of comparable grate area which has a mechanical stoker. I do not think there is any justification for installing one. The gear involved is far too elaborate for a locomotive with this grate area. Given a good steaming performance there is no reason why the fireman should be called upon to exert himself unduly.

A golden rule in firing appears to be " little and often," but I am convinced that there is no hard and fast rule. With a good quality locomotive coal it is possible for the fireman to build up a good starting fire and stoke at intervals with larger quantities and still keep up the boiler pressure, while the " little and often " rule seems a necessity with poor or slack coal.

Complaints that the fireman has had to work harder than normally, in the case of the ASG, are in my opinion definitely related to steaming performance. Doubtless there are cases where the fireman has not made the best use of the fuel available, or the quality of the coal supplied has been poor, but one cannot escape the conclusion that this matter is closely related to steaming performance and the steaming of the engine has not proved all that it should be.

Included in this subject is the question of shovelling down in the bunker. The bunker itself is of ample proportions and, given a fair quality coal, and efficient firing and steaming, the normal loading of the bunker ought to be sufficient to see the locomotive through its journey. But if it is giving a poor steaming performance, the fireman is called upon to work harder than usual, and the consequent extra consumption of coal often necessitates shovelling down the coal towards the chute, because a certain proportion of the contents of the bunker pack up at the rear. A glance at the outline drawing of the locomotive, as shown in Appendix I., indicates that the larger proportion—about three-quarters—should naturally fall towards the chute. Owing to the smooth riding of the locomotive, the portion of the coal inside the angle of repose will not shake forward, and if the locomotive is not steaming well, due to bad firing or some defect in the engine, there is more likelihood that resort will have to be made to this coal.

When improvements are made, as I have recommended, to improve the steaming capabilities of the locomotive the necessity for shovelling down should largely disappear. The question whether enginemen should be compensated for the extra work involved in shovelling down, or replenishing the bunker where the coal supply runs out, is an industrial one outside the scope of my inquiry. I understand the Railway Department does on occasion pay for this service but if any rule is to be laid down, apart from agreement, the Court of Arbitration is the proper body to deal with the matter.

Under the subject of firing, one must consider the allegation made by enginemen that great heat is generated in the cab. In Queensland this has been largely ascribed by enginemen to the fact, so they consider, that the firehole has been placed too low. In Western Australia the same allegation was made that the firehole was too low, but the complaint was made more on the score that it made firing difficult, necessitating the fireman's having to stoop slightly as he took the coal from the bunker and threw it forward into the fire. This aspect was also stressed in Queensland. A statement was made that Queensland had altered the level of the firehole, but if (as it appears) this statement was made to convey the idea that Queensland had altered all its locomotives in this respect, that statement is incorrect Only one firehole has been raised as an experiment. The job as carried out was not intended to be lasting, but merely to serve for a temporary period as a test. It is true that the alteration led to a reduction of temperature in the cab. However, interference with the boiler and firebox is a serious matter and in Queensland it has been estimated that at least £1,000 per engine would be necessary to cover the cost of the alteration if carried in a proper manner.

This is an instance where there has been a tendency to follow Queensland in making complaints without knowing all the facts. I am assured by the Administration in Queensland that when the firehole was raised in the one case many of the firemen were not even aware of it. It is rather striking that while in Tasmania there was some complaint about the older Garratt type of locomotive in regard to the heat in the cab—a complaint which does not appear to have been officially voiced by the Union there—a member of the A.F.U.L.E. in Tasmania, who was called as a witness, at the instance of the Union, and who is a fireman, stated that although he found the old type Beyer Garratt hot in the cab there was no excessive heat in the cab of the ASG.

RESULTS OF TEMPERATURE TESTS

A series of temperature readings taken during the general tests is summarised in the table below :—

Date.	Engine.	Trip.	Shade Temperature.		Average Temperature Reading at Intervals shown in Minutes.		Difference between Shade Temperature and Average Reading.
			Place.	Temperature.			
				°F.	°F.	Interval	°F.
12–2–46	ASG. 46	Brunswick-Perth	Pinjarra	88	102·3	10	14·3
15–2–46	317 ES.	Brunswick-Perth	Pinjarra	84	102·9	10	18·9
20–2–46	ASG. 46	Pinjarra-Dwarda	Wuraming	74	94·2	10	20·2
22–2–46	429 MS.	Pinjarra-Dwarda	Wuraming	74	95·3	10	21·3
27–2–46	ASG. 65	Northam-Merredin	Baandee	84	87·5	10	3·5
1–3–46	461 PR.	Northam-Merredin ...	Kellerberrin	99	114·4	10	15·4
4–3–46	ASG. 54	Norseman-Coolgardie	Widgiemooltha	83	101·9	10	18·9
7–3–46	C. 439	Norseman-Coolgardie	Widgiemooltha	85	100·0	10	15·0

The results show that, generally, temperature conditions in the cab of the ASG are not as hot as in the cabs of the other locomotives shown in the table. There is one instance where the ASG was a little hotter than another locomotive with which it was compared. I refer to the test of ASG. 54 on the 4th March, 1946, and C. 439 on the 7th March, 1946. In the case of the ASG, the difference between shade temperature and average reading in the cab was 18·9°F., and in the case of C. 439, the difference was 15°F.

Whilst these results do not show up the ASG unfavourably, I feel that measures should be provided in a modern locomotive to improve conditions and I do not think such measures have been taken here.

In Queensland, the smokebox was redesigned and this led to a considerable reduction of temperature in the cab—about seven degrees Fahrenheit. A self-cleaning spark arrester was installed and provision was made for a freer draught up the chimney, which improved steaming performance and reduced the quantity of ash in the tubes and smokebox. There is no doubt that obstruction to free blast in the smokebox can throw the heat back into the cab.

The fitting of a cab ventilator of large dimensions in the roof, which is designed to open backward or forward according to whether the engine is running bunker or chimney first, should prove a great help in keeping temperature down. I think the ventilator which has been provided on some Australian Standard Garratt cabs, could be more amply dimensioned than it is. The ventilators which have been installed in the roof to date, only lift one way.

I think provision should also be made for the fitting of a ventilator or ventilators high in the back plate of the cab, which could be opened at will according to conditions. Experience proves that near the top of the cab and to the rear there is a hot area, and I consider that freer movement of air would have a beneficial effect on the reduction of temperature.

There is call for easier access to the bunker, and the doors giving access which have been fitted on ASG. 46 have proved very satisfactory in this respect.

I do not think that the great expenditure which could be occasioned by raising the firehole is warranted. Even assuming that this is at the moment a defect, no engine is perfect in design. I saw a great many features on other locomotives which are undesirable, but no grave exception is, or could be, taken to them. In my opinion, it is not the position of the firehole that causes inconvenience, but it is the other features which I have already considered.

The gauge glasses are not entirely satisfactory because it is not easy, even with the light provided, to observe the water level. It is essential that both the driver and the fireman should be able to see the level without going over to it. A new and improved type of gauge should be fitted so as to show up the water level with greater clearness. There is also call for an alteration of the cock underneath the water gauge.

VENTILATION.

This subject has been dealt with when considering the subject of Firing and reference should be made to that portion of this report (*see* page 40).

PROVISION FOR CRIB BOXES.

There is a shelf on the back plate of the cab on the ASG locomotive where it is intended that the engine crew should place tucker boxes, etc., but criticism has been made by crews that food gets warm and unappetising if placed on this shelf, which is in one of the hottest parts of the cab. I am of the opinion that a much more satisfactory provision could be made. In Queensland, a tucker box is provided at the rear of, and abutting on, the back plate of the cab. The box is ventilated and has proved satisfactory. A somewhat similar arrangment is installed on the large Beyer Garratts on the Emu Bay railway in Tasmania. I recommend that this type be installed on the ASG.

DRAINAGE OF CAB FLOOR IN WINTER.

In winter, water collects on the floor of the cab. Both the Railway Department and the Union seem to consider that there is no solution to this problem. It is not practicable to provide drainage holes in the floor, but I think that some effort should be made to meet the difficulty. Perhaps consideration could be given to providing a slight slope towards the doors of the cab which would give the water greater facility for draining away.

SHOVELLING STOP.

This small and necessary feature was not provided in the original design. One locomotive which I saw (ASG. 46) has been equipped. The stop is a definite advantage and should be fitted to all locomotives. I understand that the Railway Department has listed this item for attention.

DUST NUISANCE.

The design of this locomotive is such that at the sides of the pivot centre there are apertures through which dust and dirt can be blown into the cab, and particularly when the locomotive is running bunker first. It is possible also for dust from the bunker to come down through the chute into the cab. I recommend that a canvas cover of the concertina type should be provided for these apertures and that some provision be made to prevent dust coming through the coal chute.

Part VII.

GENERAL OPERATING EFFICIENCY.

STEAMING.

A locomotive is built to steam and if it cannot maintain steam it fails in its purpose. The Australian Standard Garratt is built to work with a boiler pressure of 200 lbs. to the square inch and to exert a tractive effort of 34,420 lbs. at 85 per cent. of the boiler pressure. Some misunderstanding exists as to what is meant by tractive effort. It is a technical term having several meanings. As long as the term is used in the same sense in the comparison of several types of locomotive no confusion can result. Some manufacturers give the tractive effort for two sets of pressures—viz., one for 75 per cent. and the other for 85 per cent. of the boiler pressure at the cylinders. Provided comparison is made on the same basis there is no danger of fallacy. The tractive effort of a locomotive is the force developed at the rim of the driving wheels of the engine with a given proportion (generally 85 per cent. or 75 per cent.) of the boiler pressure in the cylinders. This force to be effective must be sufficient to move the locomotive on the road and leave a sufficient margin over for drawbar pull. So that any criticism of a locomotive must be made with due regard to its ability or otherwise to pull the loads adjusted within the limits of the drawbar pull which is related in turn to its tractive effort. Various maximum loads have been worked out for the locomotive according to the drawbar pull as affected by circumstances relating to the type of track and the ruling grade over which the locomotive has to operate.

There have been consistent complaints from enginemen that the engine will not handle the loads which have been worked out for it. At the same time, in every State where the locomotive operates it has been conceded by enginemen that when they do pull the load these locomotives seem to operate with ease. That does seem to point to the conclusion that the design of the boiler and firebox is satisfactory and that the difficulty must be sought elsewhere. It is obvious that if a locomotive is giving a variable performance it is time to take some remedial action.

During the course of the hearing in Western Australia it was admitted that the locomotive had not been able to live up to the steaming potential for which the designer had planned. Complaints in Queensland were not so emphatic as they were in Western Australia, and when I come to develop this subject more particularly I shall make some reference to the reason. In Tasmania, too, there is an absence of any serious complaint as regards the steaming, but it cannot be overlooked that the locomotives have not been called upon, in that State, to haul loads over the ruling grade commensurate with the loads for which they are designed owing to the absence of facilities for marshalling the loads at sidings and in yards.

There are various reasons why a locomotive will not handle the loads for which it is designed. They may exist, of course, alone or in conjunction with one another. The only ones that need concern this report are :—

Faulty design of heating apparatus, which would include the firebox, the boiler, the tubes (including, in the case of this locomotive, the superheater tubes and the elements).

Faulty design of smokebox and blast pipe.

Faulty distribution of steam to the cylinders, including loss of superheat and condensation.

Bad firing.

Poor quality coal.

It is surprising how one or two of the ASG locomotives have gained a reputation as good steamers, while the others stand condemned by enginemen as poor. If the ASG acts up to its designed potential it will give a performance better than any other locomotive in service on the Western Australian Government Railways and instances can be cited of successful runs. But the general weight of evidence shows that the locomotive has not lived up to expectations. Nor, in my opinion, is that surprising in a machine which was designed and built so quickly as a war emergency measure, and under such difficult conditions.

The installation of a dome subsequent to the production of the locomotives, and the provision of dryers, indicate that steps have been taken to ensure a better performance, but the results are by no means satisfactory yet. Granted that there are cases of bad coal and bad firing there is still much to be explained and room for improvement.

I suspect that the dryer fitted is much too small and that it causes " wire drawing " of the steam and interferes with distribution. There may also be some reason for questioning the sufficiency of the area of the cross section of the main steam pipes, but unfortunately I have not been able to come to any definite conclusion owing to the fact that proper pressure tests were not carried out, as will be presently explained.

In Western Australia when Newcastle coal was available it was supplied to these locomotives, or mixed with other coal. In Queensland the general opinion now is that with the best coal available there (Blair Athol coal) which has a higher calorific value than Western Australian coal, the locomotives give a reasonable steaming performance. It is clear from the evidence that this has been achieved by re-designing the smokebox, a matter which the Railway Administration in Western Australia also has under consideration. In the Queensland design the type used is what is known as the American self-cleaning type, or Master Mechanics front end. Before this type was adopted in Queensland the tubes and front end used to become choked up with soot, thereby affecting the steaming of the locomotive.

The Beyer Garratts which I saw in Tasmania on the Emu Bay line were fitted with a Master Mechanic front end and I was told that there was very little accumulation of ashes in the smokebox and tubes.

The different climatic conditions in Western Australia will no doubt compel consideration of a type of front end which is best suited to the drier climate of this State, because the Railways have always had to design the smokebox with a spark arrester which would restrict the escape of live sparks to atmosphere. The problem is not so acute in Queensland or Tasmania.

General Comparative Tests.

So many assertions were made that the ASG was not able to put up a steaming performance as good as other locomotives which have been in service for over 30 years, and which the ASG had superseded on certain runs, that it was decided to make steaming tests of the ASG as against older locomotives. Generally the type of locomotive selected for comparative tests is that which was doing the work on the run prior to the introduction of the ASG.

The operating costs have been worked out for all these general tests, but, for the purpose of this inquiry, the only costs taken into consideration are wages and coal, as those are considered to be sufficient to give a comparative picture. It will be noticed later when considering these tests that besides noting the coal consumption, the ton miles worked, and the cost per ton mile, the water evaporation per lb. of coal has also been recorded. This figure will require to be taken with caution in some of the tests of the ASG because there was sometimes wastage of water due to the failure of the exhaust steam injector, and what looks like a good performance in evaporation may be really a record of waste of water on the track. Where water was wasted that fact is noted against the test. On the other hand it is usual to allow credit for as much as 8 per cent. saving in water where an engine is equipped with exhaust steam injector and no adjustment has been made in any case in these tests. Operation costs have been taken out on the same basis for the special tests.

Special Pressure and Thermal Tests.

Besides testing the ASG as against other locomotives it was decided to make special tests of an ASG locomotive and other locomotives in order to ascertain the efficiency of steam pressure in the cylinders as well as the thermal efficiency of the steam.

A test code was used in preparing the locomotives and conducting the tests. This test code provides for each locomotive to be put in normal road working condition. There is evidence that the locomotives were not well prepared for the tests.

Some of the main details of the locomotives tested appear in Part I. of Appendix IX.

There is a diagram in Part 2 of Appendix IX. showing the location of the various instruments installed for the purpose of taking pressures and temperatures on the ASG.

The pressure and thermal tests were made more particularly with a view to ascertaining whether there was any considerable drop in pressure or in temperature of the steam after it left the boiler for the cylinders.

Before I left for the Eastern States in February this year it was arranged that these pressure and thermal tests should be carried out in my absence and the results forwarded to me so that I could submit them to competent opinion in the other States. In the first place, the tests were delayed because the Union unreasonably refused to permit a locomotive (ASG 48) to be tested which was the one previously decided on between the parties and a long delay ensued before the tests actually commenced. In the meantime, I had returned to Western Australia. Before I left for the Eastern States I received an assurance from the Chief Mechanical Engineer that all gauges and instruments used in testing would be scientifically checked before being fitted to the locomotives. The first test of this special series was conducted on the 24th May, 1946, and the records obtained indicated that the test was a fiasco. The department had enlisted as instrument readers to supplement its own staff certain apprentices and university students whom it considered quite competent at the time to do the work of reading and recording. In a letter written under date 27th May, 1946, forwarding the results of the test, the Department said, inter alia,

> " the data submitted comprises a general statement of coal and water consumption, etc., as for previous tests. Also, tabulation of pressures and temperatures observed. Graphs of pressure and temperature reading are being prepared and will be supplied as soon as possible.
>
> " A period of at least 15 years has elapsed since any attempt was made to conduct equally comprehensive tests on locomotives and no adequate training of observers or checking of instruments and their mounting has been possible in the very short time available on this occasion. One preliminary run only was made and this was the only opportunity for training the large number of observers. Considerable hunting of pressure gauge needles was experienced and though corrective measures were applied prior to the actual test, there was no means of determining whether the measures taken were adequate. A great improvement did result but hunting was not eliminated completely and observers had real difficulty in making accurate observations. Review of the results, however, shows that all possible care was taken and the figures submitted are the best obtainable in the circumstances."

On the 30th May, 1946, a further advance report of a test came to hand relating to ASG 48 on a run from Midland Junction to Fremantle and return and the results shown were just as unsatisfactory as the first test. In a covering letter the Department stated :—

> " The need for the greatest care in recording gauge readings was again impressed upon all observers and Mr. Mills is satisfied that everyone did his best and that no team could have produced more consistent results. Despite the care taken there are several obvious inconsistencies and inaccuracies which appear to rob these tests of much of their value. *These errors are due entirely to " hunting " of gauge needles which has not been overcome entirely.* All gauges were checked prior to the test. No attempt will be made to draw any conclusions from these tests until results have been graphed against those from tests yet to be made on other locomotives.
>
> From experience to date it is clear that a fair amount of experimental work is necessary to evolve methods of mounting gauges and damping needle movements before thoroughly reliable readings can be secured.
>
> In the peculiar circumstances surrounding these tests there has not been any opportunity for such experimental work . . . . Many years have passed since indicator diagrams were taken but attempts to use pressure gauges in the manner of these tests have not been made previously."

Smoke-box readings for each of the foregoing tests were inordinately low and I had queried these ; The letter goes on to say :—

> " The engine steamed very freely,† though smoke-box vacua still appear low. No great importance is attached to manometer readings as these are likely to vary appreciably in different parts of the smoke-box and a multiplicity of instruments would be needed on all engines tested to gain data suitable for close comparison."

On the 7th June, 1946, a further set of advance results came to hand in connection with the testing of F.S. 429 (Midland to Northam) and the information furnished was just as unsatisfactory as the previous information. In forwarding this set the Department said as follows :—

> " Pressure readings showed discrepancies somewhat similar to those noted on testing ASG 48 and are due mainly to the difficulties of reading flickering gauge needles."

The first test results for ASG 48 (test 24th May, 1946) contained many manifest absurdities and here are some of them :—

Pressures were shown on the saturated side of the header when the regulator was closed. In these circumstances such pressures would be manifestly impossible. There would be either no pressure at all or perhaps a slight vacuum.

There were other cases where pressure at the saturated side of the header was greater than at the boiler. And still further cases where pressures at remote points such as the steam chests were greater than at points preceding them in the main line of steam distribution.

A set of steam temperatures recording the temperature of saturated steam at the saturated side of the header could not be correlated with the steam pressures at the same point. When the temperatures were converted according to steam tables the average of the true corresponding pressures as derived from the table was fourteen pounds to the square inch below the pressure shown for the corresponding readings on the pressure gauges.

Other test data sheets showed similar anomalies. In view of the apparent muddle I wrote on the 14th June, 1946, through my Associate pointing out many unsatisfactory features disclosed in the tests and went on to say that the indications were that the tests made were valueless, and, that I was at a loss to know how, in the circumstances, further tests which might be equally as unsatisfactory could assist in pointing to further conclusions. The Department wrote in reply on the 17th June, 1946, expressing amazement and stated, inter alia, " the tests have produced a mass of information from which no reliable data can be deduced until the facts have been correlated and graphed one against the other. As stated in Mr. Raynor's letter to you of the 20th ultimo, Mr. Mills is satisfied that no team could have produced more consistent results—in the peculiar circumstances surrounding the test and with equipment available. The final result alone can determine whether the tests have yielded the information sought by the Royal Commission."

A substituted sheet of results for the first test was forwarded to me. This sheet contained divergencies (apart from the excision of the erroneous entries originally pointed out) from the original sheets and it appeared that the Department had corrected a good many errors which had not been pointed out in the first sheet.

In view of the notice the Department had had I am unable to see any merit in the explanation which was given. While it is true that when the time came to do the tests the locomotives had to be got ready at short notice, the Department had had many months of warning that the tests would take place. The Department asked for an opportunity of completing the tests. It now said, referring to the hunting of the gauges—" hunting of pressure gauge needles on the locomotive is due to vibration."

In view of the fact that the special tests were then almost completed I agreed that the Department should finalise the programme.

I have already mentioned a set of pressure recordings that were entered in the column—" Pressure saturated side of header "—when the regulator was closed. The Department admitted this was an error due to haste and stated that the figures really related to some temperature recordings in degrees Centigrade which were inadvertently put in the wrong column, although the figures could not have related to the series of recordings under discussion because with the regulator closed there would be no occasion in this series to record pressures or temperatures beyond the boiler. The same error was repeated in the advance data supplied in connection with the testing of locomotive S 545 on the 13th June, 1946. I do not know what was the cause of the error on this occasion. I think one might be pardoned for thinking that these test recordings would be useless, but the Department proceeded to " correct " them and " graph " them for the purpose of comparison. To make these corrections the Department employed a mathematical computation of a statistical nature in order to arrive at what it considered was the true mean, plus or minus degree of error, applicable to the majority of cases discarding all values which were manifestly absurd and others which occurred so infrequently as not to have any sensible weight in the result.

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†Note : I do not agree that the engine steamed freely (see page 83).

There is no need to go into the principle of the mathematics of the computation, which appears correct, but if the figures are based on incorrect assumptions or can have no rational application to circumstances, their use would be meaningless, and that is the case here. After ascertaining the mean variation the Department added or subtracted it from the recorded pressures affected and that became the corrected figure. A table showing the effect of these corrections is shown in Part 3 of Appendix IX. In many cases the effect of these corrections is considerable. That is surely a remarkable way of dealing with so many sets of figures which were supposed to have been recorded scientifically. I have never known of corrections being made on such a scale, and the answers to all inquiries I have made of independent persons who should know, have ridiculed such a course of wholesale correction. The same system was applied to correcting temperatures.

Having made the corrections, the Department produced a set of pressure and temperature recordings which are superficially consistent, but *only superficially* consistent, for when they are critically examined all sorts of anomalies become apparent. For example, it can be shown that on numerous occasions the " corrected " recordings show pressure drops occurring from, say, the boiler to the superheater header and for the same set of readings a smaller drop from the superheater header to the steam chests. The corrected recordings are just as wanton in the case of temperature readings. While it is possible to show steam pressure recordings which drop away less between the superheater header and the steam chests than between the boiler and the saturated side of the header, one can pick out corresponding temperature readings which are the reverse. Generally the trend of corrected recordings for the hind steam chests is to show an increase in pressure while corresponding temperature readings show a decrease.

Pressure drops to the hind steam chest of the ASG shown by the recordings is considerably less than the drop at the front steam chest, which, in my opinion, cannot be explained by any rational natural theory.

The Department proceeded to " graph " the results and the graphs are now before me for consideration. I asked the Department for the records of the degree of-cut off for each recording but apparently none was obtained, except when a recording was made for an indicator card. It is essential to know the degree of cut-off at all recordings and even if the recordings in the present case had looked prima facie correct, the degree of cut-off must be known before one can pronounce any opinion on whether the pressure or temperature drop registered at any point is normal or abnormal in the circumstances.

Special mention should be made of small pressure drops from three to four pounds between the boiler and steam chest on the hind engine of ASG 48. In view of the fact that the best articulated locomotives are not capable of putting up a better performance than a drop of from 12 to 14 pounds to the hind steam chest, I could not accept these figures as given for the ASG as being correct, more especially in view of its poor performance—the acceptance of the accuracy of this small drop is also ruled out when one considers that bigger pressure drops are recorded at the front steam chests than at the hind steam chests.

For these reasons I think the data sent forward relating to all pressures and temperatures beyond the boiler is worthless and the conduct of the special tests was no credit to the Department.

What affirmative conclusions can be derived from the material before me ? Only this, the graph of the boiler pressure recorded for ASG 48 on the 24th May, 1946, shows a marked tendency to sudden fluctuation.

This phenomenon may be due to wire drawing of the steam between the boiler and the steam chests. If, in the anomalous instances already mentioned, the temperatures at the saturated side of the header are to be taken as correct, then the actual pressures of the steam would be lower than were recorded. That would mean a marked fall from the boiler to the saturated side of the header bearing out the theory of wire drawing, which then could possibly be caused by the design of the regulator. Elsewhere I have said that I could find no evidence to fault the design of the regulator valve but it is possible that the pipe leading away from it may cause constriction or obstruction. It is a possibility that the " hunting " of the pressure gauges was due to variations in the steam pressure brought about by wire drawing.

As between the steam chests and the cylinders, the evidence convinces me that they are well designed and there is ample port area for full admission and valve events are normal and efficient.

Before leaving this part of the subject, I would again draw attention to the phenomenally low exhaust and smoke box readings and the Department's statement on this matter whilst the tests were proceeding. When the tests were finalised, the Department gave some details of the procedure adopted in taking the manometer readings. It was said that " readings could be regarded as affording a broadly true comparison but they should not be accepted as absolute values since no attempt has been made to explore variations of pressure inside any of these smoke boxes. If compared with figures given for locomotive tests in the U.S.A. these vacua will appear very low ; but the fact that no wide difference exists in the readings for the three classes of locomotive indicates that they are not exceptional. In the U.S.A. high back pressures and high vacua are common and for this there are two special reasons. Boilers are forced to high rates to meet high speed schedules and a special effort is made to discharge steam and cinders from the " self cleaning " smoke boxes high into the air. An attempt to follow that practice here would increase fire hazard enormously."

It is doubtful whether the Department is getting the best results out of any of its locomotives with such low vacua. The practice of increasing smoke box draught is not peculiar to the United States of America. It is done in other States of the Commonwealth and the fire hazard has not increased. The object is to obtain a heavy draught up the chimney while keeping down back pressure as much as possible. This means a freer passage of air through the fire, greater heat, and better steam output, with a resulting improvement in performance. Elsewhere I have pointed out that the front end arrangement of the ASG locomotive is a hindrance to steaming and I have advocated its re-design.

For an engine to steam freely the maximum variations in smoke box vacua should be from four to nine inches and this is the experience in the other States.

The indicator cards which were taken during the special tests were of very little use. One very important feature which is absent and which robs the cards of practically all their value is the neglect to show the steam chest pressure so that one can gauge the pressure drop from the boiler. In any properly taken set of cards scales should be shown in a legend and lines showing the levels of atmospheric as well as of steam chest pressure should be shown.

These indicator cards have a limited value in so far as they demonstrate that the design of the steam chest and cylinders of the ASG is good and valve events can be considered satisfactory. In that respect they bear out what the details of the design suggest and support the opinion expressed above when considering the results of the test. They also show that steam chest and cylinder design of the ASG is superior to both the S and FS.

Some of the diagrams are so asymmetrical in outline as to cast doubt on whether they were taken properly. In the case of certain diagrams relating to the ASG the asymmetry is explained by the Department as being due to a difference in temperature between the head and crank ends of the cylinder—a remarkable theory. The cylinders under consideration in relation to that theory are the hind cylinders. In pursuing the theory further the Department seeks to explain what would be an extraordinary state of affairs by attributing the assumed drop in temperature at the crank end *to the longer steam pipes*. But, if this explanation is taken in conjunction with the strange records forwarded to me indicating greater drops to the front steam chest than to the hind steam chest, it is easily seen of how little value it is. There is no record of any steam blow at the piston valve packing at the time the cards were taken, but his could be a possible explanation if there were a lower pressure at the crank end.

In drawing deductions from the cards, the Department refers to those taken from the ASG and from the FS locomotives and comes to the conclusion that the FS is close to the maximum power output which can be expected, whereas " ASG 48 had a large reserve of power." The performance of the ASG in these tests, particularly on the run to Northam, will not lead one to believe that with its present details of design it has any reserve of power. I have had the advantage of seeing certain indicator cards of the ASG which were taken by the Tasmanian Government Railways in June, 1945. These cards were taken for a special purpose. At the time, there was a rumour that there was wire drawing between the boiler and the cylinders and gross loss of pressure. The cards appear to be well taken and although some have no demonstrable value, owing to the conditions under which they were taken, there are others which tell a story and that is, that when the speed of the locomotive increases over 15 miles an hour and the demand for steam increases, the pressure falls markedly at both ends, more particularly at the rear steam chest. In some cases there is evidence of an erroneous reading of the diagrams and pressure drops are in reality considerably more than recorded. But there is this to be said from the Tasmanian cards—they generally demonstrate that the ASG in Tasmania is giving a better performance than in Western Australia as it is possible to operate them at a longer cut-off at each particular speed. It is noteworthy that the Tasmanian Government Railways got to work early and re-designed the faulty front end.

In a report and summary of results of the tests, the Department complained that the engineers were not allowed a free hand. There is no comment of any importance by the testing officers, except in two cases. Mr. Mills states that in the initial run of ASG 48 he complained about the engine crew stopping on the bank when there were two and a half inches of water showing on the gauge, but he says that Mr. Davies, the Union advocate, took him aside and told him that he should not interfere as the operation of the locomotives was left to the crew. Seeing the distance the locomotive was from the top of the bank and the apparently rapid consumption of water which was taking place, I think the crew were justified in playing safe. I do not agree that the locomotive gave a good steaming performance, on the contrary, it was a very poor performance. There is one case, (S 545 on the 13th June, 1946,) when the crew handled a locomotive badly. A large fire was built up, the engine steamed freely, and was continually blowing past the safety valve. To prevent this, the fireman opened the large door of the fire box and allowed the cold air to play on the fire. This was a waste of coal and water.

All these tests are summarised in convenient form in Part 4 of Appendix IX. Their only value is as a rough guide to economic efficiency. The following extracts from the particulars shows that the ASG although a comparatively new locomotive which should be able to put up a substantially better performance than older types is not showing up to any great advantage.

ASG—all sections—9·86d. per hundred gross ton miles.

Other locomotives—all sections—10·30d. per hundred gross ton miles.

As matters stand at present, the old FS can put up a relatively better performance in steaming and coal consumption.

I think the Department really does make some apology for the results although it is careful to note that certain remarks in the report covering the result of the tests should not be read in any sense of apologia. If they are not intended as an apology, I think that an apology is necessary. The Department emphasises that the coal consumption figures recorded do not afford an index to every-day consumption. Further, as no steps were taken to ensure that each engine was worked at its full efficiency or effectiveness, the coal used per ton mile was not a reliable guide for comparison. This does seem like an apologia because the ASG and the S do consume more coal, according to these tests, as compared with an old locomotive like the FS.

There is no reason why the figures relating to consumption should not be taken as a reliable guide for the ASG at any rate. I think the figures for the ASG show that it is not living up to its designed potential and that it will not do so unless details of design are altered ; further, all this boosting of present potential of the ASG seems flatly to contradict Mr. Marsland's evidence when he candidly admitted that the locomotives had not shone in steaming performances.

The Department states that the—

> " results of these tests cannot well be compared with the results of tests made under laboratory conditions, such as exist in the large and elaborate testing plants in the United States of America. Test plant conditions vary importantly from road test conditions because with the former a locomotive can be held at one speed for considerable periods and any desired rate of output up to the maximum can be maintained at any speed until sufficient number of observations have been made."

The Department goes on to say—

> " in road tests there is difficulty in ensuring that each locomotive shall be operated at the same speed at any given point along the track. A very large number of road tests would be necessary to give a volume of data similar to that obtained from test plants."

Reasonably accurate results are being obtained in Australia today from road tests and the degree of accuracy obtained is useful whereas in the present special tests the errors are so numerous and glaring that they are practically valueless for tracking down details.

The Department's remarks concerning the temperature recordings of saturated steam on the saturated side of the header are interesting. These figures were not included in the final test results. The Department observed in a covering note that—

> " the records presented do not make reference to the temperature of saturated steam in the boiler."

It went on to say—

> " temperatures were measured at the saturated side of the header and the data can be supplied if desired but its usefulness is not clear."

Normally such temperatures are not taken, because there is a constant relationship of temperature to a given pressure of steam and the temperatures can be obtained from any steam table. But in this case they had a value as demonstrating that something was amiss in that at least pressure readings were wrong or that the temperature readings were wrong, and very much in error.

The Department stated further, that—

> " if individual temperatures of saturated steam in the header are related to pressures, some deductions regarding wetness of the steam might be drawn but could not be regarded as conclusive."

What this means I do not know. It has already been pointed out that the relationship between pressure and temperature is constant, and this relationship will be constant notwithstanding that some condensation may take place, in which case there will be a drop in pressure and a corresponding drop in temperature. Where, on the other hand, the steam temperature is high enough to re-evaporate moisture, the balance will still be maintained.

When the Department was asked to supply the pressures for the saturated steam temperatures, according to the steam tables, it replied that " these pressures cannot be read directly from tables in the possession of this branch and interpolation will be necessary." I do not know what is meant by " interpolation." If it means some adjustment or correction, then I would not accept the figures for the reasons already stated.

The Department put forward some graphs, which are supposed to show the relative horse-power of various locomotives tested, and the ASG is shown as a very powerful machine compared with some of the other types. The graphs on which conclusions are based are empirical. They have no relation to the particular design of engine and they are based on assumptions which cannot be justified. For example, one curve to demonstrate the horse-power of the ASG assumes a firing rate of 183 pounds per square foot of grate area per hour, and the other, 100 pounds per square foot per hour. This last mentioned figure is a little less than the maximum found possible in Victoria. The graphs are so far from the plotted results that they are worthless and misleading. They rather assume (what has been pointed out before) what the ASG ought to do if all the details of design within the leading dimensions were good, whereas experience shows that is not the position.

GENERAL MAINTENANCE.

Boiler Washout and Tube Attention.

In the course of the evidence this subject was generally discussed under the heading of boiler " washout," but that term only partly covers what is meant.

Screw plugs are provided in the boiler of every locomotive so that a jet of water may be directed through the holes in which these plugs are set, in order to wash out the boiler and remove scale and impurities. Top and bottom plugs are generally provided both at the back and front end of the boiler and on either side.

I witnessed a washout test of ASG 46 at East Perth loco. depot on the 23rd January, 1946. The water washed through the boiler had little dirt in it, indicating that the boiler was wearing well although, of course, it must not be overlooked that it was new. This good condition has been largely attributed to the steel firebox and the chemical action of the short zinc rods which are attached to the ends of the washout plugs.

After the washout test the spark arrester and base plate were removed and an inspection was made of the tubes. The inspection showed that the following tubes were blocked :—

4 superheater tubes
1 in first row of small tubes
4 in second row
3 in third row
5 in fourth row
2 in fifth row
2 in sixth row
2 in eighth row
—
23
—

Five in the ninth row were partly blocked.

The last inspection of these tubes had taken place when the spark arrester had previously been taken out—20 days previously—on the 3rd January, 1946, since when this locomotive had run 1,521 miles. The Chief Mechanical Engineer expressed himself as being satisfied that this was a creditable performance.

The rule is that the boiler should be washed out once a week, except during the period of the year when the water is good and the Chief Mechanical Engineer certifies that the period may be extended, in which case the period may be extended to a fortnight. When the washout is being done the washout man should inspect the tubes, including the superheater tubes, to ascertain whether they are free of soot and other solids which are harmful and interfere with steaming. He is provided with a long rod fitted with an auger bit so that he can break through any blockages. He has also a long pullthrough to complete the job and ensure that the sides of the tube are free. The large birdcage type of spark arrester fitted to the ASG blocks the view of a good many of the tubes. As it was originally fixed by means of hinges and bolts it took 40 minutes to take off and the same time to replace, although the assembly has since been improved by using cotter pins, thus cutting the time by half.

The practice started of leaving the spark arrester for a month without taking it down, but there is no explanation of how it came about. Fairly large quantities of ash accumulate in the smokebox, particularly with this type of spark arrester and this accumulation has to be removed when washout takes place. The bottom plugs in the front end should also be removed and, owing to their situation, a little to the rear and bottom of the spark arrester, they were found difficult to remove with the ordinary spanner provided. This led to disputes and the refusal of the washout man to remove the plugs unless the spark arrester was first removed. A long box spanner was provided so that it could be operated without the washout man having to get into the smokebox behind the spark arrester. At times the front end of the engine can be uncomfortably hot. To get at the plug with the spark arrester in position this spanner must be used at an angle to the head of the plug. The objections raised really related more to the reverse process of putting the plug back, which necessitates the spanner again being used at an angle. The washout man argues that it is of course very necessary to make a steam-tight fit in putting the plug back. In order to ensure this he is supposed to screw up the plug finger tight and then use the spanner. The contention is that the plug can easily be stripped if the long box spanner is used.

Some emphasis was laid on the extra time necessitated in removing the spark arrester, as if to suggest that showed the locomotive was wasteful in time and labour. Apart from the fact that the time has been considerably reduced I do not think there is any real substance in that suggestion. It is a small element of increased cost, which may be justifiable with a larger and more powerful engine than the majority of engines on the State railway system. But what cannot be defended is the practice which has grown up of leaving the bottom tubes and some of the side tubes, which cannot be easily reached, to wait for attention until the spark arrester is removed.

In practice, if the locomotive is operating efficiently and the smokebox performing its function, a minimum of deposit should be found in the tubes. I have made extensive inquiries and no loco. depot where I inquired would countenance leaving the tubes so long without inspection or attention. The practice at other depots squares with the instructions given in the operating manual relating to the Australian Standard Garratt, which in no uncertain terms emphasises the need for regular inspection and attention to the boiler and the tubes (see pages 41–43 of the Manual). If the practice which has grown up is a device to make up for the extra time occupied in removing the spark arrester it cannot be justified. While I am not pretending to dogmatise on the period for which the boiler and tubes may be left without washout and rodding out, what I do wish to emphasise is that no system should permit the tubes to become blocked up in anything like the condition of the tubes I saw on ASG 46.

FRONT END.

In dealing with the steaming of the engine I had occasion to mention the front end. The present design has been responsible for much unnecessary work. The accumulation of ashes in the front end and the blocking of tubes with soot has been responsible for more maintenance than should be necessary if the front end is properly designed. If the Master Mechanics front end, or a modification of that type, is adopted there should be a material improvement and there will not be the same accumulation requiring attention.

HOT BOXES.

There have been remarkably few driving wheel hot boxes, but there have been too many hot boxes on the bogies. It is very difficult to say what is the cause of this condition. It does not seem that there is too small bearing surface. I am inclined to think that Mr. Kirkbride, of the Commonwealth Railways, is on the right track when he expresses the opinion that the hot boxes are due to the boxes bearing unevenly on the journals on account of distortion at the horns. He points out that the frame is very flimsy. It is true that the frame of the bogie has been stiffened, but he considers that there is still a liability to deflection at the horns.

However, this problem becomes academic, because I have elsewhere advocated discarding the existing bogie and constructing another to a fresh design. In this design I suggested that roller bearings be fitted.

ENGINE BOXES AND BOGIE BOXES.

The wear in these boxes has been very rapid and of course expensive in maintenance. There are two causes for this rapid wear. As the boxes and brasses were originally designed, only a very small bearing surface was provided for the hub of the wheel and the restriction of the bearing surface naturally caused greater wear. A further cause, which still exists, is the excessive lateral oscillation which takes place owing to the faulty design of the bogie. This should be rectified when the bogie is redesigned and the fitting of flanged leaders will be an additional advantage in preventing wear. The fitting of a brass face on the axle box was decided on when it became apparent that the bearing surface was not great enough, and this alteration in design has proved a definite advantage in reducing the rate of wear although it is still too rapid, in my opinion due to the excessive lateral oscillation.

BRASSES.

Elsewhere I have pointed out that, in general, no fault could be found with the composition of the metal of the brasses in the engine and bogie boxes. Reference has been made to the rapid wear brought about by extreme lateral oscillation. The original design provides for lubrication between the bearing surface of the brass and the journal. This is effected by means of wool rolls. These rolls are put into a recessed keep at the bottom of the box. When the brass in the box bears against the journal the wool pack is imprisoned in the keep. It is not subjected to the whole weight of the locomotive at the journal but it is made sufficiently thick to be compressed to a degree and to ensure, as far as possible, a constant contact with the part to be lubricated. When oil is poured into the keep the wool absorbs it and being constantly against the bearing surface it should provide effective lubrication. This practice is well known on railway systems. Both in Queensland and Tasmania it appears that the Administrations considered the means provided were not satisfactory and certain variations were made. But as regards the lubrication of the journal, it does seem that this method should be effective, and perhaps some difficulty has arisen by reason of the fact that the method is new on these railways. In Western Australia no real difficulty has been experienced.

The real cause for complaint, is that the original design did not provide for hub liners on the boxes, thus leading to rapid wear between the hub face and the small end surface of the brass. When ultimately these hub liners were provided no provision was made for lubrication and this is a defect which needs to be remedied.

FIREBOX FRAME STAYS AND CROWN STAYS.

The frame stays of the firebox are all rigid. The firebox is short and no doubt this would be one of the reasons advanced for the rigid stays instead of what appears to be the more usual practice of having a certain percentage made flexible. The crown stays are also rigid.

There were some early cases of the crown stays and firebox stays working loose but there were no cases of breakages of crown stays. Loose crown stays are more suggestive of faults in assembly than defects in design and manufacture. There were, however, cases of broken firebox stays but this is not unusual on all types of locomotives and the breakages were not excessive.

When the design was under consideration it was pointed out to the designer that the rigid stays were inadvisable, but he maintained that flexible stays were not necessary and also urged shortage of material and labour.

I think the better opinion is against rigid stays and I recommend that as opportunity presents itself a proportion of flexible stays should be installed.

CRACKED CYLINDERS.

Maintenance expense has been very great on this item. In all three States there have been a greater number of cracked cylinders with the ASG than with any other class of locomotive.

There is a tendency to condensation in the long steam pipes and great care must be exercised in starting the locomotive to see that the cylinders are cleared of condensate. It is also necessary, when coasting, to keep the cylinders open. Doubtless some of the trouble has been due to drivers not taking sufficient precaution. Since the fitting of domes and the spring loaded cylinder release valves the trouble has largely disappeared. This mischief, while it can never be entirely eliminated with any type of engine, can be kept within reasonable limits by the installation of effective valves, and the enginemen taking proper care. I have reason to believe that on the Beyer Garratts no great trouble is experienced and I was told by the Manager of the Emu Bay Railway Company in Tasmania that there has been no case of a cracked cylinder on the large Beyer Garratt locomotives in use on their railway.

PIVOT CENTRES.

These have already been mentioned when considering the strength of the boiler cradle frame and the engine frames carrying the bottom casting. The question of lubrication needs consideration. Lubrication of the pivot centre is not a matter of routine maintenace. Oil is put in the bottom casting when the centre is assembled and a felt pad is provided to retain the oil. I do not think this oiling system is satisfactory. There should be some means provided at the pivot centre for manually introducing oil into the bearing.

Part VIII.

ECONOMICS OF THE AUSTRALIAN STANDARD GARRATT.

A locomotive must be judged by its safety ; its performance rated in terms of loads it is able to pull over the ruling grade ; the relative cheapness of operating costs and maintenance ; and its ease of operation. In particular it must be judged by :—

- (*a*) ratio of capital cost to tractive effort ; actual weight ; axle load ; and adhesive factor ;
- (*b*) ratio of drawbar pull to unit cost. This proposition may need some qualification in the case of a locomotive which is designed, for example, to carry extra supplies of coal and water ;
- (*c*) ability to lift maximum loads from rest, to accelerate to required speed, maintain speed and come to rest ;
- (*d*) ability to haul maximum loads over ruling grades for long periods with only normal maintenance attention. This involves the greatest measure of freedom from breakdown of parts through mechanical or inherent defects, involving in turn a low ratio of repair and maintenance costs ;
- (*e*) ability to pull greater loads at speeds equivalent to, or greater than, lower powered locomotives ;
- (*f*) ability, in a State such as Western Australia, to meet restrictions imposed by track conditions, such as conditions limiting axle loads, or special speed restrictions, so as to give the largest possible range of operation over the system ;
- (*g*) ability to handle the largest varieties of work, for example—passenger, goods, mixed trains, and shunting ;
- (*h*) comparative freedom of the track from damage by the locomotive.

No system in Australia has a satisfactory method of comparing the economic efficiency of locomotives. It is not possible to get a satisfactory system. The unit basis adopted in Australia is " the cost per mile per hundred tons hauling power." But these figures provide only a rough basis for comparison. This basis takes no account of actual conditions under which a locomotive is used, *e.g.*, it is hard to define the loss sustained by a powerful and efficient locomotive which, through circumstances, is forced or placed on a part of the system where its power and efficiency are used to a limited extent, and the loss is not obvious except where the wastage of power is apparent. Again, the time factor is not taken into account. For example, if one engine hauls a number of ton miles in half the time taken by another to do the same work, that means a big advantage. No account is taken of expenses incurred in reconditioning the track where it is known that a particular locomotive has caused damage ; or of costs arising out of dislocation where an engine breaks down : Yet such costs are material if we are properly to consider the economic worth of a locomotive, because any breakdown is felt not only over the system at the time it occurs, but in after effects during the period when the engine is being restored to traffic, and more especially if the system is short of locomotive stock. Furthermore, most Australian systems totally ignore the factors of depreciation and obsolescence. Any railway authority which keeps a locomotive in traffic after the end of its economic life is really making each year a substantial contribution to its upkeep which could and would be better employed in the purchase of a new and up-to-date locomotive. The economic life of a locomotive is generally reckoned as 30 years.

One expert authority on costing favours the adoption of a horsepower basis, but this, too, is open to criticism.

I have dealt generally but briefly with this subject mainly as an introduction to some criticism I have to offer of the statistics put forward by the Railway Department for the purpose of showing the comparative efficiency of the Australian Standard Garratt as against other locomotives in service on the Western Australian Government Railways.

I find these statistics worthless. The comparisons made were with old engines which would have a very high maintenance cost. This alone rules them out.

It is obvious when one analyses the evidence that the new Australian Standard Garratt has put up a poor performance. At times these locomotives have done good work but they cannot compare with the old Beyer Garratts, which have such an enduring record of service. The Railway Department has pointed to what the locomotive ought to be able to do, and what perhaps it can be made to do, rather than what it in fact accomplishes. For a time in Queensland the engines did good work, but they needed considerable nursing which, of course, entailed a large expenditure for maintenance. Tasmania reports a similar experience. The early appearance of structural weaknesses and faults in design have caused the locomotives to break down and to be continually in out and of shops during a period in the economic life when they should be giving good service. Normally when a locomotive is put out on the road it should not come back into shops for about three years.

I think the most striking pointer is furnished in some average daily mileage figures for these engines on the Queensland and on the Western Australian systems. In central Queensland where the ASG traffic was heaviest the average daily mileage of all engines, heavy and light, was 103 miles for the last six months during which the ASG locomotives were operating, while in the same period the average daily mileage of the ASG's was only 81 miles. This average mileage is not at all satisfactory, but in Western Australia the average daily mileage for all ASG locomotives for the two years preceding my inquiry was only 40 miles, while the best daily average mileage of any one ASG was only 81 miles. It is true that these figures are loaded with the effect of ASG's which did no running at all. If the evidence is accepted that 11 is the average number of ASG's in service in the two year period (and that is a figure which tells its own story) the average daily mileage would be about 90, but this figure is open to criticism in that it allows not only for new locomotives taken into stock and waiting to go into service, but includes those out of commission through breakdowns and other causes. The real average figure would lie between 40 and 90 miles per day, which is very poor indeed when it is considered that this locomotive should be able to give the best performance of any locomotive in the service, and that its purpose was to relieve tracks which were heavily congested with traffic.

I find that the real reasons for the poor results shown are :—

(*a*) major faults and experimental nature of the design ; and the departure from normal practice in building so many locomotives without the opportunity of testing them in traffic ;

(*b*) the manufacture of components by so many different contractors leading to inevitable differences in the execution of the design and lack of homogeneity of materials.

It is impossible to set down a figure, as the Railway Department sought to do, to demonstrate the economic worth of the ASG, but I think that sufficient has been shown in evidence to establish that if the matters brought under notice in previous chapters of this report are put right the locomotives should be capable of giving reasonable service and answering the majority of tests of economic worth.

Part IX.

GENERAL CONCLUSIONS.

The Australian Standard Garratt locomotives were built for war purposes, and the design, and the cutting down of materials, suggest that a long economic life was not expected. The basic difficulties of design, the shortage of materials and the necessity to " make do " with materials other than would be used normally, and the cutting down of weights, stamp this locomotive as an austerity job. The necessity to put out various sections of the work of construction to a hundred and five sub-contractors was stressed by Mr. Mills, the designer, in emphasising the difficulties relating to production. The building of 65 locomotives of a standard type to suit various conditions on the 3 ft. 6 in. gauges of Western Australia, Queensland, Tasmania, and Central Australia can only be justified, if at all, by the stress of war.

With the wisdom or otherwise of the plan to build them, Your Excellency's Royal Commission is not concerned. It is concerned, however, with the purchase by the State of 25 of the locomotives. The question is—Were they such good buying as the Administration maintains ? The answer is, definitely—No ! Such a large number of locomotives of an experimental design should not have been bought. By July, 1944, many defects of major import had become manifest, as is shown by a series of resolutions passed at a meeting of the Mechanical Engineers' sub-committee of the Commonwealth Land Transport Board held in that month. These defects were accentuated as time went on and should have been apparent to the Railway Administration before November, 1944, when it was decided to buy the locomotives. In my opinion the decision to purchase was an error of judgment. I think the enthusiastic confidence displayed by the Chief Mechanical Engineer and the Chief Traffic Manager in recommending the purchase, in the face of their history and all the experience which had been gained, was entirely misplaced. In addition to the initial cost of £18,000 for each locomotive, the Government has to face the prospective cost of making the locomotives roadworthy and there will be a large amount of expenditure, difficult to estimate, which will have to be incurred in adjusting details. There is also the general loss which will be caused by dislocation due to taking the locomotives into shops—a loss which it is impossible to estimate.

One cannot afford to ignore the position of the State railway system in regard to locomotive stock. The situation is serious and the question to be considered is—what is to be done to prevent, as far as possible, wholesale disorganisations of traffic and loss to the State? It is unthinkable that locomotives which cost about a million and a half pounds of public money (and all of the locomotives built by the Commonwealth are affected by this Report) should be thrown on the scrapheap if they can be made roadworthy.

In Queensland the A.R.U., which is the largest organisation of railway workers, was willing to work the locomotives if certain minimum demands were granted. These were, the taking of sideplay out of the axle-boxes, the provision of means for wetting the coal and bringing it forward, the fitting of improved ventilation in the cab, and the raising of the firehole. The A.F.U.L.E., which is a sectional organisation, asked that the flangeless wheels should be provided with flanges, that compensated springing be fitted, that the bogie frames be strengthened, that the pivot centres be altered to give flexibility in an up-and-down movement, that improved injectors be fitted and improved water gauge glasses be installed, and that the ashpan be redesigned. This Union also asked for the raising of the firehole.

I can see no good reason for alteration in the level of the firehole. There is no reason to suspect that the pivot centres have anything to do with the safety of this locomotive, although I have advocated provision for the manual lubrication of these centres.

The fitting of flanged wheels and the correction of sideplay have everything to commend them, and these, as well as the other matters raised in Queensland, are covered by the recommendations which follow closely on these remarks.

The Administration is of the opinion that the cost of putting the locomotives in a roadworthy condition would be about £5,000 per locomotive, but that the additional moneys required to meet contingencies might be considerable, so that it is felt it would be better to discontinue the use of the locomotives.

In Tasmania an effort is being made to put the locomotives into serviceable condition. The Chief Mechanical Engineer considers that he is well on the way towards finding a solution of all major difficulties which have arisen in that State. The Administration is not so hopeful. However, I think the Chief Mechanical Engineer is to be commended for his determination to make the best of an unsatisfactory position and I think the same policy should be followed in Western Australia.

The locomotives have demonstrated that they can give good performances in lifting and clearing loads, but they are not consistent. After about 15 month's work the general rule seems to be that they require attention that normally they should not require until after about three years of running, and even in this short period they have to be nursed along in order to keep them in traffic. Some of the difficulties are due to reversing the usual practice of putting out one locomotive to a new design and testing it out over a period before building others.

In my opinion the locomotives can be rendered safe for traffic and more efficient in operation, so as to give a reasonable performance commensurate with their designed potential. This being so, it is, I consider, imperative that measures should be taken at once to rectify the defects which have been discovered. I do not think the drastic steps taken by Queensland are justifiable.

Although it has been stated by Railway Administration that the Australian Standard Garratt does not differ radically from the Garratt locomotives produced by Messrs. Beyer Peacock & Co., this is misleading. The main outline of the locomotive appears to have been based on the outline of a Beyer Peacock type of Garratt produced in 1932, which has a tractive effort comparable with that of the ASG, but the dominating design of the ASG appears to be that of a locomotive produced by Beyer Peacock & Co. nearly 35 years ago.

I find that the locomotive has certain features which render its operation in some degree dangerous. The remedies suggested for the removal of these features are discussed hereunder. For the moment, I summarise the factors of unsafety—

(a) There is a tendency for the leading coupled flangeless wheels to derail, which is due to faulty design of the bogie. The faulty design of the bogie and its inability to guide the locomotive effectively around curves and to control the oscillation of the rigid engine unit leads to excessive wear of the brasses in the axle boxes of the engine wheels, which in turn increases the probability of derailment. The amount of wheel bearing of the flangeless wheel on the bearing section of the rail on curves is so small in the axle boxes, that without any allowance for sideplay any tendency for the bogie to fail can easily result in the derailing of the leading coupled flangeless wheels.

(b) There is a tendency for the intermediate flanged wheels to lift on a curve when the locomotive is stationary and also to lift, to a less degree, when it is in motion, according to the speed at which it is going around the curve. It is not the fact of the lifting that is a disquieting feature in itself, but what the lifting signifies—and that is, that there is a lack of control by the bogie as a guiding unit. The probabilities are that the tension of the bogie spring together with a likely failure of the slide, due to lack of lubrication, render the bogie too stiff on occasions, with the result that a leverage is exerted about the intermediate flanged wheels as the fulcrum, the force being great enough to lift the outer wheel on the curve above the rail head. The fitting of a flanged leader would reduce this leverage, and the redesign of the bogie would in its turn result in a more predictable and reliable action at the bogie centre. This matter was raised in Queensland as early as February, 1944, and, while it appears that the reasons then advanced for the phenomenon were open to criticism, there was no doubt about the happening. While the designer, Mr. Mills, did not agree entirely with the degree of throw-over exerted at the bogie centre he did agree that the design was such that lifting would occur, but suggested no remedial measures, stating—" While some lifting of the wheel does occur when the lovomotive is stationary, or moving at very low speed over curved track, there is no danger arising from this phenomenon, as lifting does not occur at normal speeds." And he added—" I do not propose therefore to make any modification."

I do not think that this was a proper way to treat the subject when brought under notice by Queensland. No evidence was given in Western Australia concerning this fault.

(c) The tendency to derail is aggravated by driving the locomotive at too great a speed. I wish it clearly to be understood that speed is not the answer to the problem as suggested by the Railway Department, but it may be, and in some of the cases brought before me probably was, a conducing factor, which, taken in conjunction with faults in design, led to derailment.

(d) The mechanism of the brake is faulty and should not have been allowed to continue in that condition for such a long time without proper investigation and remedial measures.

(e) The locomotive has in general maintenance been allowed to develop too many steam blows which, in a clear winter atmosphere, tend to obscure the driver's vision and interfere with safety. The danger is accentuated in shunting. This is a matter which should easily be remedied and particular recommendations appear elsewhere.

Part X.

RECOMMENDATIONS.

If the Commonwealth is willing to meet the State in a readjustment of the price of the locomotives, as I believe it is, then I recommend that the following work be put in hand and that the Commonwealth be given authority to appoint an engineer to take control of all designing and supervision relating to the work.

There is, in my opinion, no justification for taking a locomotive out of traffic unless the limit of tolerance has been reached as regards sideplay between the wheel hubs and the axleboxes.

In order to obviate wholesale disorganisation of traffic, those ASG locomotives which are held up in shops awaiting repairs or adjustments should be attended to immediately.

A programme should be drawn up to cover the whole of the work to be done, and this work should be carried out with every expedition. Apart from a few major alterations, the items listed are small and the work can be easily and inexpensively carried out. The list looks more formidable than it actually is, and a few of the alterations are already scheduled by the Railway Department for attention.

DETAILS OF WORK TO BE DONE.

That all ASG locomotives be checked to see whether the limit of tolerance has been reached as regards the hubs of the wheels and the axlebox bearing, and that any found to exceed the limit be immediately taken to shops for adjustment.

That all leading coupled wheels (both leading engine and trailing engine) be flanged, and that, for this purpose, the locomotives be brought to shops, say, three at a time each month until the whole stock has been provided with flanged leaders.

That the intermediate unflanged wheel be provided with a thin flange.

Until the locomotive has been provided with flanged leaders, that the procedure for checking clearances at the boxes be carried out regularly once a fortnight.

That the bogie be entirely redesigned and that a swing-link type be substituted.

That roller bearings be provided for the bogie unit.

That until flanges have been fitted and new bogies have been provided, the speed limit of 25 miles per hour be continued.

That side bearers be provided on the frame near the pivot centres, and the question of any strengthening of the frame at this point be considered.

That provision be made for the manual oiling of the pivot centres.

That compensated springing be provided.

That the tanks on both units be lowered as far as possible (approximately 1 foot), and that further baffles and stays be provided internally.

That a proportion of flexible firebox frame stays and crown stays be provided.

That as the locomotives are brought in for the fitting of flanged wheels, adjustments be made, as recommended, for discharging condensate from the brake cylinder, rectifying the difficulty now experienced in regard to the escape of steam into the vacuum exhaust cones, and providing additional leverage at the brake lever and more effective seating of the steam brake valve.

That power reverse apparatus be provided in lieu of the reversing screw.

That better provision be made for mechanical control and adjustment of the regulator and its adjuncts.

That the exhaust steam injector be discarded and a live steam injector substituted.

That gauge glasses be fitted giving greater visibility of water level and that the water cocks under the gauges be improved.

That the lefthand side plate of the coal chute be cut away as on ASG 46.

That level taps be provided to indicate level of water in tanks as on ASG 46.

That a bunker door be provided as in ASG 46.

That a large cab ventilator be provided in the roof to slide or swing either backward or forward.

That ventilating flaps be provided on either side of the back plate of the cab as near as possible to the roof.

That provision be made for draining the floor.

That a tucker box be provided, with ventilators, as in Queensland.

That means be provided for wetting coal.

That concertina covers be provided to cover the apertures on either side of the pivot centres.

That a shovelling stop plate be fitted underneath the coal chute as on ASG 46.

That the present ashpan be replaced with a hopper type.

That improved spring loaded cylinder release valves be provided for each cylinder where provision has not already been made.

That consideration be given to redesigning the long connecting rod.

That better and more rigid levers be provided in lieu of the present levers for operating sand and release valves.

That a better type of tank filler cover be provided in order to prevent loss of water.

That better means be provided for protecting the sand in the sand boxes from getting wet, and that if necessary the position of the boxes be changed.

That speed recording apparatus be fitted to each locomotive similar in design to that which is used on the Victorian and South Australian Railways.

That regular inspections be made of the front end in order to ensure that the smoke box and tubes are kept clean.

That all shed and building outlines in districts where ASG locomotives are used be altered so as to conform to standard practice and provide the recognised clearances.

That one locomotive be put under test for a period of eighteen months in order to ascertain the best design for the dome, the dryer, the long steam pipe, and the front end, and that when experience has been gained all locomotives be altered to conform to the design proved by test to give the best results.

That after the expiration of eighteen months, or such period as may be required to make tests and obtain a proper knowledge of the work to be done and the moneys to be expended. the matter of the price of the locomotives to be paid by the State to the Commonwealth be submitted to arbitration and in the meantime all payments be suspended without any liability for interest.

SUGGESTION FOR IMPROVED TESTING APPLIANCES AND INCREASED TESTING STAFF.

From the admissions made by the Department relative to its failure properly to carry out the pressure and thermal tests, it is quite obvious that there is a call for modern appliances and a larger trained staff. This is a very important aspect of railway administration. Proper testing enables faults to be corrected and the initial outlay in testing instruments, although high, should be amply justified by results. In addition, I think the system should have a dynomometer car as, owing to the break of gauge, it is not practicable, nor in my opinion desirable, to share one with another State.

Erratum.

On page 55 the word ''Dynomometer'' should read ''Dynamometer.''

Part XI.

GENERAL COMMENT ON RAILWAY POLICY IN REGARD TO REPLACEMENT OF LOCOMOTIVE STOCK.

It has been said by the Railway Department that the underlying reason for the Union's objection to the Australian Standard Garratt locomotive is that it is large and powerful and that its use will inevitably have the effect of reducing the numbers required as engine crews. There is evidence that this view was put forward by the Union spokesmen on more than one occasion and it is difficult to see the reason for some of the questions asked of the administrative officers at this inquiry if there were not some such incipient fear in the minds of some of the members of the Union. But whatever basis there is for this statement, the official spokesman and advocate for the Union did state that the Union realised that the time had arrived for bigger and more powerful locomotives. That is, of course, only bowing to the inevitable and is a recognition of the futility of attempting to halt the march of progress. Moreover, I am interested in facts. Motives are sometimes important in assisting to establish a conclusion where the facts may be otherwise equivocal, but the evidence here clearly shows that there are many matters which have called out for attention and correction for a considerable time. The time may not be far distant when a central authority will be established to lay down safe and efficient standards of working, and then perhaps such a state of affairs as has persisted with regard to these locomotives will be prevented, and the State railways will benefit materially in acquiring modern locomotive stock and having it operated under efficient conditions.

If the railways are to survive in a world of keen competition ; if they are to fulfil their purpose in co-ordination with other forms of transport, they must be modernised. That means bigger and better locomotives. The policy of "making do" (an expensive one, which has immediate and secondary effects) must be cast aside. I am inclined to think that the Railway Department in its eagerness to get these locomotives, seized what it considered an opportunity to ease a serious shortage of locomotive stock. That explains, I think, even if it does not excuse, the purchase of such a large number of locomotives which were not really designed for general traffic conditions. Economic measures such as Transport Acts are of little use if they merely protect the Railways from competition. The Railways must be able to compete. If the Railways are unable to give service there will be a natural economic adjustment, perhaps slow, but nevertheless inexorable, in which the Railways will go down.

Part XII.

CONCLUDING REMARKS.

I wish to place on record my appreciation of the courtesy extended to me by the Right Hon. the Prime Minister of Australia, the Hon. the Premiers of the various States which I visited, in facilitating my inquiries, and also the several Railway Administrations which were always ready to place at my disposal their technical officers and to afford me the benefit of their experience and any information which could be of assistance to me.

I also wish to thank the Chief Hansard Reporter and the staff of Hansard, and the Government Printer and his staff for their efficient work.

I have the honour to be,

Your Excellency's obedient servant,

A. A. WOLFF,
J.
Royal Commissioner.

29th August, 1946.

LIST OF APPENDICES.

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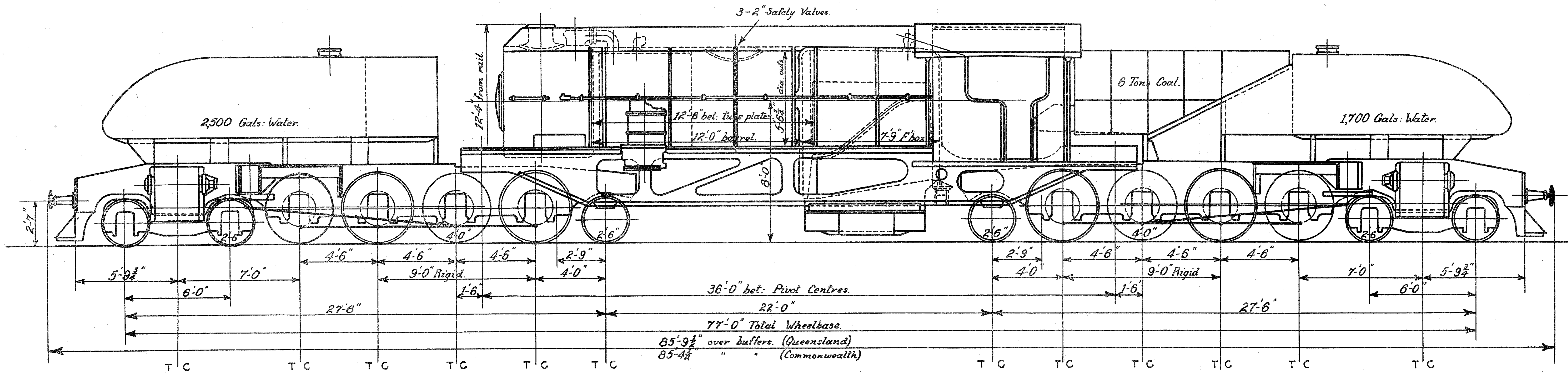
APPENDIX I.



	T C	T C	T C	T C	T C	T C	T C	T C	T C	T C	T C	T C		T C
ESTIMATED WEIGHTS	17 0	8 10	8 10	8 10	8 10	8 10	8 10	8 10	8 10	8 10	8 10	17 0	TOTAL	119 0
ACTUAL "	15 15	8 7	8 8	8 13	8 4	7 18	8 9	8 9	8 13	8 9	8 5	16 6	"	115 16

CYLINDERS	4-14¼" x 24"	TUBES	184- 1¾" DIA.	SUPERHEATING SURFACE	315 SQ. FT.	WATER CAPACITY	4,200 GALLS.
PISTON VALVES	8" DIA	FLUES	28 5¼" DIA.	GRATE AREA	35 SQ. FT.	COAL CAPACITY (WATER LEVEL)	6 TONS.
MAX. VALVE TRAVEL	6"	HEATING SURFACES. TUBES	1,054 SQ. FT.	TRACTIVE EFFORT AT 85% W.P.	34,420 LBS.	TOTAL WT. IN WORKING ORDER	119 TONS.
MAX. CUT-OFF	80%	FLUES	481 SQ. FT.	ADHESIVE WEIGHT	68 TONS	EMPTY WEIGHT	84 TONS.
COUPLED WHEELS	4'-0" DIA	FIREBOX & ARCH TUBES	163 SQ. FT.	FACTOR OF ADHESION (TANKS FULL)	4·4	WT. PER FT. RUN ENGINE UNIT	2·163 TONS.
WORKING PRESSURE	200 LBS. PER SQ. IN.	TOTAL	1,698 SQ. FT.			WT. PER FT. RUN TOTAL WHEELBASE	1·545 TONS.

AUSTRALIAN STANDARD GARRATT LOCOMOTIVE

OUTLINE.

SCALE ¼" = 1 FOOT.

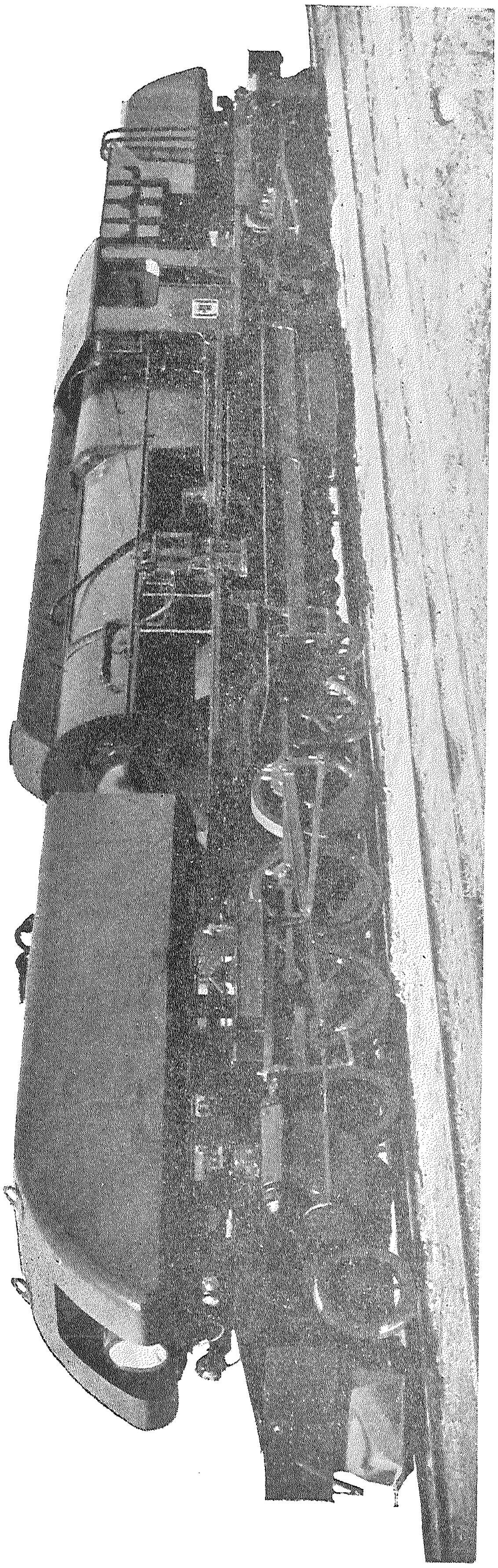
APPENDIX II.

General arrangement drawing of ASG LOCOMOTIVE

Cylinders	4-14¼" x 24"	Total Heating Surfaces	1698 sq ft
Piston Valves	8" dia	Superheating Surface	315 sq ft
Maximum Valve Travel	6"	Grate Area	35 sq ft
Maximum Cut-off	80%	Tractive Effort at 85% W.P.	34,420 lbs
Coupled Wheels	4'-0" dia	Adhesive Weight	68 Tons
Working Pressure	200 lbs per sq in	Factor of Adhesion (Tanks Full)	4·4
Tubes	164 - 1¾" dia	Water Capacity	4200 Gals
Flues	28 - 5¼" dia	Coal Capacity (Water Level)	6 Tons
Heating Surfaces Tubes	1054 sq ft	Total Weight in Working Order	119 Tons
" " Flues	481 sq ft	Weight per foot run Engine Unit	2.163 Tons
" " Firebox & Arch Tubes	163 sq ft	Weight per foot run Total Wheelbase	1.545 Tons

APPENDIX III.

Photograph of ASG locomotive.



AUSTRALIAN STANDARD GARRATT LOCOMOTIVE
ON FOUR CHAIN CURVE

FIG 2

APPENDIX V.

Resolutions passed at a meeting of Mechanical Engineers Sub-committee of the Commonwealth Land Transport Board at Melbourne on the 28th July, 1944.

Item 1.—*Sideplay that has developed on Garratt locomotives after a small mileage is giving concern. This wants attending to at once.*

Sideplay has developed quickly and it is necessary to provide a facing on the axlebox to give a greater bearing area against the wheel hub. This additional facing must incorporate white metal inserts.

Item 2.—*Bogie frames to be reinforced where necessary.* (*Frames now cracking.*)

This is being done.

Item 3.—*Bogie Centre Foundation Plates to be increased in size : whole structure re-designed.*

It was agreed that re-design of these members for engines now in service or nearly completed would cause so much delay that it cannot at present be considered. It is agreed that the modification proposed below for bogie centres will meet the position in a practical way.

Item 4.—*Bogie Centre Top and Bottom to be steel in lieu of cast iron.*

Position was discussed exhaustively. On engines in service supporting structure is deflecting but the amount of deflection cannot be measured without considerable dismantling. Welding of the stiffening strips between the two horizontal plates is not standing up.

Recommended that top bogie centres be steel castings with tensile strength 35 tons minimum ; the flange to be circular with diameter about 2 in. greater than the maximum dimension across corners of the existing flange and the thickness to be 1 in. in place of $\frac{7}{8}$ in. and machined on both sides.

Item 5.—*Pivot Centre Foundation Plates to be increased in size : whole structure re-designed.*

It was agreed that this would cause so much delay that it cannot at present be considered.

Item 6.—*Pivot Centres Top and Bottom to be cast in steel in lieu of cast iron.*

Experience to date is that since the foundation plates were stiffened, no further failures have been found.

It was agreed that the bottom castings as originally made are satisfactory. Replacement top castings are being made in high duty cast iron and in the light of experience to date, this is regarded as satisfactory.

Items 7 *and* 8.—*Cylinder release cock gear to be increased in strength ; sand gear lever rods, etc., to be increased in strength.*

It is stated that since lengthening of the sand levers, the shaft in the cab has been twisted due to excessive force.

It was agreed that this could not be treated as a major item and that solid bars could be substituted for pipe shafts as found necessary.

Mr. Denham suggested that the neck on the sand box should be increased in height and it was agreed that this also could be done on the spot.

Item 9.—*Regulator (steam) in cab to be re-designed—handle too close to boiler.*

It was agreed that the supporting bracket should be set so that the arc of movement of the regulator handle will be approximately bisected by the vertical centre line. This will give greater convenience of operation and is expected to overcome most of the complaints.

Item 10.—*Engine bogie axleboxes to have water tight covers fitted, stronger material ; axlebox pans increased in depth to hold more oil.*

It was agreed that this problem is relatively simple and a lid of stouter material with an upward turned collar to receive the spring buckle end is to be fitted. The intention is to exclude water which should remove troubles encountered in running.

Item 11.—*Radial axleboxes and truck gear to be re-designed. Axlebox pans increased in depth.*

Wick feed from the top of the axlebox then to be relied upon for lubrication and further experience to be gained before considering any additional amendment. Attachment of truck arm to axlebox to be by rivets in lieu of bolts.

Item 12.—*Cylinder Drain and Relief Valves to be increased in size and spring loaded relief valves fitted to front and rear of each cylinder.*

This matter was discussed and the consensus of opinion is that relief valves do not afford the desired protection. This discussion is without prejudice to Item 17, but it is considered that should drain cocks not be opened or water accumulate in the cylinders from any other cause, relief valves will not give protection from damage.

Item 13.—*Pistons to be constructed of cast steel and machined similar to Queensland Railways dished ends, front and rear of piston head.*

This was discussed and the consensus of opinion is that the piston should not be strengthened unless the cylinder covers are weakened so that in case of trouble, damage to cylinder may be avoided. The best practical course appears to be to replace the existing core plugs with mild steel stays securing the two walls of the piston together. Action to be taken at the same time to reduce the strength of cylinder covers by machining a breakage groove or otherwise.

Item 14.—*Crosshead Liners to be fitted more securely.*

It was agreed that the screws securing the liners should be bronze welded after tightening.

Item 15.—*The position of exhaust injector to be considered owing to amount of trouble with steam and water valve connections.* (See also Agenda Item 10).

It was agreed that while the exhaust injector is a desirable instrument, a change in position is attendant with major difficulty and the injector itself is giving rise to considerable maintenance. Mr. Hall requested that serious consideration be given to replacing the exhaust injector with a live steam injector.

Item 16.—*Water tanks and coal bunkers to be more securely fitted to engine frames.*

Mr. Campbell is of opinion that remedial measures can be taken in Queensland to keep engines in services but it was agreed that the matter should receive further consideration by Mr. Mills, particularly with regard to engine not yet completed.

Appendix V.

RESOLUTIONS PASSED AT A MEETING OF MECHANICAL ENGINEERS' SUB-COMMITTEE HELD IN MELBOURNE ON FRIDAY, 28TH JULY, 1944—*continued.*

Item 17.—*Steam Dome to be fitted to stop the amount of priming that is doing a lot to cause bent connecting rods, damaged cylinders and pistons.*

This matter was discussed but it appeared that considerable practical difficulties existed and much more consideration is required than could be given in the time available to the Committee. This proposal is for a major alteration which could not be carried out on all engines at present in Queensland in the time limit laid down.

Item 18.—*All bogie and axleboxes to have white metal inserts fitted.*

It was considered that to obtain the maximum assurance of continued operation this suggestion should be adopted.

Item 19.—*Smokebox to be fitted with appropriate means to discharge cinders in lieu of men having to use a shovel.*

This matter was discussed at length but no immediate solution of the difficulty is apparent. Further investigation and, where possible, experiment will be made.

Item 20.—*Ashpan to be re-designed so as to be of assistance to engine crews when these engines are engaged on passenger work.*

The matter was discussed and it was agreed that this would be a major item which could not be done quickly. There are many difficulties to be overcome requiring much more time for consideration than was available to the Committee. It was agreed that the item be deferred for further consideration.

Item 21.—*Main steam pipe drainage to be altered so that automatically condensed steam can be drained when engine is idle.*

The existing automatic drains function satisfactorily but there is no prospect of fitting any automatic drain to these pipes which would prevent water entering cylinders while the engine is steaming.

Item 22.—*Water Gauge Glasses—Better light for engine crews to be installed.*

It was agreed that one additional electric lamp should be provided to illuminate the right-hand water gauge. This can be done in Queensland for engines in service.

Item 23.—*Vibration of reversing lever. This action takes place during engine coasting when lever is in full and reverse position.*

It was agreed that this trouble is not one which will prevent engine operation in any way, but an undesirable vibration is experienced when the engine is coasting in full gear, and it is considered this should continue to receive investigation.

Item 24.—*Lubricator capacity to be increased, now five pint.*

It was agreed that the best practical method will be to fit a transfer filler at a convenient position below the lubricator. Normally transfer fillers are manufactured by the Detroit Lubricator Company in the United States. Western Australia is using these fittings and Mr. Mills has undertaken to have these duplicated for use on the Garratts.

APPENDIX VI.

Form of Questionnaire given to the Queensland Railways relating to derailments in Queensland.

QUEENSLAND RAILWAYS.

REPORT OF DERAILMENT.

1. Date.

2. Engine No.
   Built at
   Axle box brasses made by

3. Was the frame checked for distortion ?

4. Where did the derailment occur ?

5. What was the load ?
   What was the length, *i.e.*, No. of vehicles ?
   Was it a passenger train ?
   Was it a goods train ?
   Was it a mixed ?

6. Did the derailment happen—
   (*a*) on a straight ?
   (*b*) on a curve ?
   (*c*) just after negotiating a curve ?
   (*d*) on a level stretch ?
   (*e*) on a down grade ?
   (*f*) on an up grade ?
   (*g*) how far down the bank ?
   (*h*) how far up the bank ?

7. Weight of rail.
   Width and outline of the head.

8. (*a*) Was there any proved or suspected element of speed ?
   (*b*) If speed is known, please state.

9. When do the enginemen say they first became aware of the derailment ?
   Was it reported ?
   By whom ? When ?

10. How did the engine behave when it derailed ?
    Which wheels derailed ?
    Was any of the train derailed ?

11. Is there any record of the mileage at the time of derailment ?
    What was the mileage ?

12. Were the brasses examined at the time ?
    Was there any excessive wear ?

13. If there was excessive wear, have you any theory as to the cause ?

14. Was there any departmental inquiry as to the derailment ?
    Who were the officers concerned ?
    What was their finding and on what was it based ?

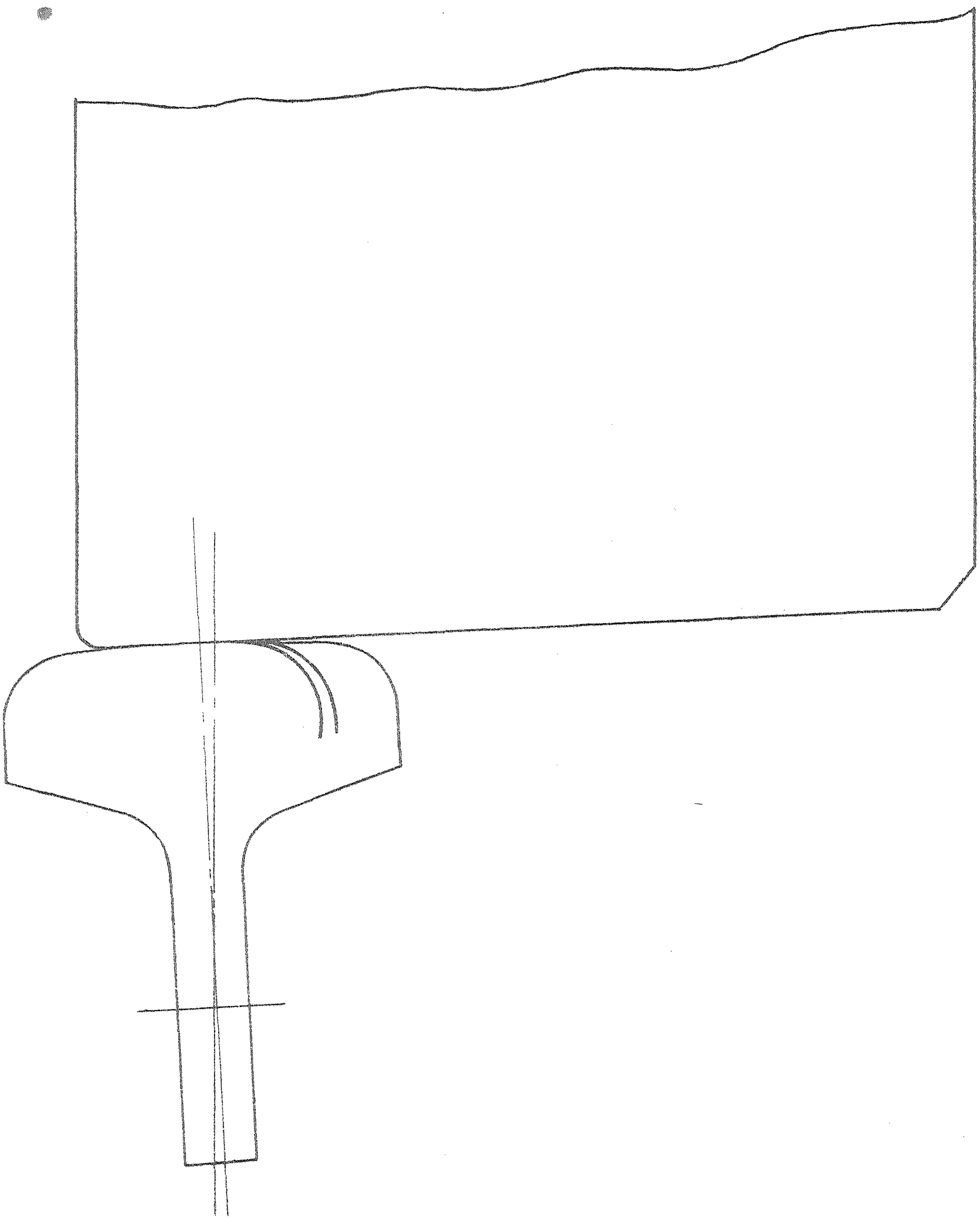
15. Does the bogie show a tendency to lateral oscillation ?
    Is it the type of bogie you use in Queensland ?

16. Have you examined the pivot centres of any of these derailed engines ?
    If so, what conditions did you find ?
    Did you find any condition which in your opinion contributed to derailment ?

17. Have you checked weight distribution ?
    With what results ?

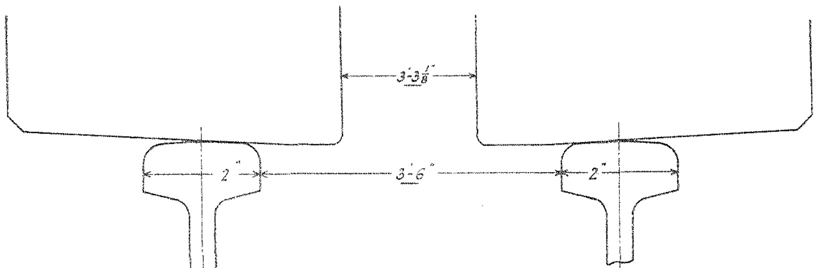
APPENDIX VII.

Sketch showing flangeless wheel bearing on 45lb. rail and 60lb. rail, and demonstrating the small amount of bearing surface.

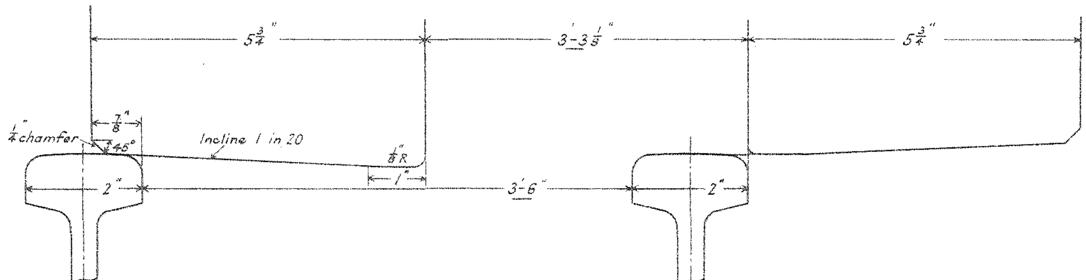


APPENDIX VIII.

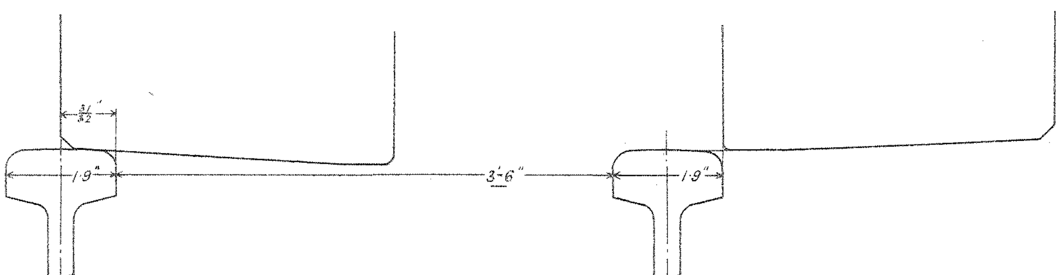
Diagrams illustrating how one leading flangeless wheel may drop off the rail while the other is still riding on the bearing surface of the other rail.



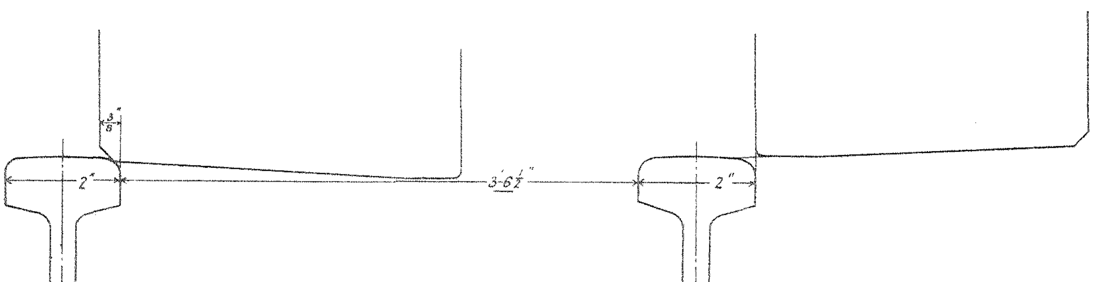
Sketch 1.



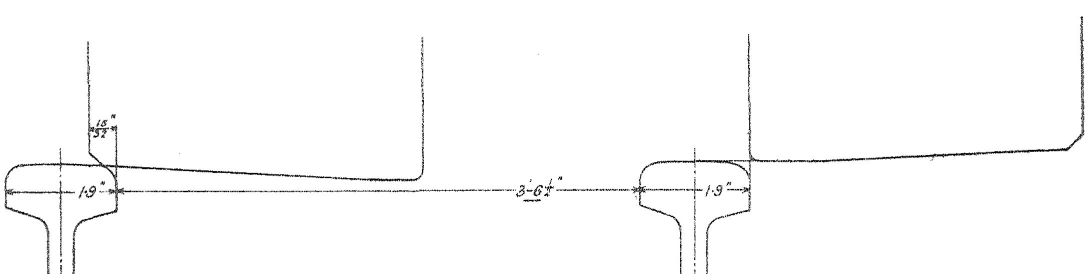
Sketch 2.



Sketch 3.



Sketch 4.



Sketch 5.

AUSTRALIAN STANDARD GARRATT LOCO
WHEEL POSITIONS

APPENDIX IX.

APPENDIX IX.

Part 1.

LOCOMOTIVE DETAILS.

Class.	Wheel Arrangement.	Wheel Diameter.	Roadworthy Weight.	Piston Stroke.	Tractive Effort. (Nominal)	Axle load.
		ins.	tons.	ins.	lbs.	tons.
ASG	4–8–2–2–8–4 ...	48	116	24	34,420	9*
FS. 281	4–8–0	$42\frac{1}{2}$	86	23	26,570	11
ES. 317	4–6–2	54	85	23	20,911	$12\frac{1}{2}$
MS. 429	2–6–6–2	39	70	20	24,488	$9\frac{1}{2}$
PR. 461	4–6–2	54	$102\frac{1}{2}$	26	25,855	14
C. 439	4–6–2	49	$70\frac{1}{2}$	22	17,113	$9\frac{1}{2}$
FS. 423	4–8–0	$42\frac{1}{2}$	86	23	23,264	11
S. 545	4–8–2	48	119	24	30,685	13

Loco. No.	Date Tested.	Year Designed.	Year Built.	Maximum Diameter of Piston Head.		Date Examined.	Date Tested.
				Front.	Hind.		
ASG. 63	24–1–46	1943	1945	R.H. $14\frac{7}{32}$ L.H. $14\frac{7}{32}$	R.H. $14\frac{7}{32}$ L.H. $14\frac{7}{32}$	13–9–45	24–1–46
FS. 281	25–1–46	1900	1902	R.H. $18\frac{15}{16}$ L.H. $18\frac{15}{16}$	... ...	27–6–45	25–1–46
ASG. 46	29–1–46	1943	1944	R.H. $14\frac{3}{16}$ L.H. $14\frac{3}{16}$	R.H. $14\frac{3}{16}$ L.H. $14\frac{5}{32}$	15–10–45	29–1–46
FS. 281	31–1–46	1900	1902	R.H. $18\frac{15}{16}$ L.H. $18\frac{15}{16}$	... ...	27–6–45	31–1–46
ASG. 46	12–2–46	1943	1944	R.H. $14\frac{3}{16}$ L.H. $14\frac{3}{16}$	R.H. $14\frac{3}{16}$ L.H. $14\frac{5}{32}$	15–10–45	12–2–46
ES. 317	15–2–46	1900	1903	R.H. $19\frac{9}{32}$ L.H. $19\frac{9}{32}$	... ...	15–12–45	15–2–46
ASG. 46	20–2–46	1943	1944	R.H. $14\frac{3}{16}$ L.H. $14\frac{3}{16}$	R.H. $14\frac{3}{16}$ L.H. $14\frac{5}{32}$	15–10–45	20–2–46
MS. 429	22–2–46	1911	1913	R.H. $13\frac{9}{64}$ L.H. $13\frac{3}{32}$	R.H. $13\frac{5}{32}$ L.H. $13\frac{1}{8}$	19–8–45	22–2–46
ASG. 65	27–2–46	1943	1945	R.H. $14\frac{7}{32}$ L.H. $14\frac{7}{32}$	R.H. $14\frac{7}{32}$ L.H. $14\frac{7}{32}$	5–9–45	27–2–46
PR. 461	1–3–46	1923	1929	R.H. $19\frac{11}{32}$ L.H. $19\frac{11}{32}$	... ...	1–12–45	1–3–46
ASG. 54	4–3–46	1943	1945	R.H. $14\frac{7}{32}$ L.H. $14\frac{7}{32}$	R.H. $14\frac{7}{32}$ L.H. $14\frac{7}{32}$	22–8–45	4–3–46
C. 439	7–3–46	1900	1915	R.H. $16\frac{9}{16}$ L.H. $16\frac{19}{32}$	... ...	21–5–45	7–3–46
ASG. 48	24–5–46	1943	1944	R.H. $14\frac{3}{16}$ L.H. $14\frac{3}{16}$	R.H. $14\frac{3}{16}$ L.H. $14\frac{1}{4}$	2–4–46	24–5–46
FS. 423	3–6–46	1900	1914	R.H. $16\frac{27}{32}$ L.H. $16\frac{29}{32}$	... ...	31–5–46	3–6–46
S. 545	13–6–46	1939	1945	R.H. $18\frac{31}{32}$ L.H. $18\frac{31}{32}$	... ...	11–3–46	13–6–46

* Originally designed $8\frac{1}{2}$ tons.

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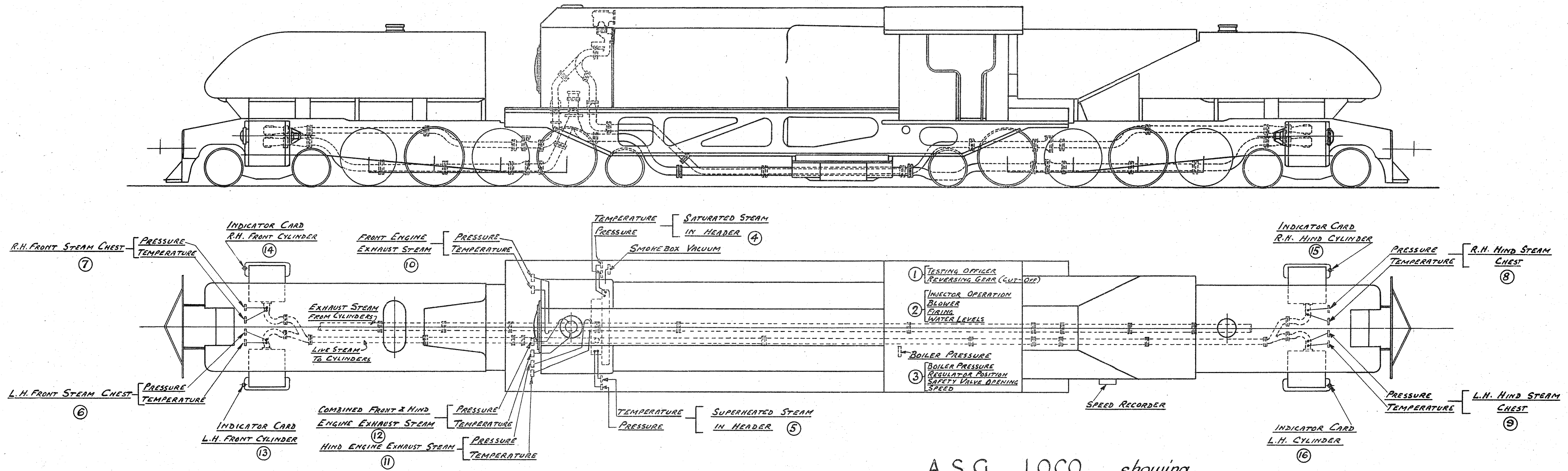
APPENDIX IX.

Part 2.



A.S.G. LOCO. *showing*

TOTAL No OF OBSERVERS 16

LOCATION OF INSTRUMENTS USED IN TESTS.

APPENDIX IX.

PART 3.

AVERAGES OF PRESSURE AND TEMPERATURE READINGS.

Showing Corrections by Department.

—	ASG 48.		Fs 423.		S. 545.
	24-5-46.	27-5-46.	3-6-46.	5-6-46.	13-6-46.
Average Boiler Pressure as read ...	188·280	189·865	170·364	169·194	197·951
Average Boiler Pressure corrected ...	N.C.	N.C.	N.C.	N.C.	195·707
Average Pressure Sat. side of Header as read ...	184·540	189·676	173·410	170·132	192·909
Average Pressure Sat. side of Header corrected ...	183·360	187·647	172·408	169·132	N.C.
Average Pressure Sup. side of Header as read ...	177·647	183·735	170·571	168·105	191·879
Average Pressure Sup. side of Header corrected ...	180·720	185·706	169·571	167·105	N.C.
Average Pressure L.F. Steam Chest as read ...	177·720	183·647	167·694	165·816	185·091
Average Pressure L.F. Steam Chest corrected ...	N.C.	185·647	N.C.	N.C.	184·091
Average Pressure R.F. Steam Chest as read ...	176·320	180·794	166·226	165·237	187·697
Average Pressure R.F. Steam Chest corrected ...	N.C.	N.C.	N.C.	N.C.	N.C.
Average Pressure L.B. Steam Chest as read ...	179·560	183·088	...	...	...
Average Pressure L.B. Steam Chest corrected ...	N.C.	N.C.	...	...	...
Average Pressure R.B. Steam Chest as read ...	180·040	182·618	...	...	...
Average Pressure R.B. Steam Chest corrected ...	N.C.	N.C.	...	...	...
Average Temperature Sat. side of Header as read ...	373·133	360·588	374·072	373·400	392·491
Average Temperature Sat. side of Header corrected ...	369·533	357·700	N.C.	N.C.	393·745
Average Temperature Sup. side of Header as read ...	619·944	613·130	619·524	614·600	632·012
Average Temperature Sup. side of Header corrected ...	N.C.	N.C.	623·140	618·256	630·212
Average Temperature L.F. Steam Chest as read ...	556·700	533·560	608·036	605·231	606·855
Average Temperature L.F. Steam Chest corrected ...	565·185	541·784	608·060	605·256	608·333
Average Temperature R.F. Steam Chest as read ...	548·700	522·870	602·312	599·877	No readings
Average Temperature R.F. Steam Chest corrected ...	561·685	535·530	606·180	603·590	No readings
Average Temperature L.B. Steam Chest as read ...	526·315	494·051	...	...	...
Average Temperature L.B. Steam Chest corrected ...	N.C.	N.C.	...	...	...
Average Temperature R.B. Steam Chest as read ...	545·222	512·141	...	...	...
Average Temperature R.B. Steam Chest corrected ...	N.C.	N.C.	...	...	...

N.C. — No Correction.

APPENDIX IX.

PART 4.

SUMMARY OF TEST RESULTS.

Date.	Engine and Tender. No.	Engine and Tender. Road-worthy Weight.	Standard Boiler Pressure (lbs. per sq. in.)	Journey. From.	Journey. To.	Ruling Grade.	Load for Ruling Grade in Tons.	Weather Conditions.	Time on Journey. Departure.	Time on Journey. Arrival.	Time on Journey. Actual Running Time.	Time on Journey. Average Speed in m.p.h.
24th Jan., 1946	ASG 46	tons. 116	200	Midland Junct.	Nth. Fremantle and return	1 in 80	795	Fine and warm	11·5 a.m. 2·33 p.m.	12·38 p.m. 4·44 p.m.	mins. 224	14·8
25th Jan., 1946	FS 281	86	160	Midland Junct.	Nth. Fremantle and return.	1 in 80	Midland Junct. to Frem. 645 Frem. to Midland Junct. 560	Fine and warm	10·49 a.m. 2·25 p.m.	12·33 p.m. 4·43 p.m.	242	13·5
29th Jan., 1946	ASG 46	116	200	Brunswick ...	Collie	1 in 40	335	Fine and warm	9·45 a.m.	1·54 p.m.	249	9·74
31st Jan., 1946	FS 281	86	160	Brunswick ...	Collie	1 in 40	266	Fine and warm	10·41 a.m.	1·4 p.m.	143	12·96
12th Feb., 1946	ASG 46	116	200	Brunswick ...	Perth	1 in 75	850	Fine—strong cross winds ...	10·30 a.m.	6·26 p.m.	248	19·58
15th Feb., 1946	ES 317	84	160	Brunswick ...	Perth	1 in 75	647	Strong cross winds—fine and warm	10·23 a.m.	6·35 p.m.	265	18·7
20th Feb., 1946	ASG 46	116	200	Pinjarra ...	Dwarda ...	1 in 30	230	Fine and warm	11·9 a.m.	8·27 p.m.	228·5	13·4
21st Feb., 1946	ASG 46	116	200	Dwarda ...	Pinjarra ...	1 in 40	360	Fine and warm	10·43 a.m.	5·30 p.m.	152·5	14·9
22nd Feb., 1946	MS 429	69·8	160	Pinjarra ...	Dwarda ...	1 in 30	160	Fine and warm	11·00 a.m.	6·49 p.m.	194·5	14·9
23rd Feb., 1946	MS 429	69·8	160	Dwarda ...	Pinjarra ...	1 in 40	250	Fine and warm	9·2 a.m.	3·22 p.m.	137	14·9
27th Feb., 1946	ASG 65	116	200	Northam ...	Merredin ...	1 in 60	540	Fine and warm	7·37 a.m.	2·53 p.m.	248·5	21·4
1st Mar., 1946	PR 461	102·5	175	Northam ...	Merredin ...	1 in 60	414	Fine and warm	7·52 a.m.	3·20 p.m.	245	22·4
4th Mar., 1946	ASG 54	116	200	Norseman ...	Coolgardie ...	1 in 40	Norseman-Pioneer ... 540 Pioneer-Widgiemooltha ... 575 Widgiemooltha-372M. 50C. 430 372M. 50C.-Coolgardie ... 575	Fine and warm	12·28 p.m.	6·52 p.m.	198	20
7th Mar., 1946	C 439	70·6	175	Norseman ...	Coolgardie ...	1 in 40	Norseman-Pioneer ... 225 Pioneer-Widgiemooltha ... 240 Widgiemooltha-372M. 50C. 205 372M. 50C.-Coolgardie ... 240	Dull—slight showers	12·23 p.m.	7·12 p.m.	240	18·8
24th May, 1946	ASG 48	116	200	Midland Junct.	Northam	Midland-Chidlow 1 in 45 Chidlow-Northam 1 in 55	350 530	Showery—following winds ...	12·34 p.m.	5·34 p.m.	165	14·5
27th May, 1946	ASG 48	116	200	Midland Junct.	Fremantle ...	1 in 80	795	Moderate wind, overcast sky—heavy and intermittent rain after reaching Perth on the up run	10·56 a.m.	1·33 p.m.	76	13·6
27th May, 1946	ASG 48	116	200	Fremantle ...	Midland ...	1 in 80	795		2·29½ p.m.	5·45 p.m.	89·5	12·9
3rd June, 1946	FS 423	86	160	Midland Junct.	Northam	Midland-Chidlow 1 in 45 Chidlow-Northam 1 in 55	240 392	Fine	12·35 p.m.	5·7 p.m.	167	14·6
5th June, 1946	FS 423	86	160	Midland Junct.	Fremantle ...	1 in 80	645	Fine	10·55 a.m.	1·15 p.m.	82	12·9
5th June, 1946	FS 423	86	160	Fremantle ...	Midland Junct.		560		2·28½ p.m.	5·44 p.m.	81·5	13·23
13th June, 1946	S 545	119	200	Midland Junct.	Northam	Midland Chidlow 1 in 45 Chidlow-Northam 1 in 55	305 455	Persistent rain	11·22½ a.m.	3·53 p.m.	142·5	15·7

Date.	Average Pressure (lbs. per sq. in.) at Various Points. Boiler in Cab.	Saturated side of Header.	Super-heated side of Header.	Steam Chests. Right Front.	Steam Chests. Left Front.	Steam Chests. Right Hind.	Steam Chests. Left Hind.	Average Temperature (°F.) at Various Points. Saturated side of Header.	Super-heated side of Header.	Steam Chests. Right Front.	Steam Chests. Left Front.	Steam Chests. Right Hind.	Steam Chests. Left Hind.
24th Jan., 1946	197·5							386·900					
25th Jan., 1946	155·2							368·700					
29th Jan., 1946	169·7							375·200					
31st Jan., 1946	157							369·400					
12th Feb., 1946	187							382·500					
15th Feb., 1946	150							366·000					
20th Feb., 1946	188							382·900					
21st Feb., 1946	192							384·600					
22nd Feb., 1946	142	Not material to these Tests.						361·800	Not material to these Tests.				
23rd Feb., 1946	142							361·800					
27th Feb., 1946	186							382·090					
1st Mar., 1946	169							374·700					
4th Mar., 1946	192							384·600					
7th Mar., 1946	162							371·500					
24th May, 1946	188·28	183·360	180·720	176·320	177·720	180·040	179·560	369·533	619·944	561·685	565·185	545·222	526·315
27th May, 1946	189·865	187·647	185·706	180·794	185·647	182·618	183·088	357·700	613·130	535·530	541·784	512·141	494·051
27th May, 1946													
3rd June, 1946	170·364	172·408	169·571	166·226	167·694	...	...	374·072	623·140	606·180	608·060	...	...
5th June, 1946	169·194	169·132	167·105	165·237	165·816	...	...	373·400	618·256	603·590	605·256	...	...
5th June, 1946													
13th June, 1946	197·951	192·909	191·879	187·697	184·091	...	...	393·745	630·212	No reading	608·333	...	...

Date.	Coal and Water Consumed (excluding Coal for Lighting-up). Class.	Lb. Used.	Water per lb.	Coal per ton mile.	Water per ton mile.	Particulars of Trains. Average No. Tons behind Tender.	No. of Axles.	Miles Run.	Ton Miles.	Cost per ton mile in Pence.	Remarks. Conduct of Test.	Remarks. Result of Test.
24th Jan., 1946	Proprietary	7,186	4·05	lb. ·224	lb. ·904	734	Midland to Fremantle 112 Fremantle to Midland 122	M. C. 21 40 22 57	17,054 15,346	·061	Well carried out	Good steaming performance—Noted disposition of vacuum brake to apply when steam brake applied independently.
25th Jan., 1946	Proprietary	5,712	4·34	·234	1·050	555	Midland to Fremantle 82 Fremantle to Midland 102	21 40 22 57	12,427 12,070	·067	Well carried out	Good steaming performance.
29th Jan., 1946	Proprietary	6,120	6·11	·803	4·910	299	104	25·40	7,625	·223	The poor steaming performance was ascribed by the Department to the blast pipe and chimney being out of alignment	Very poor. The Department's explanation is probably correct because next day the blast pipe was found to be well out of alignment. Excessive wear in the axle box brasses. Long connecting rod brushing against intermediate crankpin. Failure of exhaust steam injector.
31st Jan., 1946	Proprietary	2,601	5·88	·460	2·700	222	76	25·40	5,661	·206	Well carried out	Handled load with ease. Several driving wheels left-hand side rubbing frame. Connecting rod brushing one of the balance weights.
12th Feb., 1946	Proprietary	12,096	5·91	·171	1·010	714	124	99 18	70,830	·035	Fair	Average steaming performance. Axle brass wear still in evidence. Exhaust steam injector wasting water.
15th Feb., 1946	Proprietary	7,840	5·28	·142	·750	556	98	99 18	55,145	·034	Good	Fair steaming performance.
20th Feb., 1946	Stockton Open Cut	10,976	7·4	·900	6·670	211	100	57 61	12,202	·24	Reasonably well carried out	Average performance. Two short stops for steam.
21st Feb., 1946	Stockton Open Cut	6,720	7·48	·380	2·830	307	66	57 61	17,739	·108	Well carried out	Average steaming performance. One short stop for steam. Right-hand axle box trailing, engine pounding heavily. There would appear to be room for some improvement in coal consumption. See text of general remarks in report.
22nd Feb., 1946	Stockton Open Cut	7,784	3·874	·700	2·720	192	74	57 61	11,100	·181	Coal used poor. High proportion slack Safety Valves at 150 lb. per sq. in.	Despite disadvantage in coal and valves blowing under standard pressure the section time running was maintained and the engine gave a good performance.
23rd Feb., 1946	Stockton Open Cut	5,208	3·44	·490	1·690	184	46	57 61	10,619	·154	Coal used poor. High percentage slack safety valves blowing. Brick arch collapsed prior to journey	Despite all the disadvantages this engine put up a very good performance.
27th Feb., 1946	Proprietary	11,424	5·52	·269	1·484	414	96	102 44	42,495	·074	Reasonably well carried out. Slight priming at one stage owing to overfilling the boiler	Fair steaming performance. Quadrant of regulator lever worn and ineffective.
1st Mar., 1946	Proprietary	8,848	4·98	·244	1·220	353	84	102 44	36,205	·071	Reasonably well carried out	Very good steaming performance.
4th Mar., 1946	Proprietary	9,520	4·92	·264	1·30	333	52	108 19	36,065	·127	Test well carried out	Good steaming performance. Faulty regulator valve not lifting properly and quadrant not effective.
7th Mar., 1946	Proprietary	8,288	5·11	·453	2·32	169	36	108 19	18,276	·222	Engine badly prepared	Fair performance only. Some priming.
24th May, 1946	Proprietary	8,960	5·27	·345	1·82	471	100	55 17	25,994	·089	*See* Report, p. 44 *et seq.*	The Department regarded this locomotive as having maintained steam well and consider that the crew should not have stopped twice on the bank for steam. In my judgment the steaming performance was poor and is well illustrated by the graph. The crew were justified in stopping. The locomotive was very heavy on coal. The exhaust injector would not pick up on live steam.
27th May, 1946	Proprietary	4,256	4·11	·258	1·06	726	104	22 57	16,489	·075	*See* Report, p. 44 *et seq.*	Fair performance. Several steam blows in evidence. Exhaust steam injector still erratic. Test marred by signal stops and checks.
27th May, 1946	Proprietary	4,928	4·62	·296	1·37	733	120	22 57	16,640			
3rd June, 1946	Proprietary	5,600	4·96	·302	1·50	336	64	55 17	18,553	·082	*See* Report, p. 44 *et seq.*	Locomotive sent out with faulty valve setting on left-hand side. Engine steamed freely.
5th June, 1946	Proprietary	2,576	5·05	·206	1·04	552	100	22 57	28,388	·064	*See* Report, p. 44 *et seq.*	Signal checks and halts marred this run. Engine badly prepared for run. Snifting valve left-hand side remained closed. Left-hand valve spindle packing blowing at start of run but later made up. Left hand front and right hand back cylinder covers blowing badly. Fair steaming performance.
5th June, 1946	Proprietary	3,500	4·07	·221	·90	698	122	22 57				
13th June, 1946	Proprietary	6,272	5·66	·293	1·65	388	72	55 17	21,429	·079	*See* Report, p. 44 *et seq.*	Locomotive steamed freely. Crew wasted power by opening firehole door to damp down the fire.