DEPARTMENT OF TRANSPORT

RAILWAY ACCIDENT

Report on the Collision that occurred on 12th March 1979 at Sheffield

IN THE
EASTERN REGION
BRITISH RAILWAYS

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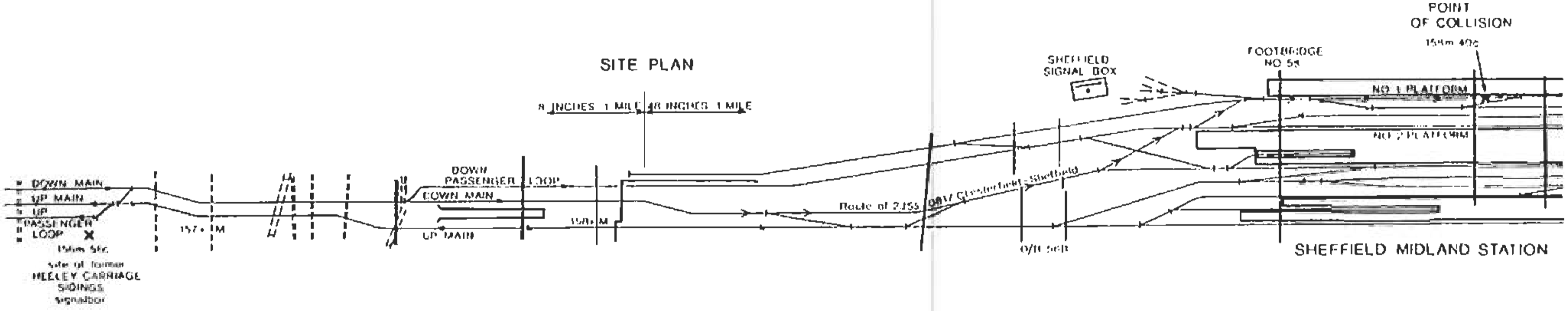

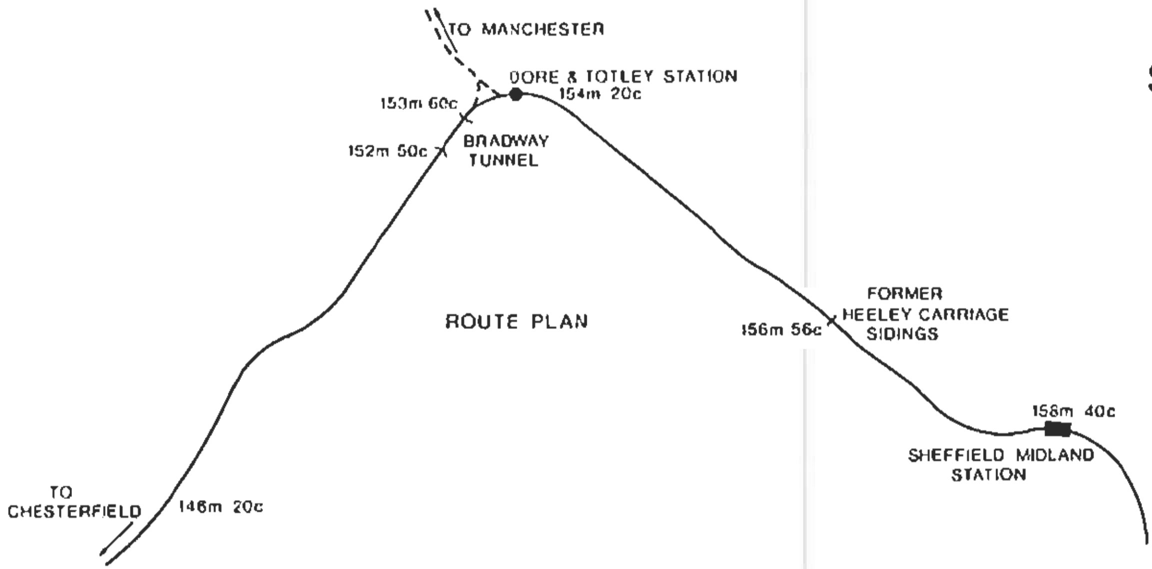

COLLISION AT SHEFFIELD MIDLAND STATION

12 MARCH 1979

Railway Inspectorate
Department of Transport
2 Marsham Street
London SW1P 3EB
19th February 1982.

Sir,

I have the honour to report for the information of the Secretary of State in accordance with the Direction dated 21st March 1979 the result of my Inquiry into the collision between a passenger train and an empty stock train that occurred at 08.35 on 12th March 1979 in Sheffield Station in the Eastern Region of British Railways.

As the 08.17 Chesterfield to Sheffield 3-car diesel multiple-unit passenger train was approaching its destination at a speed of about 70 mile/h, the driver became aware that the train was not responding properly to his brake application and, realising that there would be a collision, he applied the handbrake and began alerting passengers and moving them from the front of the train. The train entered the station at a speed estimated at 25 mile/h and collided with an empty 2-car diesel multiple-unit train that was standing at Platform 1.

The collision had been anticipated by the signalman who had alerted the emergency services and cleared signals in an attempt to indicate to the driver of the empty train that he should move off. Ambulances were at the station within 5 minutes of the collision but, of the six passengers injured, only three were taken to hospital and they were discharged after treatment.

After the collision it was found that four of the six brake cylinders on the train had failed to operate correctly and that although the driver and guard had attempted to apply the handbrakes, this had had little effect on the train's speed on the falling gradient. At the time of the accident the weather was fine and clear.

Description

The Site

1. Sheffield Station lies 158½ miles from London on the Midland Railway main line from St Pancras to Leeds. From Chesterfield Station, 146¼ miles from London, the line runs in the Down direction roughly north-westwards to a triangular junction with the Hope Valley line at Dore and Totley, 154¼ miles from London and then turns north-east to Sheffield. As far as the southern portal of Bradway Tunnel, 152¾ miles from London, the line rises, much of it at a maximum gradient of 1 in 100. After a short portion of level track in the tunnel the line falls at 1 in 100 until, at a point just before the Sheffield Station platforms, the gradient eases to 1 in 330 through the platforms. The site of the former Heeley Carriage Sidings Signal Box is at 156m 36c from London.

2. There are generally two tracks between Chesterfield and Sheffield with either Up or Down Passenger Loops providing three tracks closer to Sheffield over short distances. Sheffield Signal Box has a modern entrance-exit panel and is positioned just to the south of the station on the Down side. The station has a single-sided platform (No. 1) on the Down side with two island platforms (Nos 2 and 5 and Nos 6 and 8) to the east. The platforms are connected by a footbridge and there is another bridge carrying Shrewsbury Road over the railway just to the south of the station which restricts the view from the signal box of trains approaching from the south.

3. Trains are signalled under the Track-Circuit Block System using multiple-aspect colour-light signals. All signals, except for those in the station area, are fitted with AWS. The line speed is 80 mile/h with the following speed restrictions at the time of the accident:

FROM	TO	SPEED (mile/h)	REMARKS
148m 44c	150m 10c	70	Permanent
151m 40c	152m 38c	65	Permanent
151m 60c	152m 60c	20	Temporary
153m 73c	154m 31c	50	Permanent with "Morpeth" sign and magnet at 153m 17c in Bradway Tunnel
All lines through Sheffield Station		15	Permanent

A plan of the station area is included at the front of the report.

The Trains

4. The 08.17 Chesterfield to Sheffield 3-car diesel multiple-unit (DMU) passenger train (2J55) consisted of Class 123 Inter-City stock built at Swindon and introduced in 1963. The design of the underframes and steel bodies of these units is based on the British Railways standard Mark I coach and conforms fully to the UIC recommendations for end strength. The motor cars are each powered by two BUT (Leyland Albion) 6-cylinder horizontal diesel engines of 200 bhp driving an epicyclic gear-box through a free wheel with a reversing final drive. The empty 2-car DMU, which had run to Sheffield as 1D62 and then failed, consisted of Class 108 stock built at Derby and introduced in 1960. The trains were formed as follows:

2J55			*1D62*	
DMS(K)	52102	Leading	DMC(L)	52043
TC(K)	59826	Intermediate	—	—
DMBS(L)	52093	Trailing	DMBS	51923

DM — Driving motor, C — First and Second Class, B — Brake Compartment, S — Second Class only, K — Side Corridor and lavatory, L — Open and lavatory, T — Trailer.

5. The overall length of 2J55 was 59.4m and the weight 117.1 tonnes. The unit was equipped with the British Railways 2-pipe quick release vacuum brake with two 21-inch cylinders on each car. The total brake force normally available to the driver was 82 per cent of the total weight of the DMU ie 96 tonnes. The braking system has a 2in. BSP train pipe, continuous throughout the train, connecting a direct admission valve for each cylinder to the driver's brake valve. The direct admission (DA) valves sense the reduction of vacuum in the train pipe resulting from a brake application, the operation of a passenger communication valve, or the division of the train etc and admit air directly to the brake cylinders to make a similar reduction in vacuum to that in the train pipe. On each vehicle there is a high vacuum release reservoir connected by an automatic isolating valve to a 2in. BSP exhauster pipe, continuous throughout the train. With the drivers brake valve in the Lap or On positions the exhauster pipe and release reservoirs are normally maintained at 29 in. of vacuum by the exhausters. With the valve in the Running position during the release of the brakes air is drawn out of the cylinder into the train pipe and reservoirs and the automatic isolating valve closes if the vacuum in the reservoirs falls to 19 in. A feed valve fitted between the exhauster pipe and the brake valve ensures that the vacuum in the train pipe does not exceed 21 in. This arrangement allows both the exhausters and the release reservoirs to withdraw air from the brake pipe and compensates for the fact that the belt driven exhausters may be running at low speeds and unable to release the brakes quickly. Measurement of vacuum throughout this report is in inches of mercury.

6. The driver's brake valve has three positions:

Running: The high vacuum release reservoir is at 29 in. The train pipe and brake cylinders are at 21 in. Both are maintained by the exhausters through the driver's brake valve and the feed valve.

Lap: The high vacuum side is maintained at 29 in. and the train pipe at 21 in. or such lower figure as may have resulted from a brake application.

On: This position maintains the high vacuum side at 29 in. but admits air to the train pipe for a brake application. An emergency application of brake will not reduce vacuum further than will a full service application.

Each driving cab includes a driver's safety device which requires the throttle controller to be depressed while power is being applied. If the controller is released, after a delay of 5-7 seconds, air is admitted to the train pipe resulting in a brake application and power is cut off. At a number of points in each car, including the lavatories, passengers have access to a communication cord for emergencies which, when pulled, operates a valve admitting air to the train pipe and applying the brakes. At the end of the car in which the cord has been pulled an exterior indicator rotates. The equipment of 1D62 has no bearing on the accident but the weight of the train was 57.8 tonnes and the design end strength at drawgear level has been estimated at 80 tonnes. The body was of light alloy.

7. Mounted vertically on the bulkhead behind the driver's seat in the cab of each motor coach of Class 123 is the handbrake wheel of 13 inches diameter. It has no hand grip but the directions "On" and "Off" are cast into the wheel. Clockwise rotation of the wheel applies the brake-blocks to the wheels of both bogies of the motor coach, the resistance of one bogie providing reaction for the other. The handbrake operates through the same rigging as the brake cylinders by means of a screw thread and slotted joints. Where the guard's brake van is adjacent to the driver's cab, a handbrake wheel is mounted on the guard's side of the bulkhead between them. It is mounted on the same spindle as the driver's wheel and consequently, to apply the brakes, must be turned anti-clockwise. The handbrakes are intended for securing the vehicles when at a stand and cannot replace the power brake although in an emergency the handbrake can assist to some degree.

The Course of the Collision and the Damage Caused

8. The DMU that formed 2J55 ran as an empty coaching-stock train to Chesterfield where the driver changed ends. Neither the driver nor the guard, who travelled in the cab with him, noticed anything abnormal about the train on its outward journey. Returning from Chesterfield the brakes responded correctly to two applications at speed restrictions. However at Heeley Carriage Sidings, when the driver applied the brakes to reduce speed for the stop at Sheffield, there appeared to be no reaction nor did an emergency application appear to have any effect. While another driver, travelling to take up duty, went back with other staff in an attempt to reach and apply the other handbrake, the driver applied his handbrake as far as he could then sounded the emergency signal on the horn. Realising, when passing beneath Shrewsbury Road Bridge, that there was nothing more he could do, he went back to the passenger compartment in the first coach and attempted to move the passengers back before the collision. Meanwhile the guard saw the reduction in vacuum on his gauge and realised that speed was not being reduced sufficiently for the stop. He applied his handbrake but in his haste failed to appreciate that he was rotating it in the "Off" direction. The signalman heard the emergency sounding of the horn and realised what was happening but was prevented from diverting the train by the approach locking. All he could do was to clear signals in an attempt to start 1D62 away and to call the emergency services.

9. At a speed estimated at 20-25 mile/h, 2J55 collided violently with the rear of the standing DMU. The leading car of 2J55 (52102) being of heavy Inter-City stock over-rode the under-frame of the rear car of 1D62 (51923), which was much more lightly built and, pushing out the body side panels, completely destroyed the cab and adjoining passenger compartment as far as the first vestibule. The under-frame of 51923 was very badly damaged and the rear bogie displaced. The leading bogie of 52102 was displaced and the headstock bent, the jumper gear, bogie brake gear, canopy, and cantrail ends were damaged and the windscreens and route indicator were broken. The other vehicles of the two trains suffered no damage. Fortunately there were no passengers in the standing DMU.

EVIDENCE

As to the Running of the DMU Before the Accident

10. On 10th March *Driver C G Dickinson*, who had driven DMUs for about 10 years and those of Class 123 about once a month for 2 years, drove a 2-car unit of another class, the brakes of which he described as "All right", to Hull where, for the return to Sheffield, it was attached to the front of the 3-car unit concerned in the accident. No brake continuity test was carried out before departure. He described the brake of the Class 123 DMU as being normally "keener" than that of other classes of DMU. At the first stop on the return journey with the 5 cars he found that, whereas he would normally apply the brake sufficiently by reducing the vacuum to 15 in. he was having to destroy the vacuum completely in order to stop. The same applied all the way to Doncaster and he described the brakes of the 5-car set as "very bad". He did not however consider withdrawing the train from service, but told the driver who relieved him at Doncaster that the brakes on the 3-car unit "were not too good" expecting him to drive with care and to make an entry in the Repair Book.

11. *Driver J H Cudworth* took over the set at Doncaster and understood Driver Dickinson to say that it was "not a very good brake". His first use of the brake was to reduce speed from 40 mile/h to 20 mile/h which he considered easy to do with 5 cars although, because of what he had been told, he made a slightly heavier application than normal. As a result he felt that the brakes were quite satisfactory. However, at the first stop, he found that he had to destroy the vacuum completely in order to stop with the cab just at the end of the platform. For the next stop he braked earlier than usual, the brakes worked well, and he had to apply power to draw into the platform. After that the brakes functioned normally. On arrival at Sheffield he entered "Brakes to be examined" in the Repair Book of 52102 and said that, even without the incident at the first stop, he would have done the same because he had accepted the comment from the first driver.

12. I interviewed most of the drivers who subsequently drove the unit involved in the collision to York, Scarborough, Hull and back to Sheffield on 10th and 11th March. For some journeys the unit was coupled to other units but none of the drivers found cause to complain about the brake performance: nor did the drivers who drove the unit the short distance to Darnall Depot for stabling on the night of 11th March and back to Sheffield Station early on 12th March.

As to the Course of the Accident

13. *Driver K J Graveling* of Sheffield drove the 3-car unit involved in the collision from Sheffield Station to Chesterfield as an empty coaching-stock train on the morning of the accident. He had received one day's familiarisation training when the Class 123 units first arrived on the Eastern Region and thought that since then he had probably driven a unit of that class six times. Before departing from the siding at Sheffield, although he did not look in the Repair Book, he tested the brakes in both cabs with the unit stationary and was satisfied that they were in order. On the journey to Chesterfield he used the brakes only once to reduce speed gradually from 70 mile/h to a stop; everything was normal.

14. On the return journey the brakes were applied normally at Dronfield to reduce speed from 45 mile/h for a 20 mile/h speed restriction and again at Dore & Totley to reduce speed from 60 mile/h to 42 mile/h for a 50 mile/h speed restriction. At Heeley Carriage Sidings he made his usual brake application and heard the air rushing in but there was apparently no application of the brake blocks and speed was not appreciably reduced. Without placing the handle to the 'Lap' position, he looked at the duplex gauge which showed 10in. of vacuum in the train pipe and 28-30in. on the high vacuum side. As the brake application was having no appreciable effect he brought the brake handle round to the 'On' position but still nothing happened and he turned to the driver occupying the assistant's seat and said "Jeff. We are not stopping. There's no brake". The driver looked in the cab and replied "Put it in first gear and put the handbrake on. I'll get back".

15. Because he had released the DSD he was unable to engage first gear. So he stood up and turned round to apply the handbrake as tightly as he could and then turned to face forwards and sounded the horn. He used the two-tone horn as far as the last bridge approaching Sheffield at which point he evacuated the cab swiftly. He entered the leading compartment, shouted at the passengers "Get out quickly. We are going to crash", and was half way along the leading vehicle when the collision occurred and he was knocked over.

16. *Driver J Briddon* of Sheffield had received familiarisation training on the Class 123 units and had driven over the route about 10 times. On departure from Chesterfield he occupied, as a passenger, the assistant's seat which is outside the driver's cab. Although unable to see the controls from his seat he confirmed Driver Graveling's use of the brake which he considered was the same as his would have been. His description of the brake application at Heeley Carriage Sidings was of one continuous brake application as described by Driver Graveling and he agreed with what had been said in the brief conversation, adding that when he opened the cab door and looked in he saw the brake handle fully 'On' and the speedometer showing 65 mile/h. He went back in an attempt to reach and apply the rear cab handbrake but the collision occurred when he was in the third coach. While running back through the train he had not been aware of any great reduction of speed.

17. In charge of the train from Sheffield to Chesterfield and return was *Guard K W Spooner*. He regularly took charge of a train composed of Class 123 units and was familiar with them. From Sheffield to Chesterfield he travelled in the driver's assistant's seat in the leading cab of the empty DMU and spoke at odd times to Driver Graveling. He noticed nothing untoward during the journey and could recollect the retardation resulting from brake applications being normal. As far as Dore Station Junction on the return journey he travelled in the driver's seat in the trailing cab and confirmed that at that point the speed of 42 mile/h was indicated on the speedometer. After that he returned to his van and noticed nothing abnormal until passing Heeley Carriage Sidings Ground Frame. Here he realised that speed was not being reduced, saw the vacuum gauge needle drop to zero with no apparent effect, and realising that there would be an accident began to turn the handbrake wheel. Unfortunately, in his haste, he wound it in a clockwise direction instead of in the "On" direction and it had no effect. He was practised at estimating speeds and, although he could not feel any retardation, he said he thought that beneath the Shrewsbury Road Bridge the speed was 28-32 mile/h; there was then a violent lurch as the train travelled over the cross-over and speed along the platform was down to 22 mile/h. After the collision he helped to get passengers out of the train.

18. The Area Supervisor in Sheffield Signal Box at the time was *Mr D E Bennett*. Hearing the sound of a DMU horn he glanced out of the window, became aware that something was wrong, and had a quick glimpse of the first two coaches of 2J55 passing beneath the Shrewsbury Road Bridge before turning away. He realised that 2J55 was out of control, asked a signalman to attempt to signal 1D62 away, and called the emergency services. He thought the train was travelling at about 30 mile/h, twice as fast as normal, but he did not see any sparks or signs of heavy braking. He could not have diverted the train even if he had realised earlier that it was running away because of the two minute backlock on the routes, a safety feature of the signalling.

Examination Immediately after the Accident

19. *Traction Running Assistant J Mitchell* heard the collision as he was walking to his office. Less than 10 minutes after the accident he spoke to Driver Graveling who told him that he had applied the brake at Heeley Carriage Sidings in the normal manner, to provide initial braking, nothing happened and he then made an emergency application. The train pipe vacuum was then zero and the high vacuum reading 30in. Mr Mitchell also spoke to Driver Briddon at the scene who confirmed that the driver had made a partial brake application at Heeley and called out to him that nothing had happened. Mr Mitchell went into the cab and saw the brake handle in the emergency position, noted that the train-pipe vacuum was zero and high side vacuum was 30in. He then walked with a civil engineering supervisor over the track back to Heeley. The rails were in a dry condition with a mark like a broken line on the surface which became continuous as they left the station area. At Heeley Carriage Sidings the marks changed into being bright scuff marks which vanished opposite the middle of the sidings. He was satisfied that these were skid marks or made by wheels rotating more slowly than if they were turning freely on the rails.

20. *Senior Technical Officer D C Hall* arrived at the station at 08.40 and it was decided that he would check the brake gear of 2J55. With a carriage and wagon examiner this took him some 20 minutes

commencing at about 09.30, less than an hour after the accident. By recording the position of the pistons in the cylinders, noting the position of the brake blocks against the wheels, and feeling the tyres to see how hot they were, he came to the conclusion that only two brake cylinders out of six on the train had applied properly while, because the tyres were warm, another two might have operated at an earlier stage. The situation was:—

Brake Cylinder	Car Number	Position	Comment
1	52102	Leading	Not applied, tyres cold
2	52102	Trailing	Not applied, tyres cold
3	59826	Leading	Applied correctly, blocks hard on the wheels, tyres hot
4	59826	Trailing	Not applied, tyres warm
5	52093	Leading	Not applied, tyres warm
6	52093	Trailing	Applied correctly, blocks hard on the wheels, tyres hot.

21. Before starting the check he noted that the vacuum gauge in the leading cab showed zero vacuum for both the train pipe and high vacuum release pipe. During the check he also noted that the reserve strokes of the cylinders where the brakes had applied were satisfactory, although Mr Hall pointed out that in the time that had elapsed since the collision the pistons might have leaked off. As a result of his check he was satisfied that there were no other obvious defects with the brake gear. The handbrake at the leading end was completely off and 16 revolutions of the wheel were required to apply it fully. That at the trailing end was also completely off and it took 22 turns of the wheel to apply it. However someone else might have operated one or the other at some time before his check; he said that each handbrake applied the brakes on both bogies of the motor car on which it is situated. At a later date, sitting in a driver's seat, he found that it took him 32 seconds to apply a handbrake fully.

As to the Initial Brake Test After the Accident

22. The *Carriage and Wagon Engineer* at Sheffield, *Mr K D Hills*, had held the position for 4 years. He carried out the brake tests on the unit involved in the collision in accordance with a standing order which lays down what shall be done in cases of alleged brake failure. In order to carry out the test the pull rod was disconnected from brake cylinder 1 (52102 leading) because it was damaged and the release pipe was plugged with a wooden plug at a fracture. The following defects were found:

a. Brake cylinder 4 (59826 trailing) reacted to an emergency application of the brake but then began to leak off immediately and did not remain applied for the 15 minutes required by the test. (Later tests showed that 2 seconds after an application the cylinder began to leak off at a constant rate resulting in a gradual reduction of brake force to zero after about 40 seconds).

b. Because the piston must move slightly within the cylinder, when a brake application is made, before the rolling ring can move from its groove and form a rolling seal between cylinder and piston, the brake rigging is designed to permit this initial movement to be made before the load of the rigging and brake block application is taken up. This initial movement is called free lift. Brake cylinder 3 (59826 leading) had only a very small amount of free lift and certainly less than the 11-14mm called for.

c. To allow for brake block wear the rigging must be adjusted so that with the blocks hard on the wheels the reserve stroke of the piston rod is 89-102mm, depending on the vehicle type, when adjusted. The reserve stroke could only be measured on cylinders 2, 3, 5 and 6 and although it was adequate for operation there was 12mm less than the required dimension. Damage precluded this measurement for cylinder 1 and cylinder 4 leaked off.

d. The release valve of brake cylinder 2 (52102 trailing) was defective and did not remain open, as it should have done, after operation. Mr Hills did not think this defect had any relevance to the accident.

e. In the slow application test, which he carried out four times, using a 7/32in diameter aperture leak disc (specified for a 3-car DMU) only cylinders 3, 5, and 6 consistently operated. Because Mr Hills felt personally that with DA valves this size of aperture was too large, he carried out this test a further four times using an 11/64in. diameter aperture leak disc and only one cylinder consistently applied.

As to the Additional Brake Tests at Sheffield

23. Because of the evidence of the tests and the circumstances leading up to the accident, he came to the conclusion that the brake failure was not due to a slow application fault of the kind that can sometimes be

caused by a driver, and he therefore carried out further brake tests, in which an experienced driver operated the rear driver's brake valve (the front cab was unusable). The driver was instructed to make a normal service application in the correct manner reducing the vacuum from 21in. to about 14in. and then to place the valve into the 'Lap' position. The cylinders were then examined and the brakes were released and vacuum returned to 21in. This test was then repeated. In a third test, after the examination, a full application to zero was made. This sequence of tests was repeated several times and the results indicated that, of the 6 cylinders, 3 would not respond and one responded and then leaked off.

24. Because the failure of a cylinder to respond might have been due to the failure of either the cylinder or its associated DA valve, Mr Hills next investigated the operation of the DA valves. The operation of the valve of cylinder 2 was closely observed during four applications of the brake, as described above, in which the vacuum in the train pipe was reduced from 21 to 14in. and then to zero. The valve drew in air but on the first two applications there was no reduction of vacuum at the DA valve outlet to the cylinder and the cylinder did not operate. On the other two applications the reduction in vacuum at the DA valve outlet took place over a period of about 10 seconds after the vacuum in the train pipe had been destroyed. This valve was dismantled and the main valve spindle was found to be sticking in its guide bush; this was due to a heavy deposit of dirt and dry grease on the spindle and in the bore of the bush. The other five DA valves were identified and sent for testing on the vacuum brake test rig at Doncaster where all five functioned correctly.

25. Because Mr Hills was not satisfied that this test would reveal defects of the kind already found on one DA valve, he arranged further testing of the five valves on return to Sheffield. Each valve was fitted in turn to a recently overhauled 18in. brake cylinder with standard vacuum gauges on both the train pipe and cylinder sides of the valve. All the valves performed satisfactorily, in that reductions of train pipe vacuum were followed by cylinder side reductions with a lag of 1-2in. of vacuum. Thus, of the six DA valves, only one was identified as having been defective and this one was then reconditioned. The valves were refitted to their respective brake cylinders and the tests referred to in paragraph 23 were repeated with similar results.

26. Mr Hills summarised this work as indicating that, using the numbering in paragraph 20, cylinders 1, 2 and 5 failed to respond to the driver's application and cylinder 4 contributed little to the braking effect because it began to leak off immediately after a brake application. He considered that both cylinder 2 and its DA valve were faulty at the time of the accident. Thus, only two of the six cylinders would have applied the brakes correctly and could be relied upon to respond to an emergency application. He considered that it was an intermittent failure and that it would not to any great extent be dependent on the way in which the driver applied the brakes, although he agreed that 3 cylinders had failed the slow application test.

27. Tests carried out with a 3-car Class 123 DMU similar to that involved in the collision on a falling gradient of 1 in 100 commencing at a speed of 68 mile/h showed that a service vacuum brake application brought the train to a stand in about 1,000 m and that, using handbrakes only, the train was stopped after running slightly more than 5 km. One handbrake required 13 turns to apply fully taking 21 seconds and the other needed 20 turns taking 40 seconds. Mr Hills explained that because the handbrake relies for its operation on the resistance of one bogie to provide the reaction for the other, the damage to 52102 prevented a test being made of the handbrake on that car. However he confirmed Mr Hall's figure of 32 seconds to apply the handbrake of 52093 for 18 turns.

28. *The Divisional Maintenance Engineer Mr B Mules* summarised the further tests that had been carried out with the assistance of the Director of Mechanical and Electrical Engineering of the British Railways Board on the six cylinders involved. The variation in vacuum above and below the piston, together with the reduction in train pipe vacuum were recorded for a variety of different rates of brake application made with a driver's brake valve. The conclusions were:

Cylinder	*Comment*
1	Unreliable in operation, more likely to fail under partial application.
2	Unreliable in operation, more likely to fail under partial application.
3	Responded correctly although prone to failure under very slow application.
4	Applied and then released consistently under brake application.
5	Responded correctly although prone to failure under slow application.
6	Responded correctly.

29. It was the view of Mr Mules that the failures were intermittent and that some of the cylinders could have failed to operate correctly before the accident, although not as many as four at the same time; it was this coincidence that caused the loss of brake force and led to the accident. He considered that a train of 3 coaches with 6 brake cylinders could be brought safely to its destination with half of the cylinders defective, providing the driver was aware of the defect and able to act accordingly. He had no information that led him to believe that Class 123 is more prone to brake failure than any other.

As to the Maintenance of the Unit

30. Mr Mules explained the organisation and responsibilities of the maintenance staff in the Sheffield Division. At Darnall there is a DMU servicing, stabling, and refuelling depot which deals with about 13 units a night. Whilst none of the standard examinations are carried out there, maintenance staff are on duty at night responsible for checking the Repair Books and carrying out minor repairs and adjustments that may be necessary. For power, transmission, and major electrical work, staff are detached from a major diesel locomotive depot at Tinsley. Carriage and wagon staff at Darnall Carriage Depot nearby, who have a major 3-shift responsibility for locomotive-hauled coaching stock, deal with DMU brake adjustment, minor electrical matters, heaters etc. When a unit arrives at Darnall the chargeman fitter, who is from Tinsley, is responsible for examining its Repair Books, seeing that any booked repairs are completed, and that, if they cannot be dealt with, the unit is taken out of service and sent to its home depot. If the chargeman fitter finds that carriage and wagon work is involved he will arrange with the supervisor of the Carriage Depot for staff to come over and do the work. Work may be signed off as completed in the Repair Book by either the chargeman fitter or the supervisor.

31. In each power car there is a Repair Book in which a driver is required to enter defects of which he becomes aware while the unit is in traffic. At Sheffield most units finish their working at the station and are coupled together and taken to Darnall as is convenient, the driver having made any entry necessary in the Repair Book. However, if it is a major defect which affects the safety and running of the unit, the driver is required to report it to his supervisor on Sheffield Station as well as entering it in the Repair Book. Normally a driver would enter the fault in the Repair Book of the car with the defect. If the driver's experience indicated that more than one car might be involved he should make an entry in all the relevant Repair Books.

32. *Mr M L Rome* had been a charge-hand fitter at Sheffield Darnall for about 8 years and part of his job entailed looking round the DMUs stabled there overnight and arranging for repairs noted in the Repair Books to be carried out. As a result of his inspection on the night of 11th March of the unit that was to be involved in the collision and having found that statement in the Repair Book concerning the brakes, he decided that the brakes of 52102 required taking up but that the other two cars were in order and he telephoned the carriage and wagon staff. He took no further action because a supervisor came over with a man to do the job and he expected them to test the brakes afterwards. He only expected to find an entry concerning brakes in one Repair Book since it would clearly apply to the whole unit.

33. *The Carriage Maintenance Supervisor* at Darnall on the night of 11th March was *Mr G T Clarke* who said that he had very little experience of DMU brakes. He received a message that the brakes of a DMU required attention. The duty fitter was busy so eventually he went with *Carriage and Wagon Examiner J A Carruth* and asked Mr Rome which unit required attention. Mr Clarke said that he looked in the Repair Book and at the brakes and decided that the reserve stroke of the cylinders of 52102 was 63mm instead of "between 89 and 102 mm". He instructed Mr Carruth to adjust the brakes on that car, the engines of which were running and the brakes applied; he then went back to carry on with his other duties. When Mr Carruth returned he said that he had done the brakes. Mr Clarke expected Mr Carruth to sign the work off, even though he was not a fitter, because he had stood in for a fitter on past occasions. He also expected Mr Carruth to carry out a brake test after completing the adjustment as it was only common sense, but did not ask him if he had done so. He knew before the accident that the brakes had to be applied for the reserve stroke to be measured and how to take this measurement correctly, but he was uncertain of the dimensions for trailers and power cars. He now knew the correct figures. He was called across to the DMU shed about once a month and said that he had asked to be given instruction in DMU brakes but his requests had not been granted.

34. Mr J A Carruth confirmed what Mr Clarke had said. He had checked that the brakes were on by noting the position of the piston rods and he pulled the release cords to release the brakes on 52102. This was the first time he had adjusted the brakes on a Class 123 DMU and he found it a little difficult to do so but managed on his own. When he had taken up all 8 adjusters he entered "brake adjusted" in the Repair Book, then met *Fitter J King* who had just arrived, and together they told Mr Rome that the brakes had been adjusted. He seemed satisfied and they went back to the carriage shed. Mr Carruth said that, before the accident, if he was called to a defective cylinder or an unspecified brake defect, he would try out the brakes after the repair by using the driver's brake valve, but in this case he had been asked to adjust the brakes and did not try them out after doing so. After the accident a written instruction had been issued requiring a brake test after brakes had been adjusted. Whilst working on the brake gear of 52102 he saw no other obvious defects and he considered the reserve piston strokes of the other two cars to be good, although he did not look at the rest of the brake gear on them.

35. Fitter J King said that he knew Mr Carruth could do the brake adjustment on his own as he himself had done it without assistance in the past. Although it was not a written requirement, after he had adjusted the brakes, he would have arranged for a brake test to be carried out, probably by three separate applications using the driver's brake valve.

As to the Examinations Carried Out

36. *Mr C Philips* had been the *Maintenance Engineer (Traction and Rolling Stock)* at Botanic Gardens Depot Hull for 4 years. The unit involved in the accident is based at that depot and he explained the sequence of examinations undergone by all DMUs at the depot up to the No. 7 examination which takes place about every 8 months although the actual frequency of all examinations is dependent on mileage run and number of days worked. A No. 1 examination would be carried out every 2-4 days, a No. 2 every 6-8 days, and a No. 4 examination, including a fairly searching test of brake cylinders, about every 28 working days although again dependent on mileage. Each examination includes an element of lubrication and maintenance.

37. He said that, according to the examination records, 52102 underwent a No. 7 examination on 28th February during which the No. 2 position brake cylinder (No. 2 in paragraph 20) was replaced. After this a slow application brake test would have been carried out. No other defects were found with the brake equipment on that examination or on a No. 1 and final in set examination, including a slow application brake test, on 2nd March coupled to 59826. The car was withdrawn from traffic on 4th March for a battery charging defect and returned to traffic on 10th March. ("In set" refers to the vehicle being coupled into the complete unit or set).

38. On 9th March 52093 was released from a No. 5 examination and was coupled to 59826 and 52102 on 10th March. Car 52093 had undergone a No. 4 examination on 12th January including a slow application brake test. The car then ran until 4th March when it was taken out of traffic for the No. 5 examination. During this examination no work was required on the brakes. At the end of the examination a supervisor would have made sure that any repairs found necessary at the examination were carried out, tested the driver's safety device, and checked the free lift, the reserve piston stroke, and the condition of the brake gear. There was insufficient space at the depot to carry out a final in set examination, including a slow application brake test, at that stage and the unit would have undergone that test when it received a final in set examination at the time of its next No. 1 examination. In summary the last date before the accident when the cars involved underwent a thorough brake examination was 2nd March for 52102 and 59826 and for 52093 a slow-application test on 12th January and a test of free lift and reserve piston stroke on 9th March.

39. All the cars had been overhauled at Swindon Works BREL before being despatched to the Eastern Region; 52093 was received in June 1977, 52102 in June 1978, and 59826 in September 1978. There had been no need for maintenance staff to receive any special training since the DMUs of Class 123 were much the same as those of Class 124 already running on the Eastern Region. So far as the brakes were concerned the only differences were in detailed design because the Class 124 had a Mark I bogie and the Class 123 a later bogie designated B4. Mr Philips explained the records that are kept of examinations and repairs and said that each brake cylinder carried a tag indicating when and by which workshop it was last reconditioned. He did not consider that the Class 123 had more brake defects compared with other classes of DMU which he maintained, but felt that there were probably fewer defects than on the Class 124 because the brake gear arrangement was better.

40. *The Maintenance Supervisor at Botanic Gardens Hull, Mr R W Keith* described the brake tests that he carried out on the night of 2nd March on 52102 and 59826 during a final in set examination. Another supervisor started the engines and created vacuum while he placed a leak disc with a 7/32in. hole covered with tape over the end of the train pipe. When the other supervisor had placed the brake valve to the 'Lap' position Mr Keith removed the tape and walked the length of the set when the supervisor in the cab noted that the vacuum was totally destroyed. He could see that the pistons on 52102 operated smoothly and he checked that all the brake blocks were firmly applied by trying them with his foot. He was satisfied that the brakes were working correctly and that the ends of the piston rods were below horizontal relative to the fulcrum when fully applied, indicating that there was sufficient reserve stroke although he did not measure it. He explained that there were no automatic slack adjusters in the brake rigging and that it was really a two-man operation to adjust the brakes. After brakes had been adjusted on a Class 123 vehicle he always did a rather more careful check, and after using the driver's brake valve to apply the brakes he went round to check that the travel of each piston was correct.

As to the Overhaul of Vacuum Brake Cylinders

41. *The Divisional Maintenance Engineer at Doncaster Mr R Urie* explained that he was responsible for the DMU maintenance at Hull Botanic Gardens and for the overhaul and testing of vacuum brake cylinders at Hull Dairycoates. The brake cylinders come from both DMU and freight rolling stock and after receipt they are dismantled and overhauled according to the procedures and dimensions laid down in a standing order by the Chief Mechanical and Electrical Engineer of the Eastern Region. After reassembly four tests are required: a creepage test, a test for leakage, a slow application test, and tests of the release valve. Only if the cylinder passes all four tests together is it tagged with the depot number and date and passed out into store ready for use. The cylinders fitted to 52102 had been overhauled at Dairycoates, that in No. 1 position in September 1978 and that in No. 2 position in February 1979. During the period in which both these cylinders were overhauled the slow application part of the final tests was not being carried out at Dairycoates. Mr Urie

pointed out however that a successful slow application test was performed on 52102 and 59826 during the final in set examination on 2nd March.

42. Mr Urie explained why the slow application test was not carried out on cylinders overhauled at Dairycoates from July 1978 until March 1979. The person performing the tests claimed that he had received a letter stating that this particular test was to be discontinued but he subsequently went sick and retired and despite exhaustive enquiries no trace of the letter could be found. The person who was trained to take the job on was trained at a period when the test was not being performed and consequently omitted it after taking up the position. The omission was discovered as a result of the investigations into the accident and rectified.

43. I asked *Mr J A Sourbut* the *Chief Mechanical and Electrical Engineer* of the Eastern Region if he was satisfied that the work which had been done on the cars making up this DMU had been done in accordance with the schedules and he said that he was satisfied that the unit received the same quality of attention as any other unit. He also confirmed to me that all Class 123 DMUs held by the Eastern Region have been modified to the full present requirements of the British Railways Board.

As to the Detailed Tests of the 6 Cylinders

44. *Mr D B Nicholas* of the *Brake Section of the British Railways Board Directorate of Mechanical and Electrical Engineering* pointed out that the slow application test on a vehicle in formation at a rate of vacuum reduction of about 0.5 in/second is a much less searching test than that carried out on an individual cylinder in a test rack as should have been done at Dairycoates when the rate is about 0.01-0.02 in/second. With another member of the brake section he had provided assistance for many of the detailed tests that have been described earlier in this report and he gave me a full report. The conclusions were that not more than 50% of the braking power was available to the driver and that this could have been reduced to 33% as cylinder No. 4 leaked off and released after first applying. These figures provide calculated speeds at impact which agree with those estimated by witnesses. After the tests so far described the six cylinders were subjected to further tests at York. The details of these tests and the conclusions drawn, but not the full results, are included at Annex A.

Conclusion

45. The collision occurred because the brakes of the DMU failed to respond to the operation of the brake valve by Driver Graveling. From the evidence of the tests and of those who inspected the unit shortly after the accident, I consider that cylinders 1 and 2 failed to operate at all, cylinder 4 applied and then released, and cylinder 5 made only a partial application. Cylinders 3 and 6 operated correctly.

Remarks and Recommendations

46. I consider that the failure of cylinders 1 and 2 to operate is directly due to their condition and that they were in an unsatisfactory state when released from reconditioning at Hull Dairycoates. It is a conclusion of the report produced by the Director of Mechanical and Electrical Engineering of the British Railways Board that neither cylinder would have passed the slow application test on the rack, if it had been carried out, after reassembly. I agree with this conclusion. The fact that they subsequently passed a slow application test in formation is explained in paragraph 44 above as being due to the less stringent nature of the test carried out in formation. I consider that the release after reconditioning of cylinders, over a period of 8 months in 1978/79, when they had not undergone the slow application test indicates an unacceptably low level of supervision. I am told that action was taken to correct this omission as soon as it was detected and a review of the arrangements for supervision of the overhaul has been undertaken.

Slow Application Brake Test

47. The vehicle formation slow application brake test, which has for many years been part of the investigation into allegations of brake failure, was introduced into the No. 5 examination for DMUs (No. 4 on the London Midland Region) in 1974. An arbitrary choice was made of a rate of vacuum reduction of 0.5 in/second and there was no differentiation in choke diameters between vehicles fitted with DA valves and those without. There was still doubt in the minds of some witnesses about the correct way to perform this test and the choke sizes to be used. I recommend that all Regions introduce this test into the No. 4 examination for DMUs, that the rate of reduction of vacuum be reduced to 0.15 in/second, that choke sizes to be used should be clearly stated, and that the procedure should be altered to require 3 consecutive tests, all of which must be satisfactory. This will make the test much more stringent and should detect any cylinder with an intermittent fault.

48. I also recommend that the necessary amendment should be made to the instructions concerning the vehicle slow application brake test as part of the special examination of brakes after an accident or incident which may have been caused by a brake defect. The test should be carried out as described above and the examination schedule, which should be standard throughout British Railways, should include test dimensions such as choke diameters.

49. Although different ranges of choke diameters should be specified for vehicles with and without DA valves, to reduce the range of choke diameters the Board have proposed that no differentiation be made. The four proposed choke diameters are related solely to the number of vehicles being tested and meet the needs of both Depots and Works, the latter having a requirement for a lower rate of reduction of vacuum than the former; although, to prevent overlapping of rates of reduction, a degree of tolerance has been accepted. The choke diameters are clearly marked on the leak discs.

Free Lift

50. I commented in my Report of an Inquiry into a buffer-stops collision at Newcastle* on the need to ensure that, when a brake application begins, the piston is free to move a small distance before the load of the brake rigging is taken up, to allow the rolling ring to seat properly in the cylinder. I am told that the modification referred to, led, in the case of some Classes of DMU, to axles being scored, with a consequent risk of fatigue cracks starting. An investigation has led to the withdrawal of the modification which is to be replaced. I recommend that the work should be completed as speedily as possible. The situation in mid-1981 was that, because the modification had to be withdrawn, about 900 vehicles out of a total of 1982 had been dealt with.

Reserve Stroke and Tests after Adjustment

51. Whilst a figure of 89-102mm is quoted as the minimum reserve stroke of the piston to be achieved after a brake adjustment, no guidance is given at present on the minimum figure acceptable in traffic. I recommend that the Board should lay down a figure for the minimum acceptable reserve stroke in traffic. Some witnesses appeared to be in doubt whether the brakes should be tested after they had been adjusted. I recommend that the instructions be amended to make it quite clear that a test of the brakes is always required after both repairs and adjustments and shall specify the type of test. It must be sufficient in every case to detect any serious fault or an omission on the part of a tradesman.

Overhaul of Vacuum Brake Cylinders

52. The cause of the occasional failure under slow application conditions of cylinders 3 and 5 was wear, due probably to their age. Indeed the Report produced by the Director of Mechanical and Electrical Engineering of the British Railways Board remarked that cylinder 6 was the youngest (10 years old) of all the cylinders and the only one to pass all the tests satisfactorily, whereas the others were between 14 and 21 years old. I have discussed with Officers of the Board various measures which could be taken to improve the reliability of brake cylinders after overhaul. These include the rejection of cylinders over a certain age, the further extension of dimensional checks and surface finish criteria, and the raising of acceptability standards with increasing age.

53. I am told that considerable effort has been put into solving the problems of vacuum brake cylinders. Engineering Instructions or Standards are issued to Main Works and the Depots concerned with cylinder overhaul. Both contain surface finish criteria and dimensional tolerances and have been recently revised. Although of necessity the depots do not have the range of facilities available at Main Works for measurement and reclamation, I am assured that the standard set will lead to the rejection of unsatisfactory components. The 4 bench tests (which have also been recently revised) will detect any defective cylinders. The Instruction and Standard also refer to the repair and test of Release Valves; an Instruction dealing with DA valves is shortly to be issued.

Handbrake Marking

54. There is a strong possibility that in his haste Guard Spooner rotated the handbrake wheel in the 'Off' direction. The trial showed that the correct and full application of both handbrakes would not have prevented the collision although its severity might have been reduced. Nevertheless there are many other occasions when handbrakes must be relied upon and accordingly I recommend that the 'On' and 'Off' directions on the handbrake and its mounting shall always be painted in a colour contrasting with the background.

Design

55. The way in which the Inter-City stock withstood the collision, compared with the damage caused to the much more lightly-built Class 108 stock, bears out the importance of considering the possibility of collision damage when designing any rolling stock and the need for compatibility with other rolling stock in use on the same lines.

Minor Irregularities

56. Finally the evidence I heard indicated a number of irregularities such as the failure of train crews to carry out brake tests, the rostering of a driver to a Class of DMU with which he was not conversant, and failure

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to carry out preparation correctly. All these were dealt with by the Railway Officers and reminders, where necessary, have been issued.

57. I am grateful for the effort provided by the Director of Mechanical and Electrical Engineering of the British Railways Board to investigate the vacuum brake cylinder operation and for permission to publish part of the report produced.

I have the honour to be,

Sir,

Your obedient Servant,

A. G. B King
Major

The Permanent Secretary,
Department of Transport.

ANNEXURE A

Notes of an investigation into the performance of the Vacuum Brake System components removed from Class 123 Unit, comprising E52102, E59826, E52093 at Darnall and York Depots, ER, April-June 1979.

All cylinders, release valves and direct admission valves were sent to York Depot ER for more detailed examination. The following observations are given in respect of each position cylinder, release valve and direct admission valve, under the notation stated in the first part of this report i.e. No 1 to No 6 commencing with vehicle E52102, E59826 and E52093.

The report for each combination of cylinder, release valve and direct admission valve covers the following aspects.

Vacuum Brake Cylinders	1)	External examination and test with release valve.
	2)	Removal of release valve for separate test.
	3)	Dismantling and internal examination.
	4)	Dimensional check of cylinder and piston/piston rod.
	5)	Material and dimensional check of rolling rings.
Release Valve	1)	External examination and test.
	2)	Dismantling and internal examination.
	3)	Re-assembly and test.
Direct Admission Valve	1)	External examination and test.
	2)	Dismantling and internal examination.
	3)	Analysis of filter debris.

Conclusion Position No 1

The dimensional checks and general condition of the vacuum brake cylinder show certain limits have been exceeded. It is considered that this is less significant than the deterioration in surface finish of the piston adjacent to the relief groove over the 18 years life of the piston. This cylinder was inconsistent in performance under partial applications whether rapid or slow and failed under most 'slow' full applications. This erratic behaviour is attributable to the disposition of the rolling ring in the relief groove at the time of the application as well as being influenced by the rate of application to overcome the resistive forces to movement. Slight twist marks on the rolling ring confirm this view. If this cylinder had been subject to EI G364 when repaired it would have failed the 'slow application' test.

Conclusion for Position No 2

The general condition of the cylinder/piston assembly shows that some limits have been exceeded. Piston lip condition would indicate binding had occurred sometime during its life, but, in the absence of similar markings in the cylinder, to what extent this happened in this assembly is speculation. The age of the two components, fifteen years, is reflected in the wear adjacent to the relief groove profile which resulted in the twisting of the rolling ring under varying degrees of application. The compression of the rolling ring was less than the nominal 0.125". The response of this brake cylinder was not adversly influenced by the replacement direction admission valve since this was separately tested satisfactorily by ER Staff. Examination of trainagraph records shows repeated failure irrespective of type of application. Again as with cylinder No 1 if this cylinder had been subject to EI G364 when repaired it would have failed the 'slow application' test.

Conclusion for Position No 3

Examination of the piston/cylinder assembly indicates above nominal compression of the rolling ring. However although the cylinder surface finish was reasonably constant the piston was not, this showing a significant reduction relative to the relief groove and varying on the periphery of each measured zone. This factor in combination with the piston rod/guide bush "clearance of 0.004" min would explain why this cylinder when tested at Darnall Depot failed 'slow' applications occasionally between 0.18" Hg/sec and 0.02" Hg/sec because the resistive forces to movement with slip of the rolling ring prevented piston movement in opposition to the rate of applied force.

Conclusion No 4 Position

Generally the cylinder and piston assembly 21 years old, failed on 'slow' application, and certain dimensional limits had been exceeded. The independent tests on the release valve confirmed the tests conducted at Darnall Depot that this cylinder applied and released due to the release valve failing to seat properly.

Conclusion for Position No 5

The general state of the cylinder piston assembly shows that some limits have been exceeded. The piston rod outside the straightness limit and the guide bush within specification may explain why the cylinder failed intermittently under 'slow applications' on bench and vehicle tests. The piston rod piston assembly was also affected and hence the resistive forces to movement prevented piston movement in opposition to the rate of applied force on occasions.

Conclusion for Position No 6

Despite being covered in graphite internally, this the youngest (10 years) of the six cylinders passed all tests. The piston rod guide bush and piston rod fit ensured accurate centralisation of the piston within the cylinder both of which were dimensionally outside the limits referred to earlier. The surface finish of the piston and cylinder in combination with the degree of rolling ring compression ensure satisfactory operation under varying levels of application.

How long this satisfactory situation would have remained in view of the presence of graphite would be speculation since the signs were that the graphite was being transferred to the walls of both cylinder and piston.

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