Rail Accident Investigation Branch

RAIB Bulletin 02/2015

Derailment at Ashburys, Manchester, 13 November 2014

Preface

1 The purpose of an RAIB investigation is to improve railway safety by preventing future railway accidents or mitigating their consequences. It is inappropriate that RAIB reports should be used to assign fault or blame, or determine liability, since neither the investigation nor the reporting process has been undertaken for that purpose. The RAIB's investigation is independent of all other investigations, including those carried out by the safety authority[1] or railway industry.

Description of the accident

2 At approximately 19:35 hrs on Thursday 13 November 2014, the seventeenth of eighteen empty bogie box wagons (figure 1) on freight train 6H53[2], the 19:37 hrs from Ashburys, Manchester, to Brigg's Sidings (Dowlow, near Buxton) derailed. The train was departing from the yard at Ashburys (figure 2) and travelling at about 6 mph (9.7 km/h). The driver was alerted to the derailment by the loss of brake pipe pressure[3] causing the brakes to apply.

3 The train had arrived at Ashburys as train 6H52, the 13:02 hrs from Brigg's Sidings to Ashburys, loaded with limestone aggregate. The aggregate was unloaded from the wagons at Ashburys.

4 The derailment was caused by the fracturing, through to the axle, of the right-hand leading wheel of the trailing bogie (figure 3). This resulted in the loss of the *interference fit*[4] between the wheel and the axle and permitted the wheel to move inwards on the axle. The derailment of this wheel then pulled all the wheels of the trailing bogie off the rails (figure 1).

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[1] The Office of Rail and Road, the safety regulator for the railways of Great Britain.

[2] An alphanumeric code, known as the 'train reporting number', is allocated to every train operating on Network Rail's infrastructure.

[3] The brake pipe runs throughout the length of the train and must be pressurised to 5.0 bar to release the brakes. If the pressure is reduced, the brakes apply.

[4] Technical terms are shown in italics the first time they appear in the report and are explained in the Glossary of terms.

Figure 1: The derailed wagon

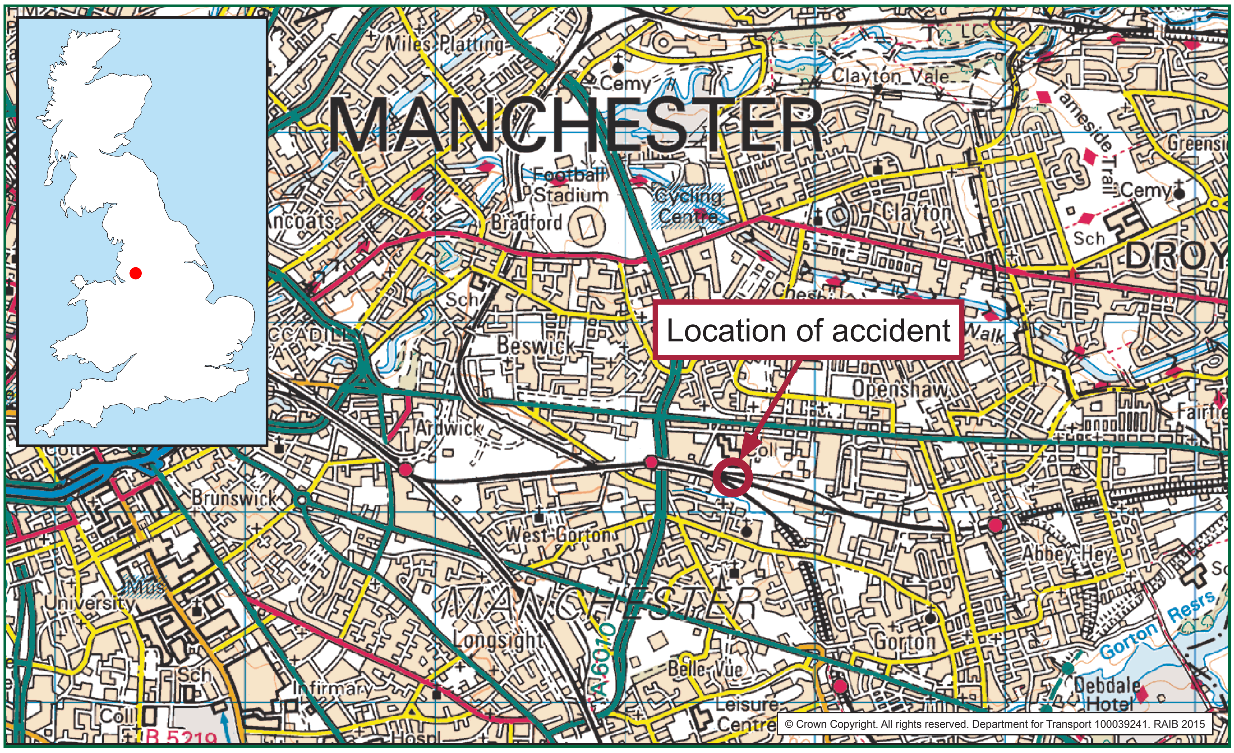

Figure 2: Extract from Ordnance Survey map showing the location of the accident

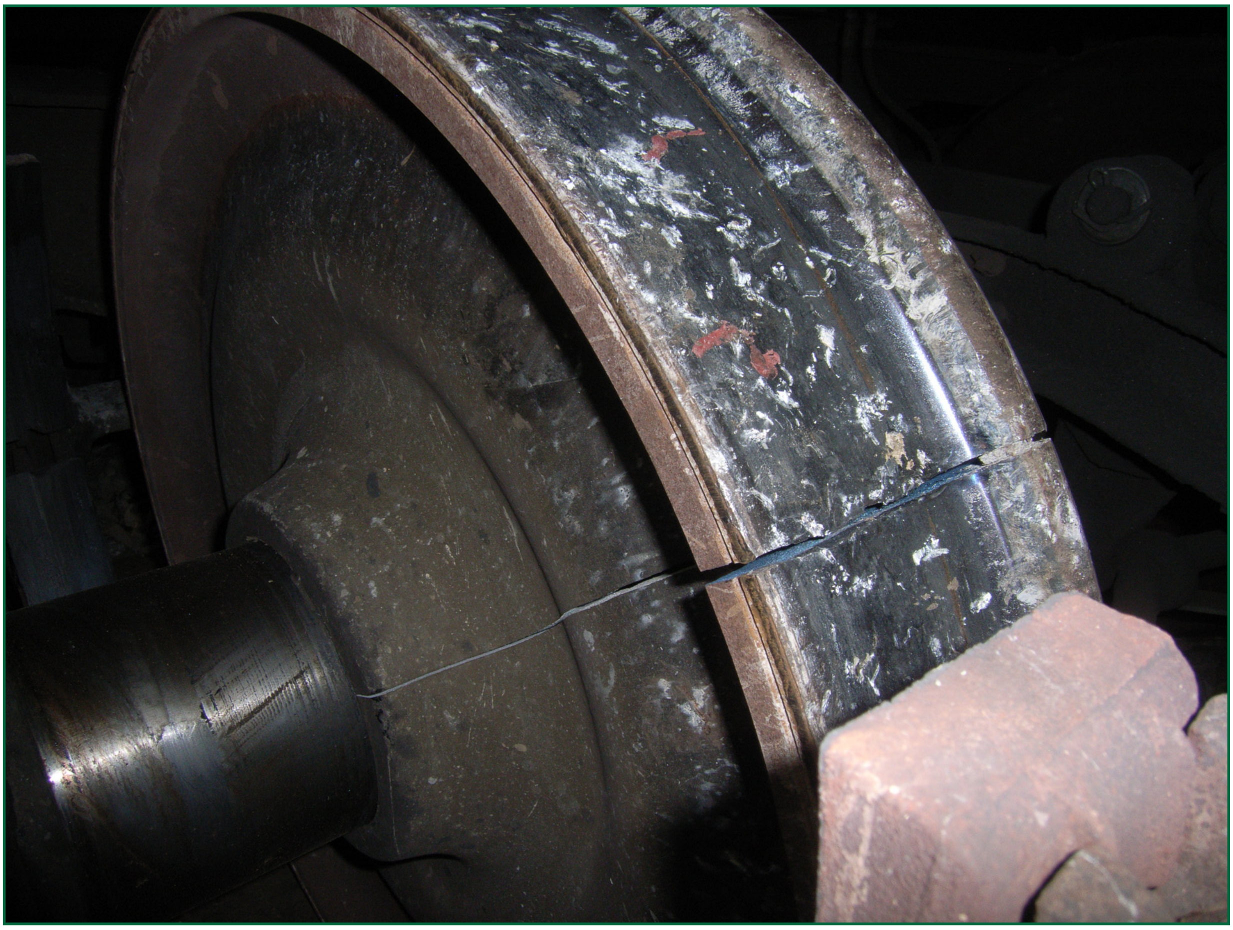

Figure 3: Right-hand leading wheel of the trailing bogie following the derailment

5 Subsequent to the derailment, further cracked wheels were identified:

- The left-hand leading wheel of the leading bogie and, though fractured through to the axle, the wheel had not moved on its axle.
- The other wheel of the wheelset described above, but the crack had not broken through to the axle. This wheelset is shown in figure 4.
- The right-hand wheel of the trailing wheelset of the trailing bogie, though not cracked through to its axle.

The layout of damaged wheels is summarised in figure 5.

Background information

6 The wagon, number 33706790077-5, is a 90 tonnes gross laden weight aggregate box wagon, *TOPS code* JRA. It was constructed in 1989 and is owned by GE Capital Rail Ltd, part of the General Electric Corporation. Along with others of the same type, it was leased to DB Schenker Rail for the regular transport of limestone aggregate from the quarry at Dowlow, a few miles south of Buxton, to the terminal at Ashburys. The wagon was maintained by Axiom Rail, part of DB Schenker Rail, on behalf of GE Capital Rail.

Figure 4: The left-hand leading wheel of the leading bogie found to be cracked through following the rerailing of the vehicle. It also shows evidence of overheating

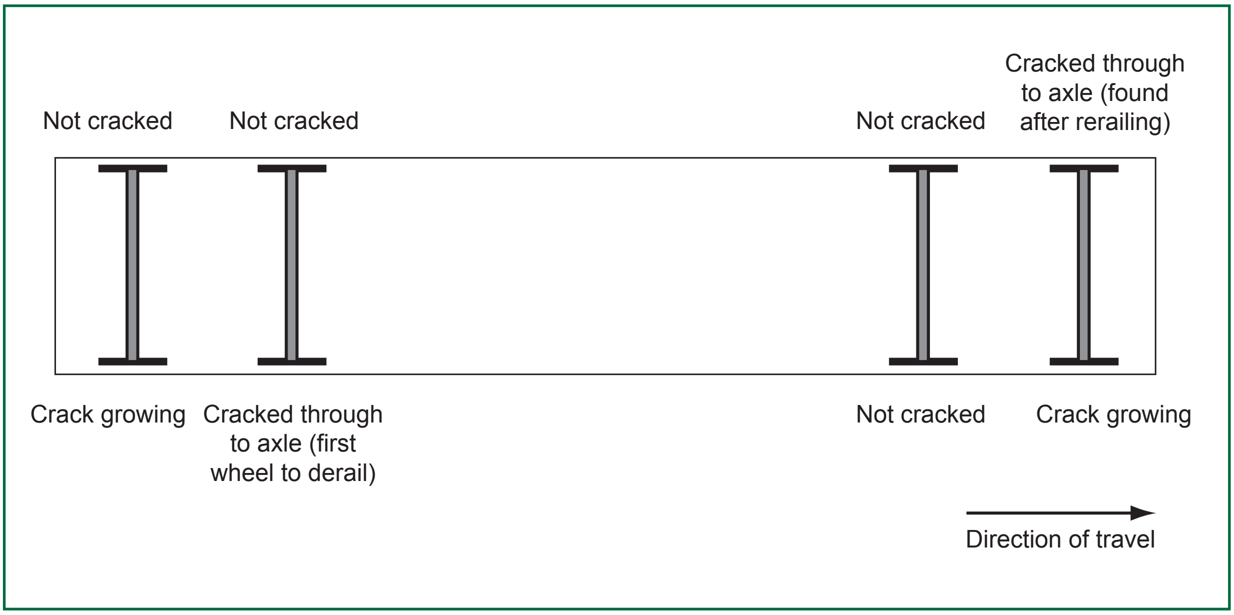

Figure 5: The layout of damaged wheels fitted to the derailed wagon

7 In accordance with EU regulation 445/2011 and UK Railway Group Standard GM/RT 2004, GE Capital Rail prescribed a maintenance regime for the wagon. This comprised inspections of the vehicle and brake tests (VIBTs) approximately every 12 months; planned preventative maintenance exams (PPMs) approximately every 6 months; and trip inspections (TIs) carried out as required. The work content of a VIBT included that of a PPM so there was no requirement to do both if the due dates coincided. A general repair, consisting of an overhaul of all aspects of the vehicle, was to be carried out every 6 years.

8 A trip inspection was carried out by a member of maintenance staff walking alongside the vehicle and carrying out a visual check of all aspects of the vehicle. Up until May 2014, trip inspections were required to be done weekly but, following risk assessment, this was changed to 'as required' by GE Capital Rail.

9 Prior to the derailment the last maintenance dates were:

- General repair 24 February 2011
- PPM 28 January 2014
- VIBT 18 May 2014
- TI 17 October 2014

The wagon was 'in date' for its maintenance, and the next PPM was due shortly after the derailment occurred.

10 The brake blocks were renewed at the VIBT on 18 May 2014.

11 All four wheelsets were of the *monobloc* type and were fitted to the wagon at the general repair in February 2011. Prior to fitment, they had been overhauled by Axiom Rail, which included reprofiling of the wheels, overhaul of the bearings, non-destructive testing and repainting.

12 By the time of the derailment, the wheelsets were worn but were well within the wear limits indicated by the *wear groove* (figure 6; the wear groove is also visible in figures 3 and 4).

13 Before the loaded train departed from Brigg's Sidings, it had been examined by a Rolling Stock Technician employed by DB Schenker Rail. The purpose of this planned pre-service examination is to identify whether there are any visible defects, such as failed or damaged components on any vehicles in a train, which could affect its safe running.

14 There is no *hot axle box detector* fitted on the route travelled by the train from Brigg's Sidings to Ashburys and back to Brigg's Sidings.

RAIB investigation findings and analysis

Wheel Metallurgical examination and condition

15 The parts of a wheel are shown in figure 6.

16 The manufacturing details and cracking related to the wheelsets fitted to the derailed wagon are shown in table 1.

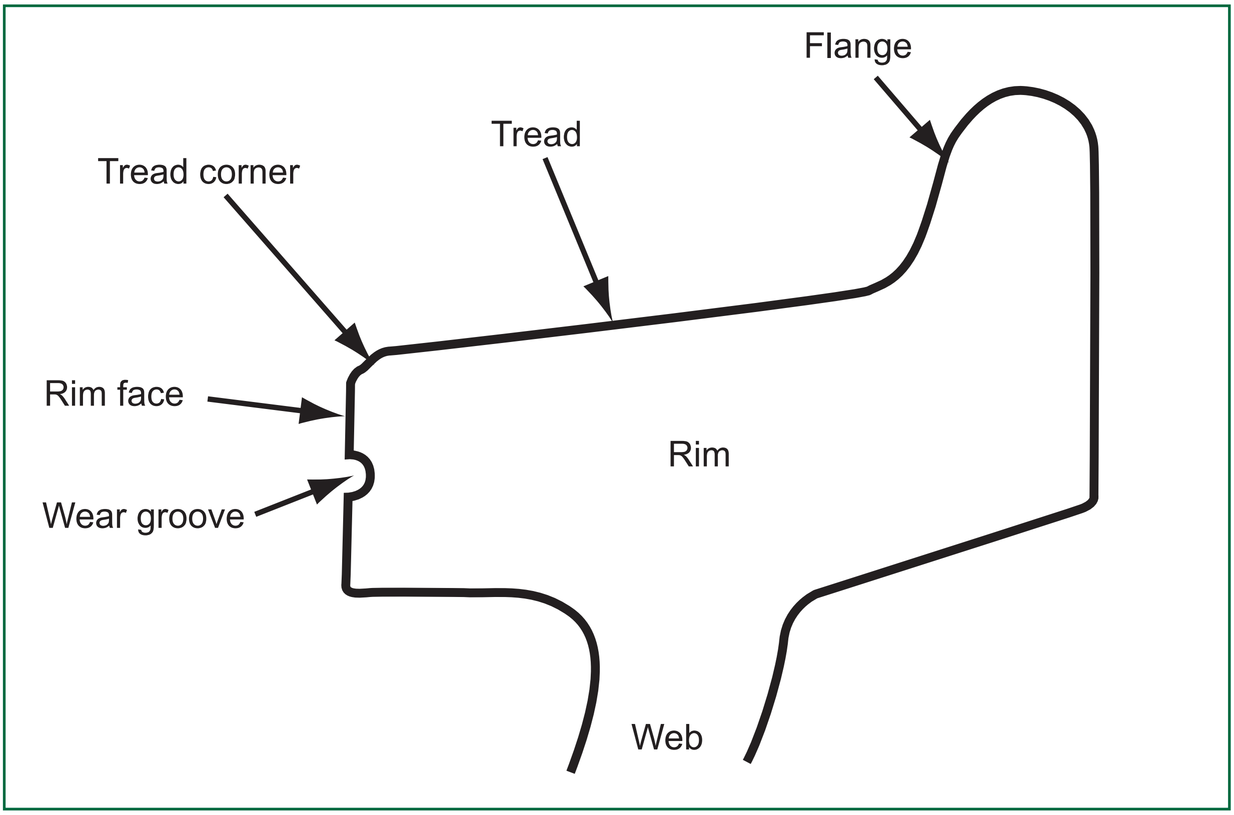

Figure 6: The parts of a monobloc railway wheel

Leading* wheelset Leading bogie	Trailing wheelset Leading bogie	Leading wheelset Trailing bogie	Trailing wheelset Trailing bogie
Wheels were manufactured by Bochumer Verein in 2005 and assembled into a wheelset by Brush Barclay in August 2005	Wheels were manufactured by Bonatrans in 1999 and assembled into a wheelset by Wabtec in December 1999	Wheels were manufactured by SC SMR SA in 2003 and assembled into a wheelset by Pullman Rail in March 2004	Wheels were manufactured by Bonatrans in 1998. It is not known when they were assembled into a wheelset or who by
Left-hand wheel cracked through to the axle; two other small cracks found growing from the tread corner Right-hand wheel found to have a significant crack growing from the tread corner and into the web	Neither wheel cracked	Left-hand wheel not cracked Right-hand wheel cracked through to the axle causing the derailment	Left-hand wheel not cracked Right-hand wheel found to have a crack growing from the tread corner into the rim

*Table 1: Details of wheelsets fitted to the derailed wagon (*in the direction of travel as the train was departing from Ashburys)*

17 All the wheelsets were sent to a metallurgical specialist for examination under the supervision of the RAIB. The cracked wheels on the two wheelsets where wheels had fractured through to the axle were subject to a more detailed examination and analysis. This found that, for the wheels that had fractured through to the axle, the cracks had opened up by about 5 mm (figures 3 and 4) at the tread suggesting that there were tensile stresses in the rim which had encouraged the growth of the cracks. Normally, these stresses are compressive, to inhibit crack growth. These are induced into the wheel rim during manufacture by *quenching* it.

18 The specialist found that there were no significant material defects in the wheels analysed. The results of chemical analysis were typical of the steel used for rail wheels and the tread surface complied with the hardness standard requirements for tread wear as specified in British Standard BS 5892-3 'Railway rolling stock materials – Part 3: Specification for monobloc wheels for traction and rolling stock'.

19 The specialist concluded that the wheel rims had either not been effectively quenched at manufacture, or overheating of the rims due to dragging brakes had reversed the residual stress. Of these, it considered that the latter was the more likely as there was significant evidence of overheating in the vicinity of the rims in the form of paint flaking and rusting (figure 4). The tread surface of the wheels was also found to be mottled (figure 7), which the specialist believed was thermal damage caused by the wheels slipping and/or sliding. Furthermore, wheels had been made by different manufacturers (table 1) and it is unlikely that the rim quenching process would have been deficient at each.

Figure 7: Example of thermal damage to the tread surface (by courtesy of Serco Rail Technical Services)

20 The RAIB also observes that although four wheels were cracked on this wagon, no defects were reported on any of the other wagons in the rake, thereby suggesting that the cause related to the wagon, rather than the individual wheels.

21 On the basis of his experience, the specialist believed that the nature of the rusting present, particularly its roughness, indicated that the overheating had taken place over a period of at least a few weeks, if not a few months before the derailment occurred. The wagon had been in regular use on the Dowlow to Ashburys working during this period. The subsequent brake testing, described in the next section, indicated that this overheating was caused by dragging brakes and may have been intermittent (paragraph 38).

22 There was no evidence of abnormal brake block wear since the blocks had been fitted at the last VIBT (paragraph 10). This indicated that the dragging was insufficient to cause significant wear of the brake blocks, either because the dragging brake forces were low, and/or the duration of the dragging was limited. However, the dragging brake forces must have been sufficiently high, and over a long enough duration, for the overheating to occur.

23 The nature of the change to the structure of the steel beneath the tread surface indicated that the temperatures reached had been in the order of 650°C to 700°C, significantly reducing the strength of the steel and causing *thermal fatigue*. This had caused cracks to initiate at the tread corners of the affected wheels[5] (figure 6) and then to propagate by fatigue.

24 Once the overheating of the wheels started, it is uncertain when the cracks initiated and how quickly they then propagated. The RAIB has not attempted to determine this.

25 All the wheels fitted to the wagon were to a UIC[6] design dating from 1974. The RAIB has not investigated the design requirements and load cases associated with dragging brakes that would have been applied, because modern wheels are designed to a more recent standard which includes type tests to confirm a wheel's resistance to being heated by a dragging brake[7].

26 The wheel failures that occurred are very rare, no other instances have been found to have occurred on Network Rail's infrastructure in the previous 10 years. This suggests that the conditions experienced by the wheels on wagon 33706790077 were particularly extreme (either in terms of the loads applied or the duration/frequency over which they were applied).

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[5] The tread corners are relatively sharp resulting in raised stresses and a greater likelihood that any cracks will initiate from them.

[6] The International Union of Railways; an organisation which exists to spread best practice among member railways and introduce common standards.

[7] EN 13979-1: 2003, 'Railway applications – Wheelsets and bogies – Monobloc wheels – Technical approval procedure – Part 1: Forged and rolled wheels'. This includes tests relating to the ability of wheels to withstand dragging brakes. The tests make ten drag brakings, to parameters that are defined in the standard, on a wheel, and their effect on the residual stresses in the rim and the lateral displacement of the rim are measured. Should specific criteria in the standard be exceeded, there is a second stage test to verify that a wheel with a pre-cracked rim withstands specified drag braking without undergoing any radial fracture.

27 Crack initiation from the tread corner can also occur if the brake blocks have been *flanging*. There was little evidence[8] that this had occurred, because flanging brake blocks normally wear the angled tread corner (which was present) into a more rounded tread corner. The area of heat input into the tread indicated that the brake blocks had been applying to the main area of the tread. Examination of the brake blocks showed that they had not been flanging and their wear did not appear to be excessive since being fitted at the last VIBT in May 2014 (paragraph 7).

Brake testing

28 Given the number of wheel failures on this wagon, the likelihood that this had been caused by dragging brakes, and the lack of reported defects on other wagons in the rake, the RAIB investigated the braking system on the wagon that derailed.

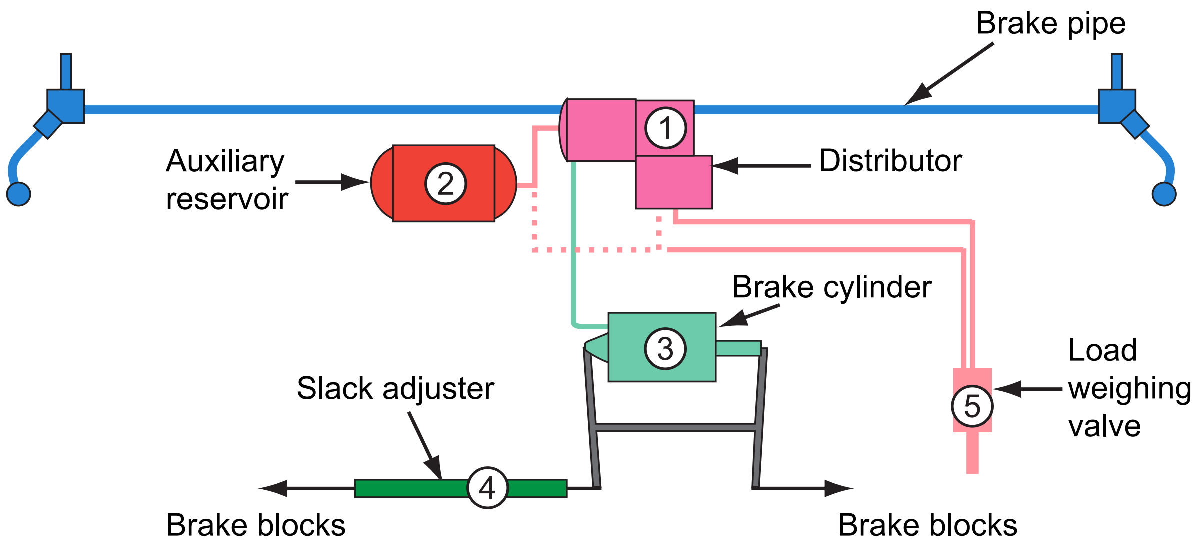
29 After the wagon had been rerailed, its brakes were tested at Ashburys to GE Capital Rail's standard procedure used for a VIBT. This found that the distributor[9] (figure 8) did not function as it should have done resulting in a residual brake cylinder pressure of 1-2 lbs/in² (0.07-0.14 bar) when the brakes should have been fully released. These pressures caused the brake blocks to only rub lightly against the wheel rims.

Figure 8: The wagon's distributor (the red handle can be operated to isolate the distributor)

[8] A worn band around the rim face adjacent to the tread corner of the wheel that caused the derailment suggests a possibility that there had been flanging brake blocks before the wheel was last reprofiled in 2011. The other failed wheels did not have such a worn band.

[9] The distributor, fitted to each vehicle, responds to changes of pressure in the brake pipe, which runs the length of the train and is normally charged at 5 bar when the brakes are released. When the driver applies the brake, the brake pipe pressure is reduced and the distributor responds by permitting air to flow from a reservoir on the vehicle into the brake cylinder in proportion to the amount of reduction of brake pipe pressure.

30 The wagon was therefore moved to the works of Axiom Rail (paragraph 6) for more in-depth testing of the brakes under the supervision of the RAIB. This testing included a repeat of the brake tests carried out at a VIBT and the measurement of the brake forces at two of the wheels. Bench testing of the distributor, brake cylinder, *slack adjuster* and *load weighing valve* was also carried out. The tests were carried out with the brake system responding to both an empty wagon and a loaded wagon condition. A diagram of the brake system as fitted to the wagon is shown in figure 9.



1 The distributor feeds air to the brake cylinder when pressure drops in the brake pipe.

2 The auxiliary reservoir provides the air to feed the brake cylinder.

3 The brake cylinder acts through a mechanical linkage (brake rigging) to apply the brake blocks to the wheels.

4 The slack adjuster automatically adjusts the brake rigging to maintain correct brake block clearances to the wheels.

5 The load weighing valve automatically increases the brake cylinder pressure as the weight of the wagon increases.

Figure 9: Diagram of the wagon's brake system

31 The brake testing found that the distributor, of the Westinghouse P4a type, did not function consistently. Although in several of the tests full brake release was achieved, in one of the tests a residual brake cylinder pressure of 8 lbs/in^2 (0.55 bar) remained when the brakes should have been fully released. The two transducers fitted in place of a brake block pair on one side of a wheel recorded a brake force of 1.8 kN at this pressure. This was approximately 25% of the brake force from a full service brake application when empty, and 7.3% when loaded.

32 The distributor was removed from the wagon and fitted to a test rig. When tested, the distributor mirrored the performance found when the brakes were tested following rerailing at Ashburys (paragraph 29). It was then dismantled in an attempt to discover what within the distributor was causing it to act in an inconsistent manner.

33 The only defect found was that the empty load relay piston changeover valve was found to be sticking in its housing. This resulted in an incorrect response by the brake system as the wagon load increased. The RAIB concluded that this was unrelated to the defect causing dragging brakes.

34 No other component parts of the distributor were found to be defective. It was subsequently overhauled and refitted to the wagon that had derailed. During the dismantling for overhaul, none of the parts were found to have any obvious defects.

35 The distributor had last been overhauled in 2002 and was next due to be overhauled in 2016 in accordance with the normal industry periodicity of every 14 years (this periodicity dates from the 1980s).

36 The other brake components were bench tested and found to perform satisfactorily. They were overhauled and refitted to the wagon.

37 The wagon was then subjected to a further brake test to the GE Capital Rail specification for a VIBT, witnessed by the RAIB. This testing demonstrated consistent satisfactory performance of the brakes.

38 The RAIB concludes that the dragging brakes, which caused the wheels to severely overheat, were probably caused by a defective distributor. The nature of the defect probably caused the distributor to act in an inconsistent way over a period of several weeks/months. The RAIB has not been able to discover why the distributor was defective, but it is possible that a contaminant affected its operation intermittently, and this was disturbed when the distributor was initially dismantled.

39 The RAIB has not been able to entirely discount the possibility that the handbrake (which applies to all wheels) was left partially applied at some time, providing further heat input to the wheels. However, no evidence was found to substantiate this. The 'roll-by' test (described in paragraph 41 below) includes a check that handbrakes have been released.

Train examination

40 All the wheels on the wagon that derailed exhibited similar signs of overheating and those signs (flaking paint and rust – figure 4) had apparently not been observed during train examination[10] and therefore the wagon was not withdrawn from service. Given that the signs of overheating had probably been present for some time prior to the accident (paragraph 21), it is likely that these signs had been overlooked on multiple occasions.

[10] Overheating of the wheels had also not been reported at the last trip inspection on 17 October 2014 (paragraph 9).

41 In accordance with the procedures of DB Schenker Rail, a loaded train from Brigg's Sidings to Ashburys must be examined by a Rolling Stock Technician before departure (paragraph 13). This examination includes a 'roll-by' test in which the loaded train must be observed as it departs to check that all the wheels are rotating, the brakes sound to be clear of the wheels; and the wheels sound normal on the rail head. However, it would be difficult to identify signs of overheating during the roll-by test because much of the wheel is obstructed by bogie, suspension and axlebox components. Trains departing from Ashburys were not required to be examined.

42 DB Schenker Rail's engineering manual covering the examination of freight trains and vehicles lists one of the examination criteria as overheated wheels where there are signs of excessive heat or burnt paint. If such an instance is found, the manual prescribes that the vehicle should be withdrawn from service.

43 The training course for Rolling Stock Technicians includes how to recognise the signs of an overheated wheel, such as burnt paint.

44 Witness evidence was that the wagon was inspected as part of the train's examination by a rolling stock technician prior to departure from Brigg's Sidings. This person had been trained and passed as competent in train examination. However, even though the signs of overheating would likely have been present (flaking paint and rust), and it was daylight when the train departed, no action was taken to take the vehicle out of service suggesting that the signs were either not observed, recognised or acted upon.

45 The RAIB observes that proper examination of the wheels is made difficult by bogie, suspension and axlebox components obstructing the view of each wheel (figure 4). This probably explains why no other railway personnel observed the hot wheels. Also, by the time the examination was carried out, the wheels would have cooled had they been subject to overheating on the inward journey from Ashburys the previous day, so any radiation of heat would not have been felt.

Learning point

46 The RAIB has identified the following Learning point[11]:

- Staff who undertake the examination of freight trains should check for signs of overheated wheels, such as rust and flaking paint, and take appropriate action, such as arranging for a more detailed inspection or withdrawing the vehicle from traffic. It also confirms the need for yard management arrangements to include regular checks on the efficacy of train preparation and inspection procedures.

47 DB Schenker Rail has issued a safety alert notice to its staff reminding them of the need to check for overheated wheels as indicated by signs of excessive heat or burnt paint.

[11] 'Learning points' are intended to disseminate safety learning that is not covered by a recommendation. They are included in a report when the RAIB wishes to reinforce the importance of compliance with existing safety arrangements (where the RAIB has not identified management issues that justify a recommendation) and the consequences of failing to do so. They also record good practice and actions already taken by industry bodies that may have a wider application.

Glossary of terms

Flanging (of brake blocks)	Occurs when the brake blocks are not correctly adjusted to apply wholly on the surface of the wheel tread resulting in a part of each block wearing over the tread corner and creating a flange on the wearing surface of the brake block.
Hot axle box detector	Lineside equipment that will detect an overheated wheelset component (typically a bearing) and raise an alarm to a signal box/signalling control centre. In this event, the signaller will arrange for the train to be stopped so that the affected wagon can be checked and taken out of traffic if necessary.
Interference fit	The locking of two components together by friction. In relation to a wheelset, the hole in each wheel is made slightly smaller than the diameter of the axle so that the surfaces must deform when the wheel is pressed on creating very high forces that lock the components together.
Load weighing valve	Acts to vary the amount of brake cylinder pressure in response to the weight of the load being carried.
Monobloc wheel	A wheel in which the wheel rim is integral with the wheel web as opposed to tyred wheels, where a wheel tyre is a separate part of the wheel and is secured to the web by a retaining ring.
Quenching (of steel)	A process in which heated steel is cooled rapidly to obtain certain material properties and make the steel harder.
Slack adjuster	A mechanical device in the brake rigging, which automatically takes up the slack in the rigging as the brake blocks wear.
Thermal fatigue	Repeated mechanical and thermal loading causing crack initiation and propagation.
TOPS code	TOPS stands for Total Operations Processing System and is a computer system to manage the maintenance and movement of railway locomotives and freight wagons. Each class of locomotive and type of wagon has been allocated a unique TOPS code.
Wear groove	A groove machined around the face of the wheel rim marking the limit beyond which the wheel should not wear or be re-profiled. When reached, it indicates that the wheelset should be withdrawn for scrapping.

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