

# Rail Accident Report



## **Extensive track damage between Ferryside and Llangennech, Carmarthenshire 30 October 2017**

Report 17/2018  
October 2018

This investigation was carried out in accordance with:

- the Railway Safety Directive 2004/49/EC;
- the Railways and Transport Safety Act 2003; and
- the Railways (Accident Investigation and Reporting) Regulations 2005.

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## Preface

The purpose of a Rail Accident Investigation Branch (RAIB) investigation is to improve railway safety by preventing future railway accidents or by mitigating their consequences. It is not the purpose of such an investigation to establish blame or liability. Accordingly, 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 findings are based on its own evaluation of the evidence that was available at the time of the investigation and are intended to explain what happened, and why, in a fair and unbiased manner.

Where the RAIB has described a factor as being linked to cause and the term is unqualified, this means that the RAIB has satisfied itself that the evidence supports both the presence of the factor and its direct relevance to the causation of the accident. However, where the RAIB is less confident about the existence of a factor, or its role in the causation of the accident, the RAIB will qualify its findings by use of the words 'probable' or 'possible', as appropriate. Where there is more than one potential explanation the RAIB may describe one factor as being 'more' or 'less' likely than the other.

In some cases factors are described as 'underlying'. Such factors are also relevant to the causation of the accident but are associated with the underlying management arrangements or organisational issues (such as working culture). Where necessary, the words 'probable' or 'possible' can also be used to qualify 'underlying factor'.

Use of the word 'probable' means that, although it is considered highly likely that the factor applied, some small element of uncertainty remains. Use of the word 'possible' means that, although there is some evidence that supports this factor, there remains a more significant degree of uncertainty.

An 'observation' is a safety issue discovered as part of the investigation that is not considered to be causal or underlying to the event being investigated, but does deserve scrutiny because of a perceived potential for safety learning.

The above terms are intended to assist readers' interpretation of the report, and to provide suitable explanations where uncertainty remains. The report should therefore be interpreted as the view of the RAIB, expressed with the sole purpose of improving railway safety.

The RAIB's investigation (including its scope, methods, conclusions and recommendations) is independent of any inquest or fatal accident inquiry, and all other investigations, including those carried out by the safety authority, police or railway industry.

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## **30 October 2017**

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## Summary

On 30 October 2017, train 6B13, which was carrying oil-based products from Robeston oil terminal, Milford Haven, to Westerleigh oil terminal, Bristol, caused extensive damage to railway infrastructure over approximately 25 miles (40 km). After the train had been stopped, at the entrance to Llangyfelach Tunnel near Swansea, the driver found that there had been a catastrophic failure of the braking system on one of the fully laden wagons.

The investigation found that one of the wheelsets on the damaged wagon had locked up and slid, causing severe wheel flats, before starting to rotate again. Impacts from the wheel flats subsequently damaged the rails as well as equipment mounted on the bogie, some of which partially detached and was dragged under the train, causing damage to track-mounted equipment. The wheelset had locked up and then started rotating again because an object became caught between one of the wheels and the adjacent brake block holder. This was most likely to have been one of the brake blocks, which had fallen off the wagon during the journey of train 6B13, probably due to the omission of key components when the brake blocks were replaced on 27 October.

The RAIB has made one recommendation to Touax Rail and other affected parties regarding a risk assessment of the facilities and processes used for maintaining wagons operating out of Robeston terminal. The RAIB has also identified three learning points about checking the security of brake blocks before permitting a vehicle to re-enter traffic, the application of general signalling regulation 19, and signallers and control staff being aware of the potential consequences of an incident involving a train carrying dangerous goods.

## Introduction

### Key definitions

- 1 Metric units are used in this report, except when it is normal railway practice to give speeds and locations in imperial units. Where appropriate the equivalent metric value is also given.
- 2 The terms 'up' and 'down' refer to the lines heading towards and away from London respectively. Distances on the South Wales Main Line are normally measured from London Paddington station. For ease of reference, distances in this report are quoted from the start of the journey of train 6B13 at Robeston oil terminal, approximately 284.5 miles (457.9 km) from Paddington. The distance travelled was recorded by the on train data recorder (OTDR) fitted to the train's locomotive, and has been calibrated using known points along the train's route.
- 3 The report contains abbreviations which are explained at appendix A. Sources of evidence used in the investigation are listed at appendix B.

### Acknowledgement

- 4 The RAIB would like to thank Davis Wagon Services Ltd for its assistance with technical aspects of the investigation.

## The accident

### Summary of the accident

- 5 On 30 October 2017, train 6B13 was carrying oil-based products from Robeston oil terminal, Milford Haven, east to Westerleigh oil terminal, Bristol (figure 1). At 06:47 hrs, the signaller at Kidwelly signal box telephoned the signaller at the adjacent signal box to the west, Ferryside, to advise him that a track circuit<sup>1</sup> between Ferryside and Kidwelly was still showing 'occupied' following the passage of the train, and that the following train should be cautioned and used to examine the line.

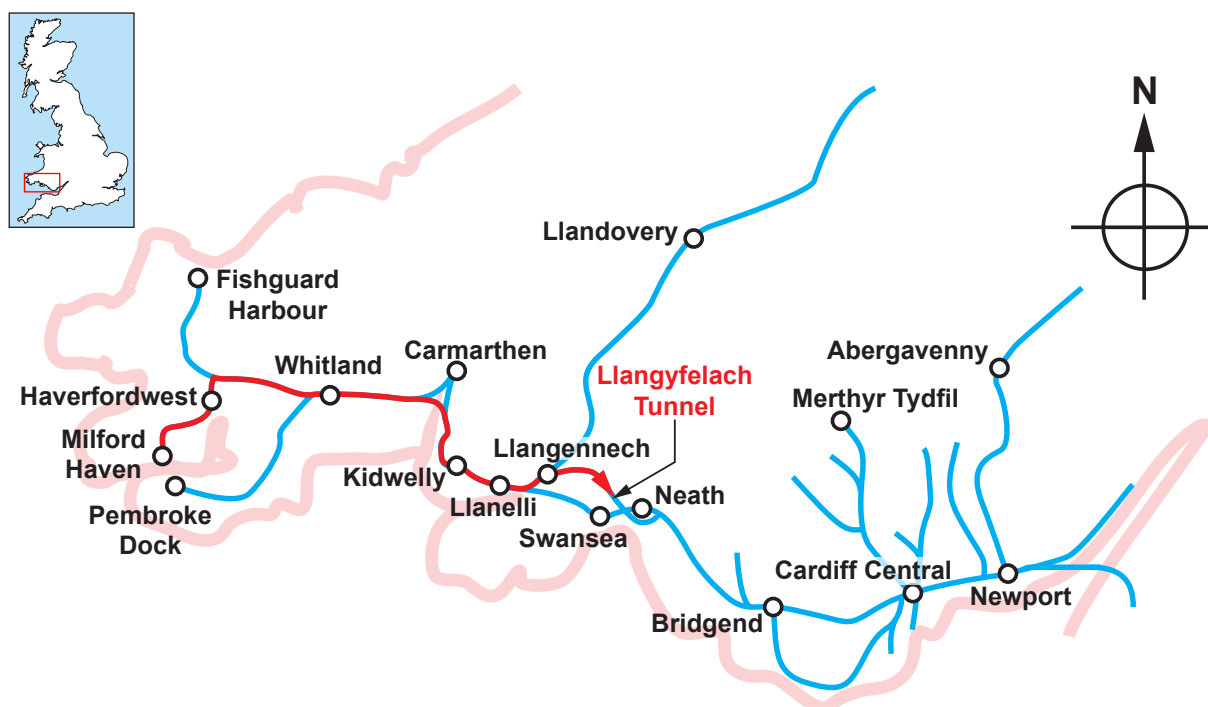


Figure 1: Overview of the route of train 6B13 from Robeston to Llangyfelach Tunnel

- 6 Train 6B13 was eventually stopped at the entrance to Llangyfelach Tunnel, 70.5 miles (113.5 km) from Robeston, at 08:14 hrs (figure 2). Following the passage of the train, Network Rail found extensive damage to its infrastructure, starting at 44.9 miles (72.2 km); this included nine broken rails, as well as damage to eight level crossing installations and five TPWS loops<sup>2</sup> (paragraphs 48 and 49). Examination of the train revealed that one of the wagons had suffered a catastrophic failure of its braking system, and had developed severe wheel flats. The train did not derail and there were no injuries.
- 7 The South Wales Main Line remained closed while repairs were carried out until 01:40 hrs on 1 November 2017, and the Swansea District Line until 06:00 hrs on the same day.

<sup>1</sup> A means of detecting the absence of a train that relies on an electrical current flowing along the rails. A broken rail may interrupt this current and incorrectly indicate the presence of a train.

<sup>2</sup> An electronic transmitter forming part of the train protection and warning system (TPWS) and providing a signal to a receiver mounted on the underside of a train. TPWS loops are normally installed in pairs, consisting of an 'arming loop' and a 'trigger loop', and are located in the four foot (ie between the rails).

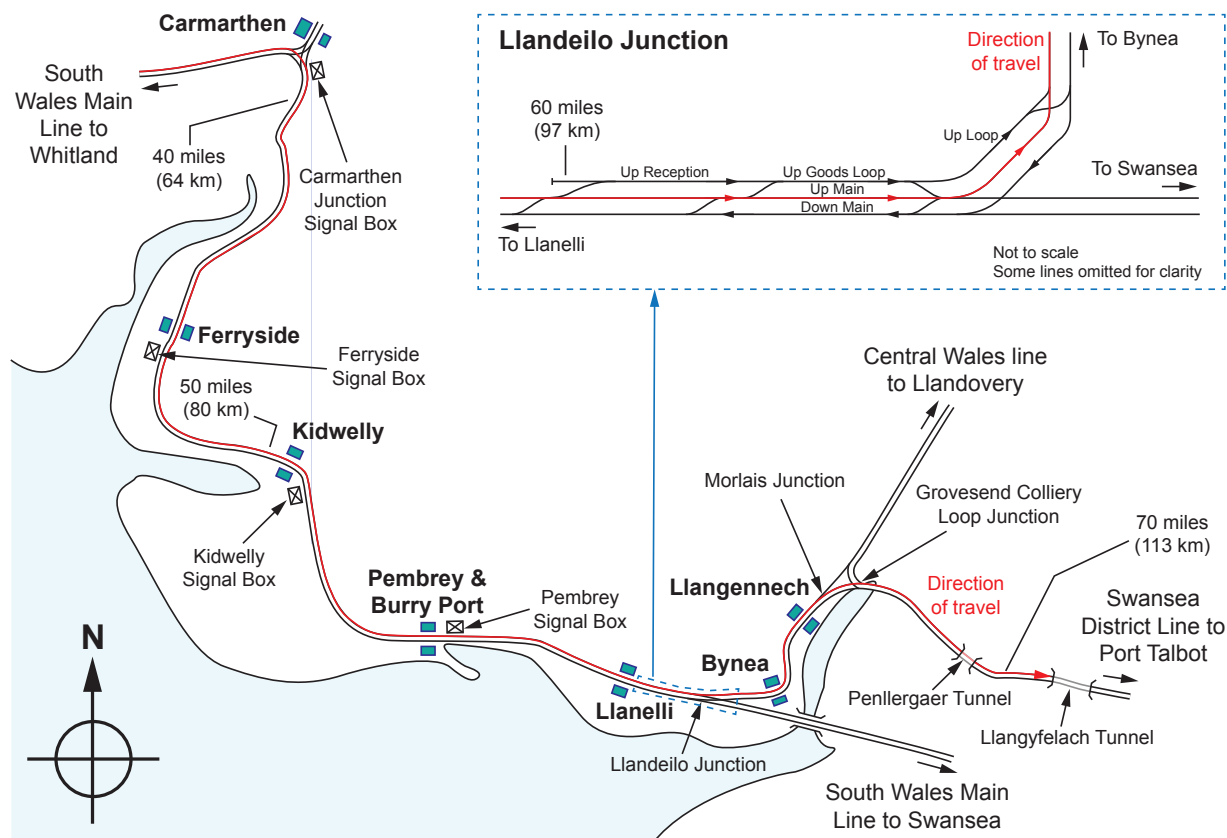


Figure 2: Detail of the route of train 6B13, showing mileages from Robeston

## Context

### Location

- 8 After starting its journey at Robeston, train 6B13 travelled to Haverfordwest, before continuing eastwards along the South Wales Main Line via Whitland and Carmarthen Junction, as far as Llandeilo Junction (figure 2). It was then routed along the Swansea District Line, turning east at Morlais Junction towards Neath and Port Talbot, before stopping at the entrance to Llangyfelach Tunnel.
- 9 No infrastructure damage was reported west of Carmarthen.

### Organisations involved

- 10 Network Rail is the owner of the railway infrastructure between Robeston oil terminal and Llangyfelach Tunnel. It employs the signalling and control staff who managed the emerging situation.
- 11 DB Cargo was the operator of the train (on behalf of Puma Energy) and employs its driver. It also contracted with an agency for the provision of ground staff who carried out the train preparation at Robeston.
- 12 Puma Energy operates Robeston oil terminal and loaded the wagons forming the train.



- 13 Touax Rail is the owner of wagon GERS89009. It is also the entity in charge of maintenance (ECM)<sup>3</sup> and carries out functions I, II and III of the system of maintenance for the wagon, explained at appendix C.
- 14 DB Cargo Maintenance (formerly Axiom Rail Maintenance) carries out the day to day maintenance of wagon GERS89009 (function IV of the system of maintenance, appendix C). It employs the wagon maintenance staff based at Robeston.
- 15 Axiom Rail Components, formerly Powell Duffryn Rail, designed and manufactured the TF25 bogies fitted to wagon GERS89009. At the time of the accident, Axiom Rail Components was part of DB Cargo; it has since become part of Wabtec Faiveley.
- 16 Wabtec Faiveley designed and manufactured the BFCB braking system that was installed on the bogies of wagon GERS89009.
- 17 All of the organisations involved freely co-operated with the investigation.

#### Train involved

- 18 Train 6B13 was the 05:00 hrs train from Robeston oil terminal to Westerleigh oil terminal, operated by DB Cargo; it consisted of a class 60 locomotive, no. 60001, and 29 bogie tank wagons with a combined weight of 3,005 tonnes. All of the wagons were of type TEA, except one which was of type TIA. Wagon nos. 1 to 15, numbered from the front of the train, were carrying diesel fuel, nos. 16 to 22 were carrying kerosene and 23 to 29 were carrying petrol.
- 19 Only one of the vehicles in the train was involved in the accident; this was the first wagon behind the locomotive, numbered GERS89009 (figure 3). This was a wagon of type TEA, loaded with 90,889 litres of diesel (gross weight 101.2 tonnes).
- 20 The maintenance records for wagon GERS89009 indicate that a seven-yearly 'general repair' overhaul had been completed on 16 September 2016. Since then, it had received a planned preventative maintenance (PPM) examination<sup>4</sup> on 1 April 2017 and a yearly vehicle inspection and brake test (VIBT) examination on 4 August 2017.

#### Rail equipment involved

- 21 The route is signalled using track circuit block principles for the first 14.3 miles (23.0 km) from Robeston, and then by absolute block to the start of the Port Talbot signalling area, approximately 57.6 miles (95.4 km) from Robeston (1.8 miles (2.8 km) east of Pembrey signal box, figure 2)), where it becomes track circuit block.

<sup>3</sup> The role of the ECM is defined in regulation 18A of 'The Railways and Other Guided Transport Systems (Safety) Regulations 2006' (ROGS), as amended by 'The Railways and Other Guided Transport System (Safety) (Amendment) Regulations 2011' and 'The Railways and Other Guided Transport Systems (Miscellaneous Amendments) Regulations 2013'. This requires that no person may place in service or use a vehicle on the mainline railway unless that vehicle has an entity in charge of maintenance (ECM) assigned to it, and that entity in charge of maintenance is registered as such in the National Vehicle Register.

<sup>4</sup> PPM exams are normally carried out twice in between the annual VIBT exams, at four monthly intervals. According to this schedule, the PPM exam in April 2017 was 2½ months late, although this had no relevance to the accident on 30 October 2017.



Figure 3: Wagon GERS89009 at Margam after the accident (courtesy DB Cargo)

- 22 The track on the route is made up of continuous welded rail laid on concrete sleepers. The rail is predominantly to specification BS113A (56.4 kg/m), dating from the 1960s and 70s, with some sections of rail to BS110A (54.4 kg/m) and 109 lb/yd (54.1 kg/m), dating from the 1950s and 60s.

### Staff involved

- 23 The Axiom Rail Maintenance fitter had approximately 5 years' experience, all of it spent working at Robeston, and was certificated as competent to carry out wagon maintenance tasks in accordance with DB Cargo's competence management system.
- 24 The Axiom Rail Maintenance supervisor had approximately 35 years' experience, of which 15 had been at Robeston, and was certificated as competent to carry out wagon maintenance tasks in accordance with DB Cargo's competence management system.
- 25 The member of ground staff at Robeston was employed through an agency, Trackline Training, on behalf of DB Cargo. He was certificated as competent by Trackline Training, in accordance with the City & Guilds level 2 NVQ (National Vocational Qualification) in Rail Transport Operations (Shunting).
- 26 The signallers at Kidwelly, Pembrey and Port Talbot panel signal boxes are all employed and certificated as competent by Network Rail in accordance with its competence management system.

### External circumstances

- 27 The RAIB has reviewed records from weather stations at Haverfordwest, Whitland, Kidwelly and Llanelli. The temperature during the journey of train 6B13 between Haverfordwest and Llanelli was 3 - 5°C and it was mostly dry (light rain was recorded 30 mins before 6B13 passed Whitland; no rain was recorded at either Kidwelly or Llanelli).
- 28 The external circumstances did not affect the accident.

## The sequence of events

### Events preceding the accident

- 29 On Wednesday 25 October 2017, the maintenance supervisor at Robeston emailed Touax Rail, requesting authorisation to replace the brake blocks on wagon GERS89009, as they were worn. This is a routine operation that is carried out every few months, when required (ie independently from PPM and VIBT examinations (paragraph 20)), either because the brake blocks are cracked or because they are worn. Records show that they had previously been replaced on the wagon due to wear on 24 July 2017. Touax Rail approved this request by return email on 26 October.
- 30 Axiom Rail Maintenance records indicate that the brake blocks were changed on wagon GERS89009 by the fitter at Robeston on Friday 27 October. The supervisor completed a weekly 'trip' examination of the wagon on the same day; Touax Rail's specification for this check of a wagon's running gear includes checking brake blocks for security, alignment, cracking and wear.
- 31 On Sunday 29 October, the loaded wagons that were to form train 6B13 were prepared for departure by a member of ground staff based at Robeston.
- 32 The train departed from Robeston oil terminal at 03:36 hrs on Monday 30 October; the member of ground staff reported that he conducted his departure check (roll-by examination) of the train using the headlights of his van, which was parked at the terminal gate, and noted nothing amiss. As the train had left ahead of its scheduled departure time (05:00 hrs), it paused at Haverfordwest from 04:06 hrs to 05:32 hrs.

### Events during the accident

- 33 At 06:32 hrs, the train passed through a 20 mph (32 km/h) permanent speed restriction, starting 40.5 miles (65.2 km) from Robeston, shortly after passing Carmarthen Junction. After the accident track maintenance staff found the first signs of damage on the rail head at 41.6 miles (67.0 km) (figure 4). This damage continued along the route of the train and was consistent with impacts from the wheel flats that were subsequently discovered on the wheels of wagon GERS89009.
- 34 The first broken rail occurred at 44.9 miles (72.2 km), adjacent to a welded rail joint (figure 5). There are no track circuits at this location, so the fault was not apparent to the signaller. Train 6B13 passed this location at 06:40 hrs.
- 35 At 06:47 hrs, the train passed Kidwelly signal box, 50.3 miles (81.0 km) from Robeston. The signaller noticed that the indicator for a track circuit on the approach to the signal box was continuing to show 'occupied' after he had seen the complete train go past (meaning the section of track was no longer occupied); broken welds were subsequently discovered at 49.2 and 49.9 miles (79.1 and 80.2 km) from Robeston. At 06:48 hrs, the signaller at Kidwelly telephoned the signaller at the previous signal box, Ferryside, to advise him that the next train in the up direction would need to examine the line; this is a requirement of Module TS1 of the railway Rule Book. At 06:50 hrs, the signaller at Kidwelly reported the failure of the track circuit to Network Rail's Wales Route control office.





Figure 4: Rail head damage (six foot rail) 43.2 miles (69.5 km) from Robeston, still visible in April 2018



Figure 5: Broken weld 44.9 miles (72.2 km) from Robeston (courtesy Network Rail)

- 36 The signaller at Kidwelly then observed that the automatic half barrier (AHB) level crossing at Penybedd (between Kidwelly and Pembrey) had failed to reset behind train 6B13, which had cleared the crossing at 06:50 hrs. Broken rail welds were later found at 51.9 and 52.4 miles (83.6 and 84.3 km). Track circuits at these locations form part of the controls for the level crossing and are not individually indicated in Kidwelly signal box. At 06:53 hrs the signaller telephoned the signaller at Pembrey to advise him that the next up train would be delayed as it would be examining the line. During this call, at 06:54 hrs, the Kidwelly signaller received a failure alarm for Penybedd AHB level crossing.

- 37 While the same telephone call was taking place, a broken rail occurred at 55.9 miles (89.9 km), just after train 6B13 had passed Pembrey signal box. This left another track circuit showing 'occupied' behind the train, and became apparent to the signaller at Pembrey at 06:54 hrs, after the train had passed into the area controlled by the Port Talbot panel signal box.
- 38 At 06:57 hrs a track circuit indication on panel C at Port Talbot showed 'occupied' after the passage of the train. This was caused by a broken welded rail joint at 58.9 miles (94.7 km) from Robeston.
- 39 Based on the report from the signaller at Kidwelly (paragraph 35), the train running controller<sup>5</sup> from the Wales Route control office telephoned the signaller at Port Talbot (panel C) at 07:01 hrs to advise him that train 6B13 was causing track circuit failures and would need to be stopped for examination (this telephone call is discussed further at paragraph 98). The signaller told the train running controller that the train had also left a track circuit in his area showing 'occupied' behind it. They agreed that the best place to stop the train would be on the Up Flying Loop Line at Briton Ferry, near Neath (approximately 78 miles (125 km) from Robeston).
- 40 Once he had finished speaking to the train running controller, the signaller at Port Talbot (panel C) telephoned the incident support controller<sup>6</sup> at the Wales Route control office at 07:02 hrs to report the failure of the track circuit on his panel. At about the same time, the signaller at Pembrey telephoned the incident controller<sup>7</sup> at the Wales Route control office to report the track circuit failure in his area.
- 41 The Pembrey signaller telephoned the signaller at Port Talbot (panel C) at 07:06 hrs to advise him that there might be a problem with 6B13, as it had caused failures at Kidwelly and Pembrey. By this time the train had left the area controlled by Port Talbot (panel C). The Pembrey signaller went on to say that the train had been noisy and that he had heard a 'clunk' as it went past, although he also observed that the oil trains are often noisy.
- 42 At 07:02 hrs, train 6B13 passed Techan Fach UWC (user worked level crossing), 61.7 miles (99.2 km) from Robeston, which was later found to have been damaged. This was the first damage that was found to equipment in the four foot except for some scuffing of the anti-trespass guards at Penybedd level crossing, 9 miles (14 km) earlier (refer to paragraph 48). At 07:08 hrs, the train passed Morlais Junction on the Swansea District Line, at 64.6 miles (103.9 km), and started the climb towards Llangyfelach Tunnel (figure 6).

<sup>5</sup> *Train Running Controllers* are required to manage train services and ensure that trains run as close to scheduled time as possible, without compromising safety and according to the agreed train plan. In the event of an incident they are responsible for liaising and negotiating with train operating companies to regulate services, whilst trying to keep delays to a minimum, as well as communicating with other Network Rail staff to ensure the service recovers as quickly as possible.

<sup>6</sup> *Incident Support Controllers* are required to support the monitoring of train services and ensure that trains run as close to scheduled time as possible, without compromising safety. In the event of an incident they support the management responsible for liaising and negotiating with train operating companies to regulate services, whilst trying to keep delays to a minimum, as well as communicating with other Network Rail staff to ensure the service recovers as quickly as possible. They are responsible for co-ordinating the process relating to infrastructure faults.

<sup>7</sup> *Incident Controllers* are required to manage operational incidents and ensure that these are managed in a safe, effective and timely manner. In the event of an incident they are responsible for leading Network Rail and external affected parties so that the network operation is re-established successfully and the impact on train passengers and freight operations is minimised.



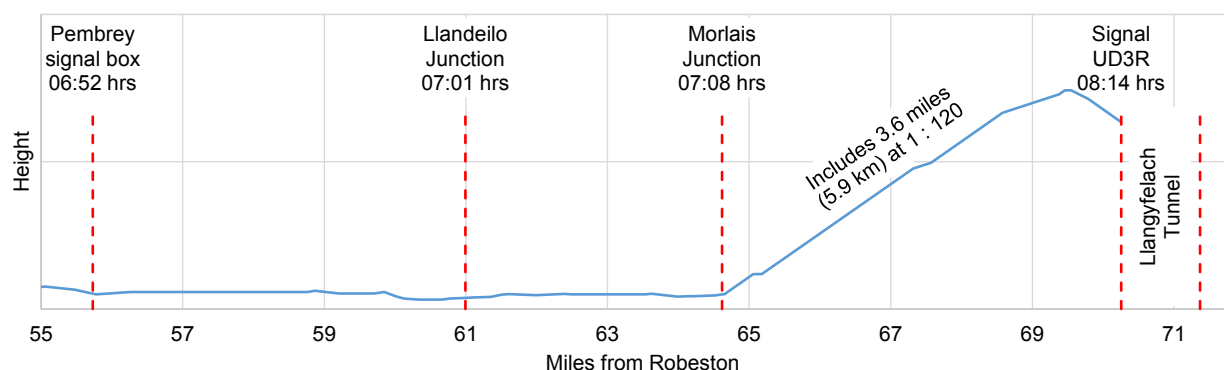


Figure 6: Gradient profile between Pembrey and Llangyfelach Tunnel

- 43 The adjacent signaller at Port Talbot, working on panel B (covering the area to the east of panel C), radioed the driver of train 6B13 at 07:36 hrs to advise him that he would need to stop and examine the train due to the track circuit failures that were occurring behind the train; at the time the train was 68.4 miles (110.1 km) from Robeston. The driver reported that he was then travelling at about 0.25 mph (0.4 km/h). The train's timetabled speed is 17.5 mph (28.2 km/h) over this section of the route, but witness evidence indicates that, particularly at this time of year, it was common for this train to experience the effects of low adhesion on the gradient east of Morlais Junction; the average speed of the train over this section of its journey was 5.4 mph (8.8 km/h) and the OTDR recorded extensive wheelslip. A wheelburn<sup>8</sup> was later found at 67.2 miles (108.1 km) (figure 7). The signaller and driver agreed that the best place for the train to stop would be at signal PT395 (71.6 miles (115.2 km)), once it had finished the ascent.
- 44 At 08:14 hrs, the driver radioed the signaller to say that he had been able to stop the train earlier than agreed. This was at signal UD3R, 70.5 miles (113.5 km) from Robeston, after finishing the ascent and before entering Llangyfelach Tunnel. The signaller then blocked the Down District Line and gave the driver permission to examine the train.



Figure 7: Damage to the rail head 67.2 miles (108.1 km) from Robeston (courtesy Network Rail)

<sup>8</sup> Damage to the rail head caused by rotation of a powered wheel that has lost adhesion.



### Events following the accident

- 45 The driver of the train contacted the signaller at 08:21 hrs to advise him that the brake frame (actually the master brake beam, see paragraph 52) under the leading wagon had collapsed and was dragging under the train (figure 8).

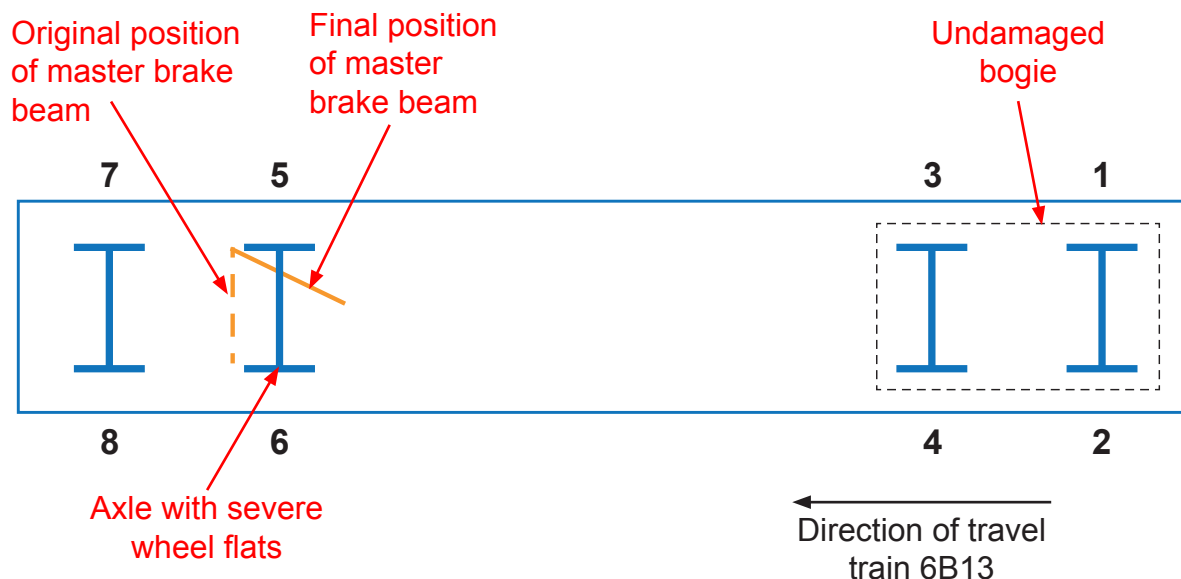


Figure 8: Schematic of wagon GERS89009 showing wheel numbering in black, and the final position of the master brake beam

- 46 DB Cargo's re-railing team arrived at 18:15 hrs and had fitted wheelskates<sup>9</sup> to wagon GERS89009 by 00:28 hrs on 31 October. The train was then moved to Margam yard, approximately 85 miles (136 km) from Robeston, between 00:52 and 04:00 hrs.
- 47 When it inspected the track following the accident, Network Rail found the broken rails listed at table 1<sup>10</sup>. The RAIB considers that the pre-existing defects noted are generally minor and that those at joints are typical of joints made using thermite welding. They may however explain why the rails broke at these locations when subjected to heavy impact loading from the wheel flats on wagon GERS89009.

<sup>9</sup> Devices that allow damaged wheels to be lifted clear of the rails, allowing a vehicle to be moved at reduced speed.

<sup>10</sup> There was also a horizontal defect in the web of a rail approximately 120 metres from the second entry in the table. This was not a rail break and there is no evidence that it was linked to the passage of train 6B13.

Distance from Robeston		Rail <sup>11</sup> position	At welded joint?	Rail type	Pre-existing rail defects
miles	km				
44.9	72.2	Six foot	Yes	BS110A	Single point minor porosity in the web
49.2	79.1	Cess	Yes	109lb	Cold spot in the foot
49.9	80.2	Cess	Yes	BS113A	Porosity in the foot
51.9	83.6	Six foot	Yes	BS113A	Single porosity in the head
52.4	84.3	Cess	Yes	BS113A	Porosity in the lower fillet and in the foot
53.3	85.7	Six foot	Yes	109lb	Slight porosity in the upper fillet
55.9	89.9	Cess	No	BS113A	No defects
58.9	94.7	Cess	Yes	BS113A	Some porosity in the web
63.8	102.8	Cess	No	BS113A	Split in the foot of the rail

Table 1: Broken rails identified by Network Rail after the passage of train 6B13

- 48 In addition to the broken rails, Network Rail also found damage to equipment mounted in the four foot, listed at table 2. All of this, except the damage to Penybedd AHB, had occurred within the 7.7 miles (12.4 km) east of Llandeilo Junction.

Distance from Robeston		Equipment damaged
miles	km	
52.8	84.9	Penybedd automatic half barrier crossing (anti-trespass guards)
61.7	99.2	Techan Fach UWC (crossing surface)
62.4	100.4	Ffos Fach Isaf UWC (crossing surface)
63.0	101.4	Pencoed Uchaf UWC (crossing surface)
63.6	102.4	Morlais Tinplate Works footpath crossing (crossing surface)
63.9	102.9	Llangennech station UWC (anti-trespass guards)
64.2	103.3	TPWS overspeed loop, signal PT381
64.3	103.6	TPWS train stop loop, signal PT381
65.0	104.5	TPWS overspeed loops (two), signal PT383
65.1	104.7	TPWS train stop loop, signal PT383
67.9	109.3	Glanlliw UWC (crossing surface)
69.3	111.6	Sir John Llewellyn 2 footpath crossing (panel carried along track)

Table 2: Damage to equipment in the four foot identified by Network Rail after the passage of train 6B13

- 49 Once infrastructure repairs had been completed, the South Wales Main Line reopened at 01:40 hrs on 1 November; this was followed by the Swansea District Line at 06:00 hrs.

<sup>11</sup> The six foot rail is the right-hand rail in the direction of travel, and the cess rail the left-hand.

## Key facts and analysis

### Background information

#### Bogie history

50 Wagon GERS89009 was fitted with TF25 bogies when it was built, in 2001. This type of bogie was developed by Powell Duffryn Rail, later known as Axiom Rail Components (now part of Wabtec Faiveley); production versions of the bogie have been in use since 2001. The TF25 bogie was later rebranded as LN25 and there have been a number of developments of the design. As at March 2018, 5,900 TF25/LN25 bogies were in use, exclusively in Britain, and a further 250 were being manufactured.

#### Faiveley BFCB Braking System

51 The brake actuating system fitted to wagon GERS89009 is known as BFCB and was developed by Faiveley Transport in Sweden (now Wabtec Faiveley). It has been in use since 2001 and nearly 11,000 examples have been sold internationally. 4,000 of these have been installed on TF25/LN25 bogies and a further 1,400 of a very similar design were fitted to ABC-NACO's Axle Motion III bogies.

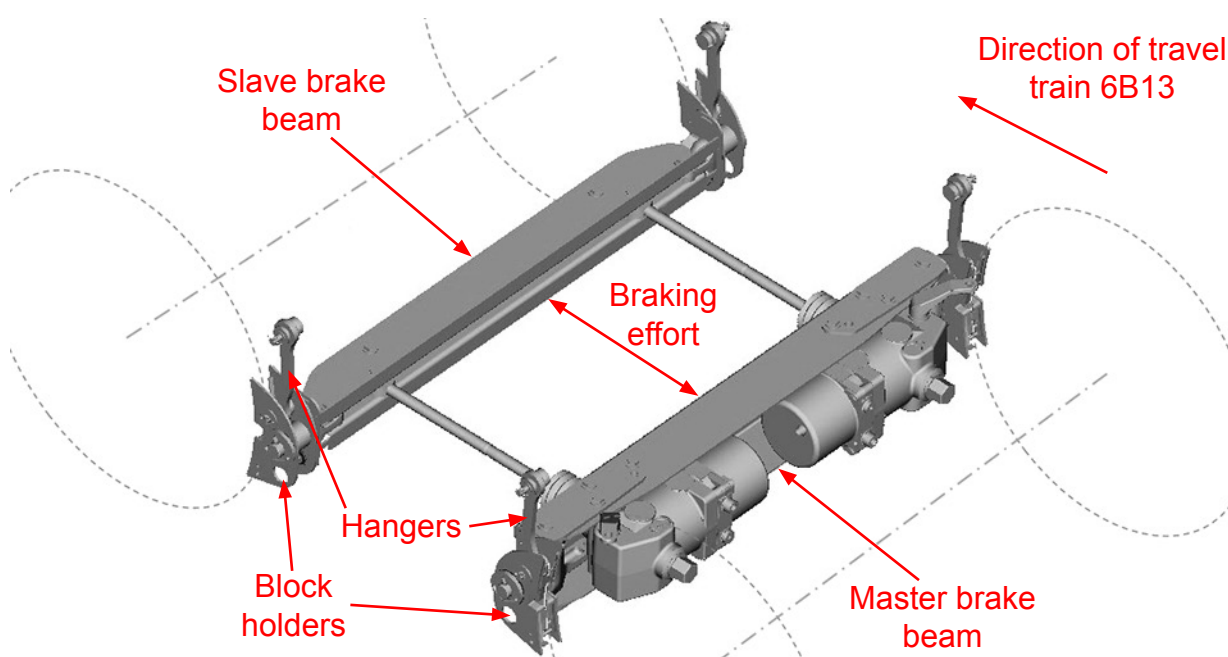


Figure 9: BFCB braking system for one bogie; brake blocks not shown (courtesy Wabtec Faiveley)

52 As fitted to each bogie of wagon GERS89009, the BFCB system consists of two transverse beams fitted between the axles (figure 9). The ends of each beam are attached to brake block holders, suspended from brackets on the bogie by hangers. The inner 'master' beam (ie nearest the centre of the wagon) carries a pair of actuators that operate by extending longitudinal spindles, which pass through the bogie frame. The spindles push the beams apart, pressing the brake blocks against the wheels with equal force (figure 10). The system is self-adjusting, automatically taking up excessive slack (for example caused by brake block wear) by means of a ratchet mechanism that operates when the brakes are applied and released.

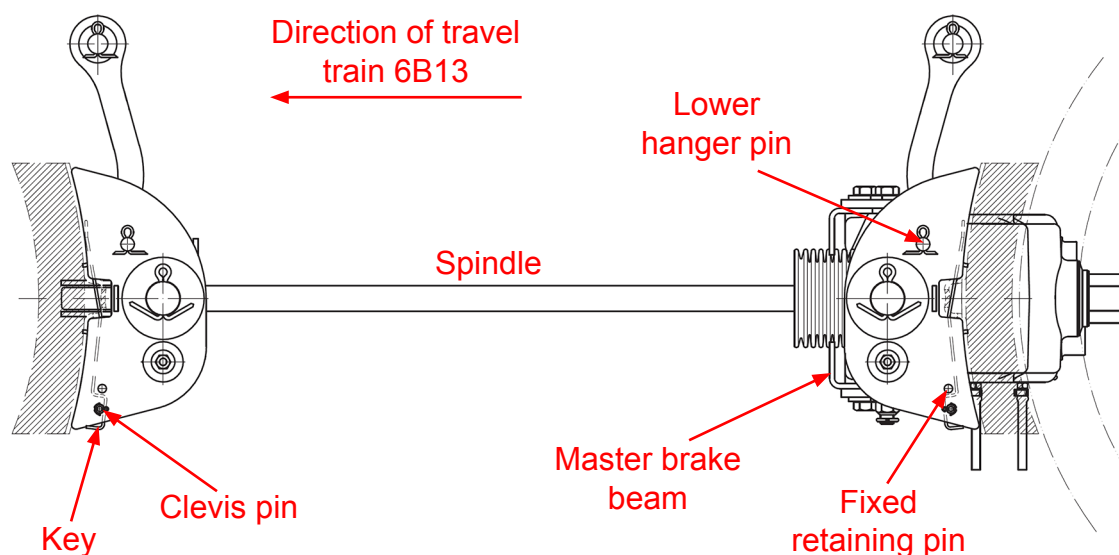


Figure 10: Side view of BFCB block holders (courtesy Wabtec Faiveley)

- 53 The bogie involved was also equipped with a handbrake mechanism (used to hold a wagon stationary) that applies the braking force via a mechanical linkage connected to the spindles, so that the force is shared equally between the wheelsets<sup>12</sup> (figure 11).

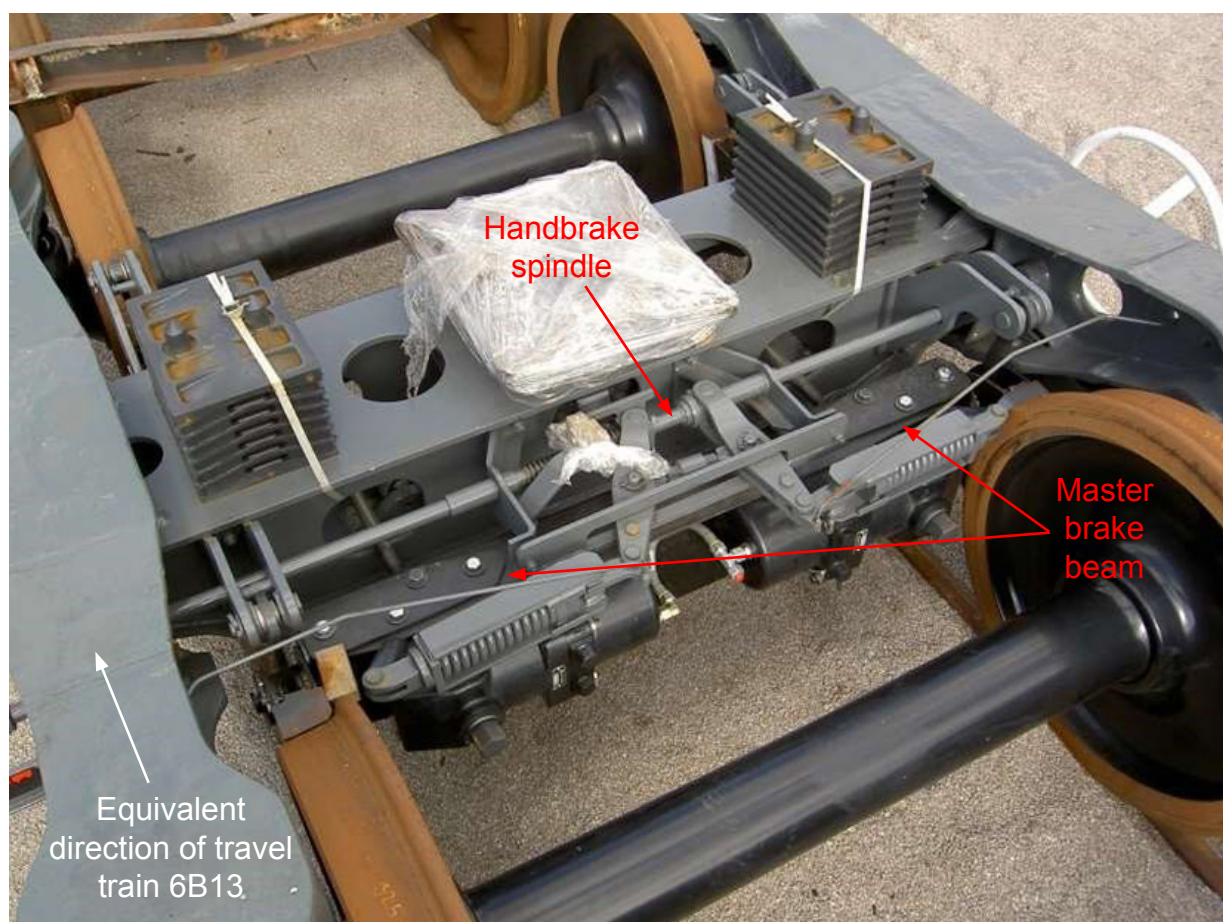


Figure 11: BFCB braking system mounted on TF25 handbrake bogie (courtesy DB Cargo)

<sup>12</sup> A wheelset consists of an axle and a pair of wheels.



- 54 The brake blocks are attached to the block holders by keys that slot into lugs on the back of the blocks (figure 12).

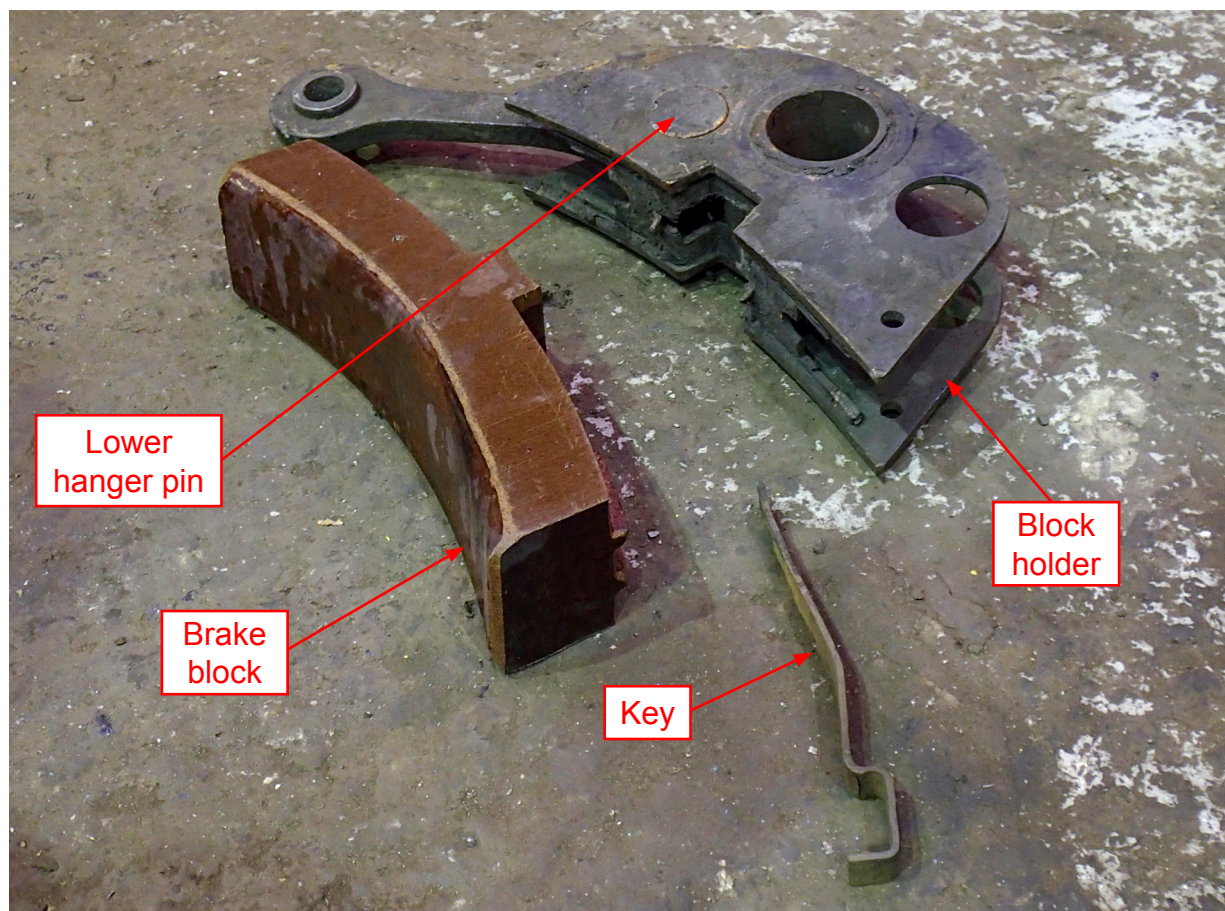


Figure 12: Block holder, key and brake block

- 55 On the 'G1' version of the BFCB system, as fitted to wagon GERS89009, the keys are inserted from underneath the block holder. They are held in place against fixed retaining pins by removable clevis pins of 10 mm diameter; in turn, these are secured with split pins of 3.2 mm diameter (figure 13). On some later variants the clevis pins are replaced with 10 mm diameter split pins, and on some others the keys are inserted from above.

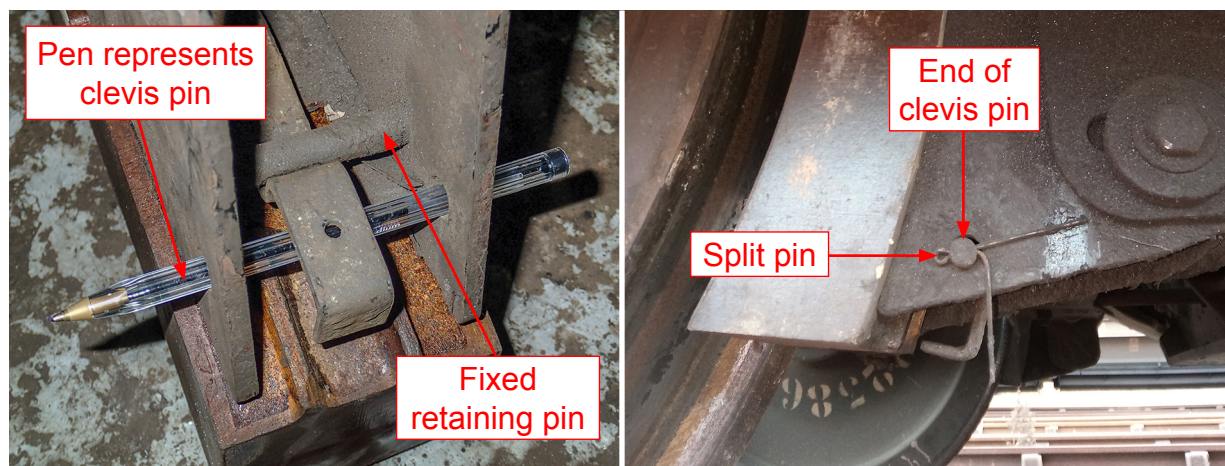


Figure 13: Arrangement of brake block, block holder, key and clevis pin; the right-hand image shows wheel position 1 on the trailing bogie of wagon GERS89009 after the accident (courtesy DB Cargo)



- 56 The fixed retaining pins are fitted through holes in the inner and outer plates of the block holders, and are welded to the faces of the plates (figure 14).

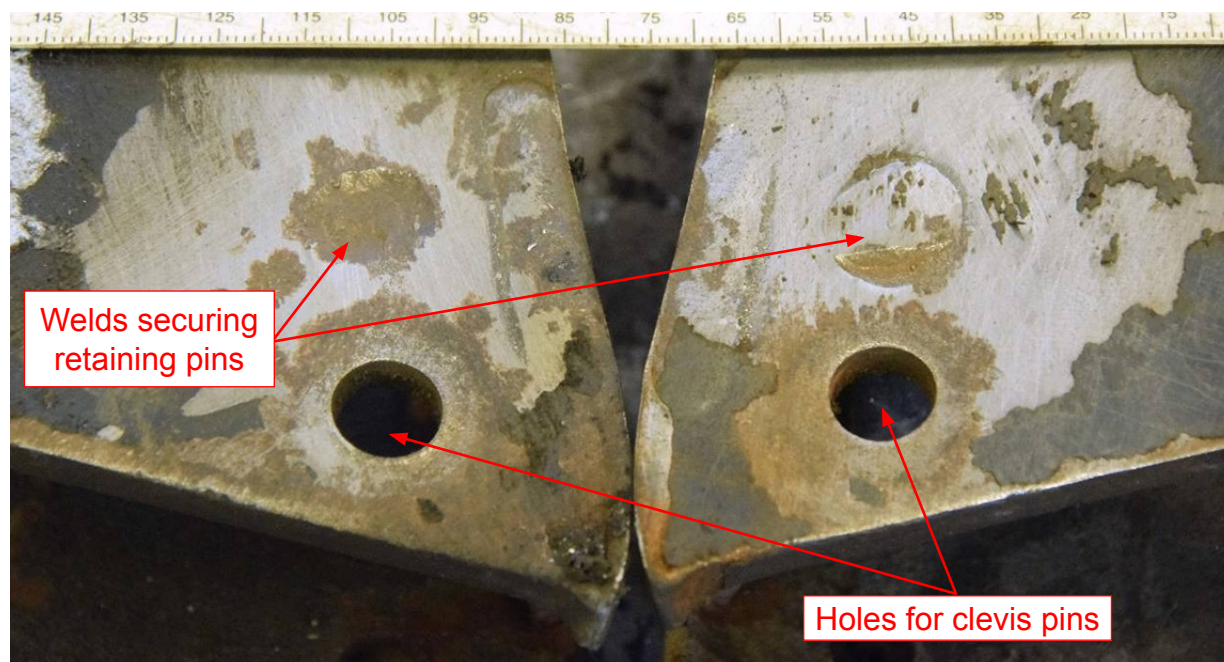


Figure 14: Outer faces of block holders from wheel positions 7 and 8, partially cleaned (courtesy Serco Rail Technical Services)

### Analysis of bogie damage

- 57 The damage to the braking system on the leading bogie, no. 2741, of wagon GERS89009 is summarised at appendix D.
- 58 Damage to the wheels at positions 5 and 6 (paragraph D5, appendix D) indicates that the second wheelset of the bogie had locked up and slid for 5 to 10 miles (8 to 16 km) before starting to rotate again shortly after the train had passed Carmarthen Junction, indicated by the start of rail damage (paragraph 33). There was no evidence that the leading wheelset had locked up during the journey (refer to paragraph 89). After the second wheelset started rotating, eight of the nine broken rails occurred while the train was travelling at speeds of between 44 and 53 mph (71 to 85 km/h); the final rail break occurred when it had slowed to 32 mph (52 km/h). Impact loading on rails due to wheel flats increases with vehicle speed.
- 59 The design of the BFCB system is such that the brake force is equally distributed between the master and slave brake beams (paragraph 52). Consequently a brake application that resulted in one wheelset locking up would normally cause both wheelsets on a bogie to do so. The forces that caused the second wheelset to lock up were therefore probably transmitted to one or both wheels of the wheelset independently from any force applied through the braking system.
- 60 A summary of the journey of train 6B13 is shown at table 3, using calibrated data from the OTDR. This shows that only light brake applications were made during the journey, with the exception of the period during which the train was stationary at Haverfordwest, when the brakes were fully applied after the train had stopped.



Time (hrs)	Speed (mph)	Speed (km/h)	Distance (miles)	Distance (km)	Comment <sup>13</sup>	Brake effort (% maximum)
03:36	0	0	0.0	0.0	6B13 departs Robeston	
03:43	19	30	0.8	1.3	<i>Brakes applied (21 secs)</i>	24%
03:45	11	18	1.4	2.2	6B13 passes Herbrandston Jn	
03:56	45	73	4.9	7.9	<i>Brakes applied (4 mins 34 secs)</i>	42%
04:06	1	1	8.6	13.9	<i>Brakes applied (84 mins 49 secs)</i>	100% <sup>14</sup>
05:31	1	2	8.6	13.9	6B13 departs Haverfordwest	
05:49	12	19	13.5	21.7	6B13 passes Clarbeston Road Jn	
06:04	54	86	22.4	36.0	<i>Brakes applied (32 secs)</i>	20%
06:05	48	76	23.6	37.9	<i>Brakes applied (38 secs)</i>	33%
06:09	42	68	25.8	41.5	6B13 passes Whitland signal box	
06:26	38	61	38.1	61.3	<i>Brakes applied (1 min 41 secs)</i>	38%
06:28	22	36	39.2	63.2	6B13 passes Carmarthen Bridge Jn	
06:35	23	36	41.6	67.0	<b>Start of rail head bruising</b>	
06:38	40	65	43.6	70.2	<b>Brake block fragment found</b>	
06:40	44	70	44.9	72.2	<b>First broken rail</b>	
06:41	46	75	46.1	74.1	6B13 passes Ferryside signal box	
06:46	52	83	50.3	81.0	6B13 passes Kidwelly signal box	
06:52	50	81	55.8	89.7	6B13 passes Pembrey signal box	
06:57	44	71	59.5	95.7	<i>Brakes applied (28 secs)</i>	6%
06:59	23	36	60.5	97.3	<i>Brakes applied (19 secs)</i>	16%
07:01	20	32	61.0	98.2	6B13 passes Llandeilo Jn	
07:02	20	33	61.7	99.2	<b>Start of damage in four foot</b>	
07:08	36	58	64.6	103.9	6B13 passes Morlais Jn	
08:11	11	17	70.0	112.7	<i>Brakes applied (1 min 16 secs)</i>	22%
08:13	8	12	70.4	113.2	<i>Brakes applied (1 min 2 secs)</i>	31%
08:14	0	0	70.5	113.5	6B13 stops	

Table 3: Summary of journey of train 6B13, showing brake applications

- 61 The lower hanger pin at wheel position 6 had sheared (paragraph D10, appendix D), allowing the end of the master brake beam to break free. The associated block holder was pulled apart and the head of the hanger pin, together with part of the brake block holder, has not been found.
- 62 The brake spindles had snapped (paragraph D12, appendix D), and the brake beam had fallen into the four foot where it was dragged along under the wagon (paragraph D3, appendix D), damaging infrastructure equipment (paragraph 48).
- 63 When the wagon was later examined at Margam, all of the brake blocks were missing from both brake beams of the leading bogie, together with their keys and clevis pins (paragraph 55). This was the first journey that wagon GERS89009 had made after the work to replace the brake blocks on 27 October. The RAIB has concluded that the brake blocks fell off the bogie during the journey.

<sup>13</sup> The comment 'brakes applied' refers to the start of the brake application; the time quoted refers to the subsequent duration.

<sup>14</sup> Maximum 6% while the train was moving.

- 64 The following alternative scenarios were considered, but evidence indicates that they almost certainly did not occur:
- a. That all four brake blocks were missing from the leading bogie of the wagon when train 6B13 left Robeston. It is unlikely that four missing brake blocks would have been unnoticed during the trip inspection on 27 October and train preparation on 29 October, which were carried out by different individuals (paragraphs 30 and 31). If the brake blocks had not been replaced when the old ones were removed, the subsequent brake applications would have taken up the slack in the system (paragraph 52) and there would have been evidence of wear on the faces of the block holders (rather than just the corners). The absence of brake blocks would also not explain how the second wheelset locked up and subsequently started to rotate.
  - b. That the brake blocks on the slave beam were removed during the recovery operation (paragraph 46) (and those on the master brake beam had been torn off while it was being dragged under the train). DB Cargo has advised that the re-railing team did not remove any brake blocks from the leading wheelset; there was also no reason for them to have done so as they did not fit wheelskates to this wheelset. Furthermore, the wear on the corners of the block holders demonstrates that all of the brake blocks had been missing while the wheels were rotating (paragraph D8, appendix D).
- 65 Once the wheelset had started rotating again, the bogie-mounted equipment was subjected to sustained impact loading for over 35 minutes, until the speed of the train reduced significantly after passing Morlais Junction. However, the RAIB considers that this would not have caused the clevis pins or brake block keys to fall out, in particular from the slave brake beam, unless the split pins (paragraph 55) were missing. As a result, the RAIB has concluded that the brake blocks did not fall off as a result of the wheelset developing wheel flats.
- 66 The damage to bogie 2741 was similar to, although more extensive than, the damage to the TF25 bogie of the coal hopper that was involved in an incident on 1 April 2015 (paragraph 108). The wagon owner concluded in that instance that the brake blocks of the damaged wheelset had fallen off because they had been incorrectly fitted. This resulted in severe wheel flats, as well as breaking the spindles between the brake beams.

## Identification of the immediate cause

- 67 **The damage to the infrastructure was caused by impact loading from rotation of the wheelset with severe wheel flats, and dragging of the master brake beam under the wagon after its left-hand end had broken free.**
- 68 The rail breaks occurred during the passage of the train (paragraphs 33 to 44) as a result of the impact loading from the significant wheel flats on the second axle of the fully laden wagon. The master brake beam on the leading bogie of the wagon broke free, either as a direct result of the impact loading or indirectly when the spindles failed (paragraph 61); this caused damage to TPWS loops and level crossing equipment in the four foot.

## Identification of probable causal factor

- 69 **It is probable that the wheelset locked up and developed wheel flats because an object became caught between one of the wheels and the adjacent brake block holder. This object was most likely to have been one of the brake blocks when it fell off the bogie.**
- 70 The brake blocks and associated keys and clevis pins were missing from all four wheels of the leading bogie (paragraph 63), and they were all present on the trailing bogie. Since a well secured brake block is unlikely to fall from a train, even in the event of vibrating or overheating, it can be concluded that the brake blocks were either missing or poorly secured when the train left Robeston. For the reasons given at paragraph 64a, the possibility that the brake blocks were missing on departure can be discounted. It is therefore most likely that the locking up of the second wheelset of the leading bogie was associated with a brake block coming loose and interfering with its rotation. This important evidence is considered further at paragraph 72.
- 71 There is insufficient evidence to be certain of the succession of events, however the RAIB considers that the most likely sequence was:
- the brake block at wheel position 6 became jammed between the block holder and the wheel when it fell off (paragraph 63 and figure 15), although the exact mechanism is unclear<sup>15</sup>.
  - the jamming of the brake block caused the wheelset to lock up, resulting in a sudden transmission of torque to the block holder.
  - the shock load on the block holder pulled the block holder apart and caused the lower hanger pin to shear (paragraph 61).
  - the brake block subsequently disintegrated or broke free, allowing the wheelset to start rotating again.
  - the hanger was no longer supporting the master brake beam (with attached actuators), so this was suspended from the brake spindles.
  - the spindles were then unable to withstand the dynamic loading from the mass of the brake beam, causing them to fail (paragraph D12, appendix D) and the beam to fall into the four foot.

### Replacement of the brake blocks

- 72 **It is probable that the brake blocks fell off because split pins were not fitted to the block holders on the leading bogie, as required when the blocks were replaced on 27 October 2017.**
- 73 Each brake block is attached using a split pin, a clevis pin and a key (paragraphs 54 and 55). The function of the split pin is to secure the clevis pin in position and to prevent it from working loose. When the block is replaced, these components are removed and then replaced in sequence. The split pin is renewed irrespective of condition, as required by the Touax Rail maintenance specification, Ref. DT-432.

<sup>15</sup> The brake block from wheel position 5 could also have caused the wheelset to lock up. However, the RAIB considers that this would have been less likely to cause the lower hanger pin at wheel position 6 to shear.

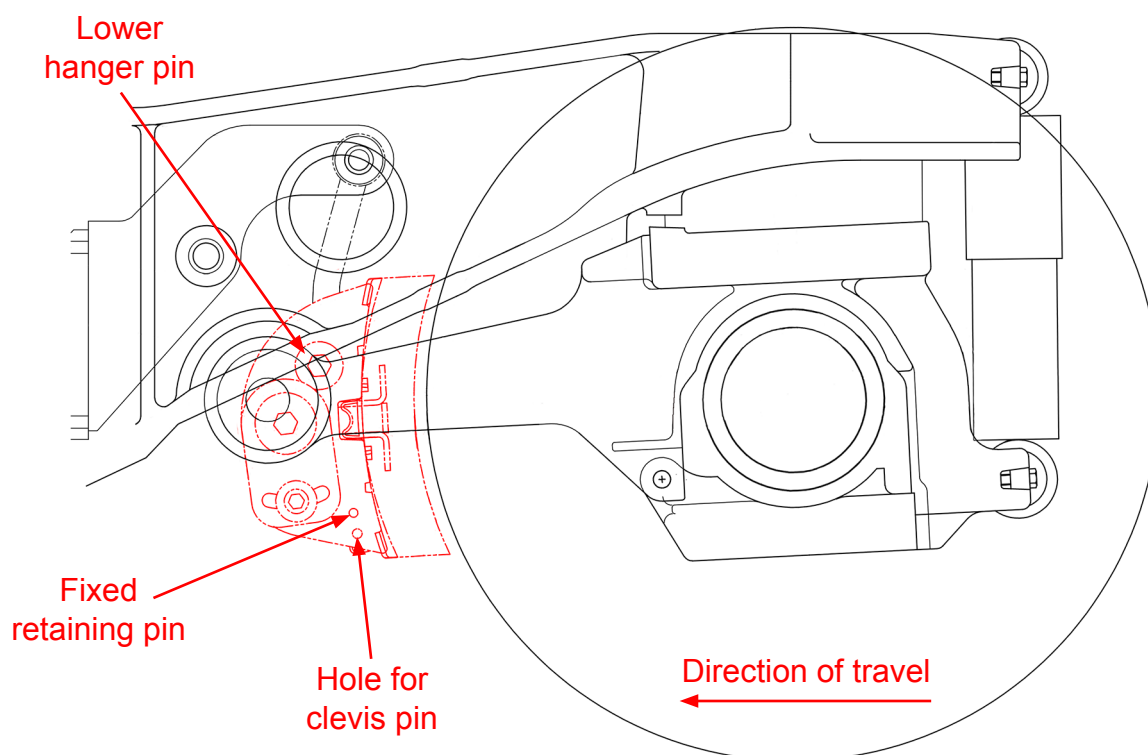


Figure 15: View of bogie at wheel position 6 (block holder and brake block shown in red) (based on a drawing supplied by Wabtec Faiveley)

- 74 All of the relevant components (split pins, clevis pins, keys and brake blocks) were missing from all four wheels of the leading bogie of wagon GERS89009 after the accident; they were all present on the trailing bogie (eg see figure 13). However, witnesses stated that there was nothing abnormal about the replacement of the brake blocks of the leading bogie on 27 October (paragraph 30). The work was carried out by the fitter, and the supervisor signed the repair work sheet to certify that the repairs had been carried out in accordance with the relevant Touax Rail maintenance plan.
- 75 The practice at Robeston is for two members of staff to take the required tools and components to the wagon using a shunting locomotive. The fitter then replaces the brake blocks on each bogie in turn, before connecting the wagon to the locomotive's air supply and making a number of brake applications until the brakes have self-adjusted correctly.

- 76 The RAIB observed the task of replacing the brake blocks on a wagon with the BFCB braking system, as carried out by staff at Robeston. It considered the working conditions, working practices, training, experience, witness evidence and the documentary record; it also modelled the task using a human factors analysis process known as SHERPA (Systematic Human Error Reduction and Prediction Analysis)<sup>16</sup>. The analysis took account of the possible types of error<sup>17</sup>, the similarity of components and the environment in which the task is routinely carried out. Based on this analysis, the most likely error was that the split pins that secure the removable clevis pins were not replaced when the new brake blocks were fitted to the leading bogie.
- 77 The fitter who replaced the brake blocks stated that he did not agree with the RAIB's conclusion and that the brake blocks had been fitted correctly. The supervisor stated that he completed his trip inspection (paragraph 30) after the blocks had been replaced, and he signed the repair work sheet to certify that the work had been completed in accordance with the Touax Rail maintenance plan.

### Possible alternative explanations

- 78 The RAIB has considered possible alternative reasons why the second wheelset of wagon GERS89009 locked up and then started rotating again. It has concluded that these are either not credible or that they do not explain why the brake blocks and associated components were missing. They include the following possibilities:
- malicious removal of the split pins after the brake blocks were replaced (paragraph 79);
  - loss of the fixed retaining pins from one or both block holders on the master brake beam (paragraph 80);
  - the handbrake on wagon GERS89009 being left on prior to departure of the train from Robeston (paragraph 84);
  - the presence of an intermittent fault in one of the bearings (paragraph 86);
  - an unidentified object becoming caught between the brake beam and the bogie frame and/or the wheelset (paragraph 88);
  - pre-existing wheel flats developing into much larger wheel flats (paragraph 89); and
  - a malfunction of the braking system (paragraph 92).
- Each of these factors is now considered in turn.

<sup>16</sup> Embrey, D. (2014). SHERPA: A Systematic Human Error Reduction and Prediction Approach to modelling and assessing human reliability in complex tasks. In Steenbergen, R., van Gelder, P., Miraglia, S. and Vrouwenvelder, A. (Eds.). Safety, Reliability and Risk Analysis. London: CRC Press.

<sup>17</sup> eg carrying out operations in an incorrect sequence, omitting components, using incorrect components, etc.



### Malicious removal of the split pins

- 79 The RAIB considered whether the split pins could have been removed by someone unknown, for malicious reasons. Access to the site at Robeston is strictly controlled, so the only opportunity would have been when the train made its unscheduled stop at Haverfordwest at 04:06 hrs (paragraph 32). As this stop could not have been reliably predicted, and the purpose of any such action is unclear, the RAIB has concluded that this is not a credible scenario.

### Failure of fixed retaining pin(s)

- 80 The fixed retaining pins that form part of the mechanism for attaching the brake blocks were missing from the block holders on the second wheelset of bogie 2741 (paragraph D9, appendix D). If one or both of these pins had fallen out, the associated key could also fall out and the brake block would no longer be restrained.
- 81 While the block holder from wheel position 6 (figure 8) was destroyed, accounting for the loss of that retaining pin, the block holder from wheel position 5 remained intact. The welds that secured the pin in position had failed (compare figure 16 with figure 14).



Figure 16: Inside corner of block holder from wheel position 5 (courtesy Serco Rail Technical Services)

- 82 The block holder from wheel position 5 connected the brake hanger to the master brake beam, so it was subjected to the forces necessary to drag the brake beam along under the train after the left-hand end had broken free (paragraph D2, appendix D), as well as to the impact loading due to the wheel flats (paragraph 65). It was distorted during the accident and it is therefore possible that loss of the retaining pin was a consequence of the damage to the bogie.



- 83 The fitter who replaced the brake blocks stated that he had never seen one of these retaining pins to be missing, and that he would have noticed if one had been missing; there is also no record of such a failure in the rail industry's system for recording NIRs (national incident reports)<sup>18</sup>. In addition, loss of the pins from the block holders on the master brake beam would not explain why the brake blocks, keys and clevis pins were missing from both block holders on the slave brake beam (figure 9 and paragraph 63).

#### The handbrake on wagon GERS89009 being left on

- 84 Wagon handbrakes that have been left on have been causal factors in previous accidents (eg the freight train derailment at Hatherley on 18 October 2005, [RAIB report 08/2006](#)), which is one reason for roll-by examinations such as that carried out as train 6B13 left Robeston (paragraph 32). Wagons are provided with tell-tale indicators showing the status of the handbrake.



Figure 17: Handbrake indicator on wagon GERS89009 after the accident (courtesy Network Rail)

- 85 After the accident, the handbrake indicator on wagon GERS89009 was found in the 'on' position (figure 17). Later examination of the braking system revealed that the linkage to the indicator had been extensively damaged in the accident. Examination of the remainder of the mechanism showed it to be consistent with the handbrake having been in the 'off' position. The handbrake also acts equally on both wheelsets (paragraph 53), so it is improbable that it could have caused one wheelset to lock without the other.

<sup>18</sup> Reports of urgent safety related defects affecting rail vehicles.

### Intermittent bearing faults

- 86 Bearing faults usually manifest themselves with evidence of overheating. There were no such signs on the second wheelset of bogie 2741 after the accident, and there were no reports of any problems with rotation of the wheelset when the wheelskates were later fitted (paragraph 46).
- 87 Post-accident examination of the bearings by the manufacturer, Timken, also did not reveal any defect that could have caused a wheelset to lock up (paragraph D16, appendix D). Furthermore, a defective bearing would not explain why the brake blocks, keys and clevis pins were missing from the block holders on the slave brake beam.

### An extraneous object

- 88 The RAIB has considered the possibility that an unidentified object might have become caught between the brake beam and bogie frame. There is no evidence to suggest either that the wagon had struck something that had been left on the track, such as track maintenance tools, or that anything had become wrapped around the rotating wheelset so as to cause the wheelset to lock.

### Pre-existing wheel flats

- 89 If there had been pre-existing wheel flats on the second wheelset of bogie 2741, these might have created the opportunity for the wheels to slide under heavy braking and poor adhesion. However, there was no evidence of any significant damage to this wheelset on the wagon's previous journey. At 21:00 hrs on Thursday 26 October, wagon GERS89009 passed Network Rail's Gotcha wheel monitoring site<sup>19</sup> at Marshfield; it was running as part of train 6B41, formed of empty oil wagons being returned from Westerleigh to Robeston. The RAIB has extrapolated the Gotcha readings, using the measured ratio of peak force to mean force, in order to understand the dynamic forces that would have been likely when the wagon was fully laden. This indicates that the wheel at position 8 (the wheelset that was leading during the journey of train 6B13) would have exceeded the level 2 and possibly the level 3 thresholds contained in Network Rail's business process document NR/SP/TRK/0133, 'Control of wheel impact forces'<sup>20</sup>. This wheel had a small flat spot when it was examined after the accident (paragraph D6, appendix D), which is consistent with the Gotcha readings and demonstrates it had not sustained significant further damage by sliding during the journey of train 6B13. In comparison, the wheels at positions 5 and 6 (those found with severe wheel flats after the accident) would not have exceeded the level 1 threshold in NR/SP/TRK/0133. Based on its review of the Gotcha data, Network Rail subsequently described the wagon as having 'slight wheel damage but nothing excessive'.
- 90 There was also no evidence of heavy braking during the journey of train 6B13 that would create the conditions necessary for the wheels to slide (paragraph 60).

<sup>19</sup> Gotcha monitoring systems (<https://www.railway-technology.com/contractors/track/gotcha/>) obtain real-time information about the state of different aspects of passing vehicles, such as weight distributions, wheel loads, wheel defects, noise emission and axle box quality. Network Rail has a number of such installations that enable it to identify vehicles with damaged wheels and causing unacceptably high impact loads.

<sup>20</sup> A level 1 activation requires the train operator to be notified, a level 2 activation requires freight trains such as 6B13 to operate at a maximum 30 mph (48 km/h); level 3 and 4 activations require trains to operate at further reduced speeds until they can be taken out of service.

- 91 Furthermore, the presence of the wheel flats that were found after the accident would explain neither why the brake blocks, keys and clevis pins were missing from the block holders on the slave brake beam nor why the fragment of brake block was found so soon after the badly damaged wheelset had started to rotate again (paragraph D5, appendix D).

#### A malfunction of the braking system

- 92 A malfunction of the braking system on the bogie would normally result in equal force being applied to both brake beams, so the cause of the second wheelset locking up (and not the leading one) was probably independent from operation of the braking system itself (paragraph 59). Nevertheless, the brake system components were examined by Wabtec Faiveley after the accident in order to identify any pre-existing defect (paragraph D13, appendix D). This examination did not reveal any relevant anomalies.

### **Factor affecting the severity of consequences**

#### **93 Network Rail signallers did not immediately arrange for the driver of the train to stop and examine the train, as required by the railway rule book.**

- 94 General signalling regulation 19 of the rule book (appendix E) requires a signaller who becomes aware of anything unusual or wrong with a train to stop it 'immediately' and to arrange for it to be examined. The signaller should also look for damage such as multiple or sequential track circuit failures. If it is not possible to stop the train before it enters the area controlled by another signaller, the first signaller must 'immediately' alert the second and then tell them what has happened.
- 95 The first indication that there was a problem with train 6B13 came when a track circuit continued to show 'occupied' behind the train, as it was passing Kidwelly signal box at 06:47 hrs. The train was not stopped until 08:14 hrs, by which time at least four signallers and three members of staff at the Wales Route control office had become aware that it was leaving track circuits showing 'occupied' behind it. None of the staff appeared to have been aware of the potential consequences if the train had derailed. General signalling regulation 16 of the rule book details the actions to be taken by a signaller in the event of a dangerous goods incident. However, this did not apply to the circumstances involving train 6B13, and there is nothing in the rule book that required the signallers to treat the train differently from any other train that was leaving track circuits showing 'occupied' behind it.
- 96 The signaller at Kidwelly was aware that a track circuit was showing 'occupied' and that Penybedd AHB had failed to reset behind train 6B13 when he called the signaller at Pembrey at 06:53 hrs (paragraphs 35 and 36). He did not alert the Pembrey signaller to the need for the train to be stopped and examined.

- 97 Witness evidence indicates that the Pembrey signaller did not understand that the track circuit at his signal box failing behind train 6B13 should be considered together with the earlier failures that he had been discussing with the Kidwelly signaller, and that general signalling regulation 19 should be applied (ie that he should send an emergency alarm to the next signal box, at Port Talbot). After the end of this telephone call, there was a period of 1½ minutes during which it might have been possible for the Pembrey signaller to have alerted the signaller on panel C at Port Talbot in time for him to reroute the train onto the Up Reception Line / Up Goods Loop before it reached Llandeilo Junction (figure 2)<sup>21</sup>.
- 98 The signaller on panel C at Port Talbot received an indication that a track circuit was continuing to show 'occupied' behind the train at 06:57 hrs (paragraph 38). He later stated that he did not notice this until the train running controller contacted him at 07:01 hrs to advise him that train 6B13 would need to be stopped for examination, as it was leaving failed track circuits behind it. The train running controller suggested that the best place for this would be the Flying Loop at Briton Ferry (78 miles (125 km) from Robeston), because the timetable for the train included an allowance [of 15 minutes] there. The signaller did not advise the controller that general signalling regulation 19 in fact required the train to be stopped immediately. This would have required him to advise his colleague on the adjacent panel B, as train 6B13 had passed the last signal controlled from panel C before the call ended; it had been in the panel C control area for 6 minutes.
- 99 Also at 07:02 hrs, the signaller on panel C telephoned to the incident support controller to report that a track circuit on his panel was continuing to show 'occupied'. After this call ended there was a period of 3 minutes during which the signaller might have alerted his colleague on panel B at Port Talbot in time for him to have stopped the train before it passed Morlais Junction<sup>22</sup>. It passed this junction at 07:08 hrs and started the climb towards Llangyfelach (paragraph 42).
- 100 The signaller on panel C called the incident support controller at 07:20 hrs to report that two further track circuits had failed behind train 6B13; the controller requested the signaller to stop the train 'as soon as'. Evidence from voice recordings of conversations between the signallers and control staff indicates that the signaller on panel C then advised his colleague on panel B that train 6B13 needed to be stopped. The signaller on panel B contacted the incident controller at 07:23 hrs to say that he did not want to stop the train on the rising gradient as it would never get started again. The incident controller agreed to the signaller's proposal to stop the train at Lonlas (6.4 miles (10.3 km) beyond its location at that time).
- 101 The signaller on panel B at Port Talbot contacted the driver of train 6B13 using the GSM-R radio at 07:36 hrs (paragraph 43) to advise him that he needed to stop and examine the train.

<sup>21</sup> The telephone call ended at approx. 06:55:06 hrs and train 6B13 reached the sighting point for signal PT247 at 06:56:40 hrs. This is braking distance from signal PT251 at the turnout onto the Up Reception Line.

<sup>22</sup> The telephone call ended at approx. 07:03:54 hrs and train 6B13 reached the sighting point for signal PT381R at 07:07:07 hrs. This is the distant signal for signal PT381 at Morlais Junction.



- 102 Although it would have been possible to stop train 6B13 earlier (paragraphs 97 and 99), and this would have reduced the extent of the infrastructure damage, eight of the nine rail breaks had already taken place before the train passed Llandeilo Junction. Most of the other damage to equipment had taken place before the train passed Morlais Junction.

## Observation

### 103 The facilities at Robeston are suboptimal for carrying out safety critical wagon maintenance tasks such as replacing brake blocks.

- 104 The maintenance facilities at the terminal are located at the end of the marshalling yard. A small concrete pad is used for PPM and VIBT examinations. Other activities, such as brake block replacement, are sometimes carried out without shunting the wagons to the pad; the necessary tools and replacement components are carried to the wagon on a shunting locomotive (paragraph 75). There is no pit at Robeston to facilitate access to the underside of wagons (DB Cargo has advised that a pit would be unsuitable for use at this location due to the possible accumulation of hazardous gases).
- 105 Touax Rail's maintenance plan includes guidance on the minimum facilities that should be available for specified examinations (appendix G), although it does not provide similar guidance for any required maintenance activities. The task of replacing brake blocks on a wagon such as GERS89009 involves working on the block holders that are located inboard of the bogie's radial arms and close to the ground. The clevis pins are approximately 300 mm above the rail and the keys are removed and replaced from underneath. As a result, replacement of the brake blocks requires the staff to lie down adjacent to each wheel in turn and carry out the work across their body. This work is carried out in all weathers and sometimes during the hours of darkness. In such circumstances, errors are more likely to occur, although DB Cargo has advised that there is no history of defect issues for wagons maintained at Robeston (see also paragraph 117).

## Previous occurrences of a similar character

- 106 On 5 January 2006 three broken rails occurred between Urchfont and Kennington after the passage of train 6F95 ([RAIB report 27/2006](#)). One of the loaded wagons was later found to have severe wheel flats (approx. 120 mm in length and 7 to 8 mm deep). A roll-by test had not been undertaken when the train left the Meldon Branch Line, where the flats were most likely to have been created, and the wheel flats were not detected during the subsequent journey from Coleford Junction to Hinksey Yard. The wagon had a different type of bogie and braking system from GERS89009.

- 107 On 23 February 2011 one of the wagons forming train 6E69 derailed at Dalchalm level crossing, Highland, and ran derailed for around 340 metres before becoming re-railed ([RAIB bulletin 03/2011](#)). Following the incident, the brake block holder and brake hanger were found to be missing from one of the wheels, and the associated brake beam was dragging in the four foot; a wheelset further along the train derailed when it struck the detached block holder. The cause of the derailment was that the upper brake hanger pin either fractured or worked loose, possibly due to a missing split pin. This allowed the brake hanger to detach from the bogie frame and the brake beam to drop. The wagon had a different type of bogie and braking system from GERS89009.
- 108 On 1 April 2015, train 6M95 was stopped after the signallers at Preston power signal box heard a loud banging noise as the train passed. Severe wheel flats were found on the leading bogie of the second wagon (a 102 tonne coal hopper, no. 370174), which was equipped with TF25 bogies and the Faiveley BFCB braking system. The brake blocks were missing from the damaged wheelset and the wagon owner, Freightliner, concluded that they had been incorrectly fitted when they were changed immediately before the journey in question. This resulted in the blocks becoming dislodged in service and locking the wheelset at speed, subsequently breaking the spindles connecting the brake beams.
- 109 On 13 December 2016, thirteen rail breaks occurred during the passage of freight train no. 72049 (travelling from Mazières-en-Gâtine to Bassens, in France), loaded with aggregates (Ref. BEATT-2016-010). The leading wheelset of the second wagon was found to have wheel flats approximately 110 mm long, and the resulting impact loading had caused the rail breaks. The wheel flats had probably developed during a previous journey while the wagon was unladen. The wagon was equipped with the Faiveley BFCB braking system, although the bogie type was different from GERS89009.
- 110 On 15 June 2018, train 6E02 was stopped after the signaller at Annan signal box reported sparks coming from the first wheelset of the first wagon. The wheelset was later found to have severe wheel damage and the wheel bearings appeared to be rotating freely; the causes are still under investigation by the wagon owner, Toaux Rail<sup>23</sup>. The wagon was equipped with TF25 bogies but a different type of braking system.

<sup>23</sup> At the end of August 2018, Touax Rail had still been unable to examine the wagon because it could not persuade the freight operators involved to move it to a suitable location.

## Summary of conclusions

### Immediate cause

- 111 The damage to the infrastructure was caused by impact loading from rotation of the wheelset with severe wheel flats, and dragging of the master brake beam under the wagon after its left-hand end had broken free (paragraph 67).

### Probable causal factor

- 112 It is probable that the second wheelset of wagon GERS89009 locked up and developed wheel flats because an object became caught between one of the wheels and the adjacent brake block holder. This object was most likely to have been one of the brake blocks when it fell off the bogie (paragraph 69, **Learning point 1**).
- 113 It is probable that the brake blocks fell off because split pins were not fitted to the block holders on the leading bogie when the blocks were replaced on 27 October (paragraph 72, **Learning point 1**).

### Factor affecting the severity of consequences

- 114 Network Rail signallers did not immediately arrange for the driver of the train to stop and examine the train, as required by the railway rule book (paragraph 93, **Learning points 2 and 3**).

### Observation

- 115 The facilities at Robeston are suboptimal for carrying out safety critical wagon maintenance tasks such as replacing brake blocks (paragraph 103, **Recommendation 1**).

## **Actions reported as already taken or in progress relevant to this report, that address factors which otherwise would have resulted in a RAIB recommendation or learning point**

- 116 Network Rail has briefed its signallers on the lessons from the accident on 30 October 2017, including the application of general signalling regulation 19 (appendix F).

### **Other reported actions**

- 117 DB Cargo reported that it had issued an 'engineering special check' following the accident, requiring inspection of the installation of brake shoes for the tanker wagon fleet based at Robeston, and that this had not revealed any anomalies.
- 118 Touax Rail has reported that it discussed with Wabtec Faiveley the possibility of replacing the clevis pin and associated split pin used on the 'G1' version of the BFCB brake block holder with a split pin of equivalent diameter (see paragraph 55). However, it was found that there is insufficient space for the head of such a split pin on this generation of BFCB equipment<sup>24</sup>.
- 119 Touax Rail is also considering painting or marking the split pin used on the existing clevis pin. This would help verify correct installation following replacement of brake blocks.

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<sup>24</sup> Wabtec Faiveley has advised that the G1 version of the BFCB was fitted to 1,182 TF25 bogies.



## Recommendation and learning points

### Recommendation

120 The RAIB makes the following recommendation<sup>25</sup>:

- 1 *The intent of this recommendation is to improve the working environment for safety critical wagon maintenance activities at Robeston.*

Touax Rail, in conjunction with DB Cargo Maintenance and Puma Energy, together with the owners of other wagons based at Milford Haven, should carry out a risk assessment of the facilities and processes that are used for maintenance of tank wagons operating out of Robeston terminal, taking account of the dangerous goods that are carried and the working environment at the site. A time-bound plan should be developed for any necessary improvements that are identified (paragraph 115).

This recommendation may also apply to other organisations which are responsible for the maintenance of wagons that carry dangerous goods, where such maintenance is carried out in outside environments.

### Learning points

121 The RAIB has identified the following key learning points<sup>26</sup>:

- 1 Insecure brake blocks have the potential to cause significant damage to rolling stock and also railway infrastructure if they fall off a vehicle. It is therefore important to check that brake blocks have been correctly fitted and secured before permitting a vehicle to re-enter traffic.

<sup>25</sup> Those identified in the recommendation have a general and ongoing obligation to comply with health and safety legislation, and need to take this recommendation into account in ensuring the safety of their employees and others.

Additionally, for the purposes of regulation 12(1) of the Railways (Accident Investigation and Reporting) Regulations 2005, this recommendation is addressed to the Office of Rail and Road to enable it to carry out its duties under regulation 12(2) to:

- (a) ensure that recommendations are duly considered and where appropriate acted upon; and
- (b) report back to RAIB details of any implementation measures, or the reasons why no implementation measures are being taken.

Copies of both the regulations and the accompanying guidance notes (paragraphs 200 to 203) can be found on RAIB's website [www.gov.uk/raib](http://www.gov.uk/raib).

<sup>26</sup> '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.

- 2 Application of general signalling regulation 19 requires signallers to take immediate and decisive action if they suspect a train is leaving track circuits showing 'occupied' behind it. Delaying this action until the train is at a convenient location introduces additional risk to the train and infrastructure.
- 3 Signallers and control staff should be aware of the potential consequences of an incident involving a train carrying dangerous goods, even where the circumstances are different to those envisaged in general signalling regulation 16.

## Appendices

### Appendix A - Glossary of abbreviations and acronyms

AHB	Automatic half barrier level crossing
BFCB	A braking system supplied by Wabtec Faiveley
ECM	Entity in charge of maintenance
GSM-R	Global System for Mobile Communications – Railways
NIR	National incident report
OTDR	On train data recorder
PPM	Planned preventative maintenance
ROGS	The Railways and Other Guided Transport Systems (Safety) Regulations 2006
UWC	User worked level crossing
VIBT	Vehicle inspection and brake test

## Appendix B - Investigation details

The RAIB used the following sources of evidence in this investigation:

- information taken from the on-train data recorder (OTDR) of locomotive 60001;
- weather reports;
- information provided by witnesses;
- maintenance records for wagon GERS89009 and bogie 2741;
- Touax Rail maintenance specification Ref. DT-432;
- staff competence records;
- site visits, including a track walk extending approximately 5 miles either side of Carmarthen Bridge Junction;
- measurements taken from plans of the train's route as well as satellite imagery;
- examination and photographs of the damage to wagon GERS89009 and brake system components;
- reports and photographs of the damaged wagon and the wheelsets from bogie 2741, produced by DB Cargo;
- reports of the metallurgical analysis of brake system components carried out by Serco Rail Technical Services;
- reports on the examination of air operated brake components by Wabtec Faiveley;
- a report on the post-accident examination of the wheel bearing from bogie 2741 by Timken Rail Services;
- Network Rail Wales Route's control log;
- Network Rail's report on repairs to broken rails;
- recordings of telephone calls made to and/or from Network Rail's signallers;
- a review of previous incidents held in the rail industry's system for recording national incident reports (NIRs); and
- a review of previous investigations that had relevance to this accident.



## Appendix C - Entities in charge of maintenance of railway vehicles

C1 The Office of Rail and Road (ORR) document 'Guidance on the requirements in ROGS (regulation 18A) that relate to entities in charge of maintenance of railway vehicles' includes the following:

4.2. The ECM is responsible for developing a system of maintenance to manage and implement maintenance activities for the vehicles it is responsible for. ECMs can demonstrate compliance with regulations 18A(2) and (3) of ROGS by developing a system of maintenance along the lines of Annex III of European Commission Regulation 445/2011 ("the ECM Regulation") ... Annex III of the ECM Regulation has been adapted for this RDG, (at Annex A) to make it applicable to all vehicles.

C2 Annex A of the ORR guidance document explains that a system of maintenance is composed of the following four functions:

- (I) the *management* function, which supervises and coordinates the maintenance functions referred to in points (II) to (IV) and ensures the safe state of the vehicles in the railway system;
- (II) the *maintenance development* function, which is responsible for the management of the maintenance documentation, including the configuration management, based on design and operational data as well as on performance and return on experience;
- (III) the *fleet maintenance management* function, which manages the vehicle's removal for maintenance and its return to operation after maintenance; and
- (IV) the *maintenance delivery* function, which delivers the required technical maintenance of a vehicle or parts of it, including the release to service documentation.

## Appendix D - Damage to bogie 2741

- D1 After train 6B13 was moved to Margam (paragraph 46), wagon GERS89009 was detached and held for examination. The diesel fuel was drained from the wagon on 8 January 2018, allowing the wagon to be lifted and the damaged leading bogie, no. 2741, to be swapped on 25 January. The bogie was then taken to Axiom Rail (Wabtec Faiveley) at Stoke on Trent, where it was examined by representatives of Touax Rail, DB Cargo, Wabtec Faiveley, Serco, ORR and RAIB on 13 February.
- D2 Examination of the bogie revealed that the lower left-hand hanger pin had sheared on the master brake beam, allowing the end of the brake beam to break free. The right-hand hanger was still intact, although twisted, and had pulled the partially detached beam along the four foot (figure D1).

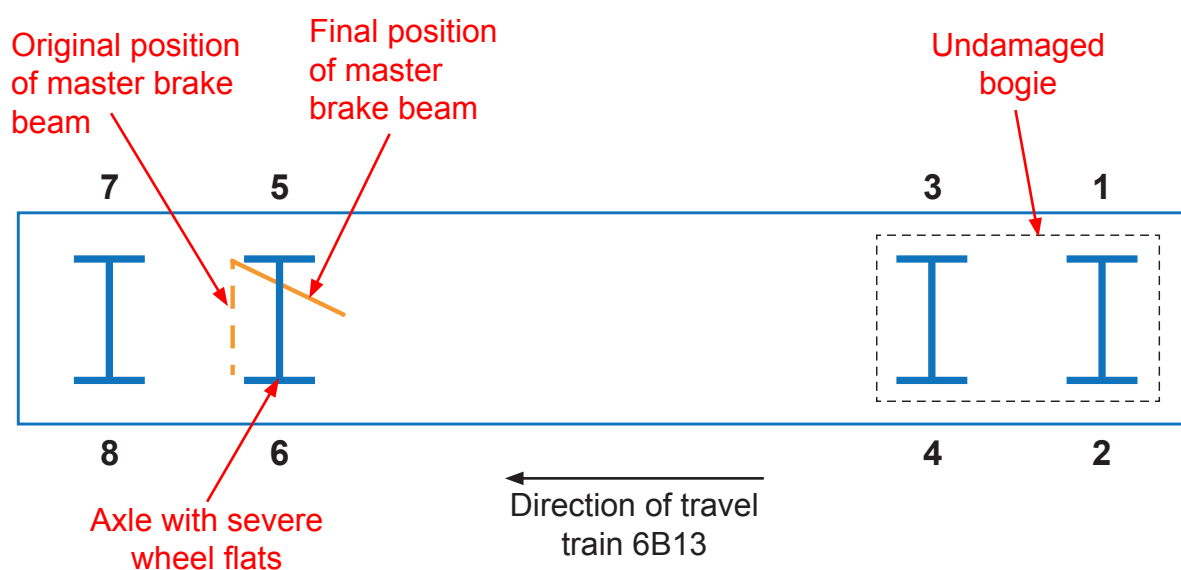


Figure D1: Schematic of wagon GERS89009 showing wheel numbering and the final position of the master brake beam

- D3 The master brake beam had bent around the middle (figure D2). The bending was consistent with the beam having come into contact with the trailing axle of the bogie while bouncing along at speed under the wagon. The left-hand block holder (wheel position 6) was missing from the end of the beam; part of it (the outer face) was later found 62.1 miles (100.0 km) from Robeston.

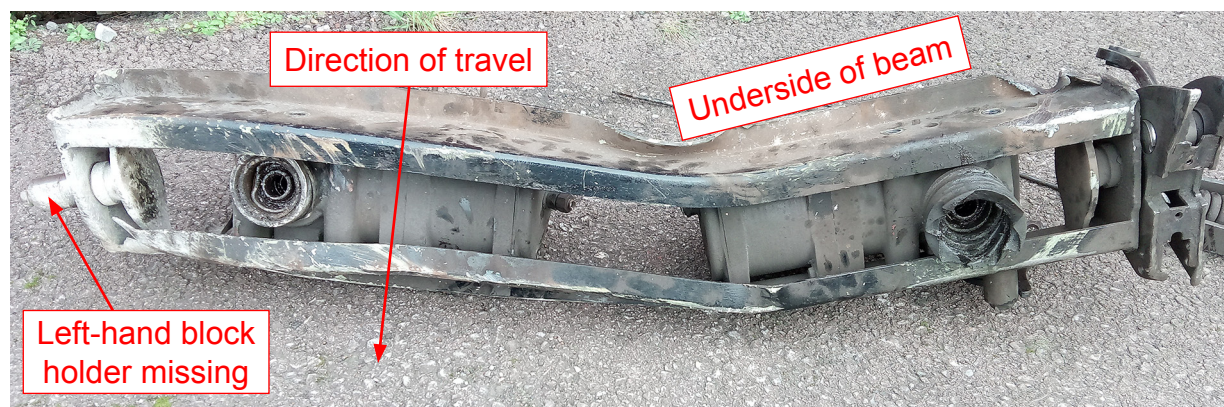


Figure D2: Master brake beam from bogie 2741 (courtesy DB Cargo)

- D4 The welded joint at the left-hand end of the slave brake beam was found to be cracked adjacent to the block holder (figure D3).

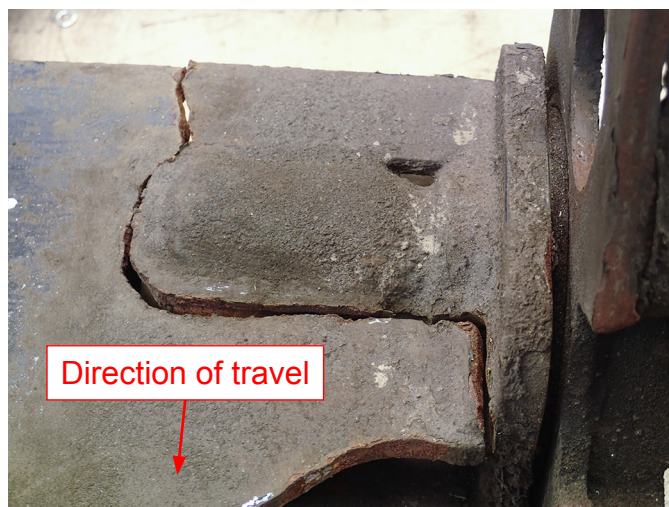


Figure D3: Cracking of slave brake beam at wheel position 8

- D5 The second wheelset (wheel positions 5 and 6) of bogie 2741 had wheel flats approximately 250 mm long and 10 mm deep (figure D4). The size of the flats is consistent with the wheels having slid an estimated 5 to 10 miles (8 to 16 km) while the wagon was fully laden with a 25 tonne axle load. The marks on the rail head (paragraph 33) and the broken rails over the following 22 miles (36 km) indicate that the second wheelset had started turning again approximately 42 miles (67 km) from Robeston.



Figure D4: Flat on wheel at position 5 (courtesy DB Cargo)

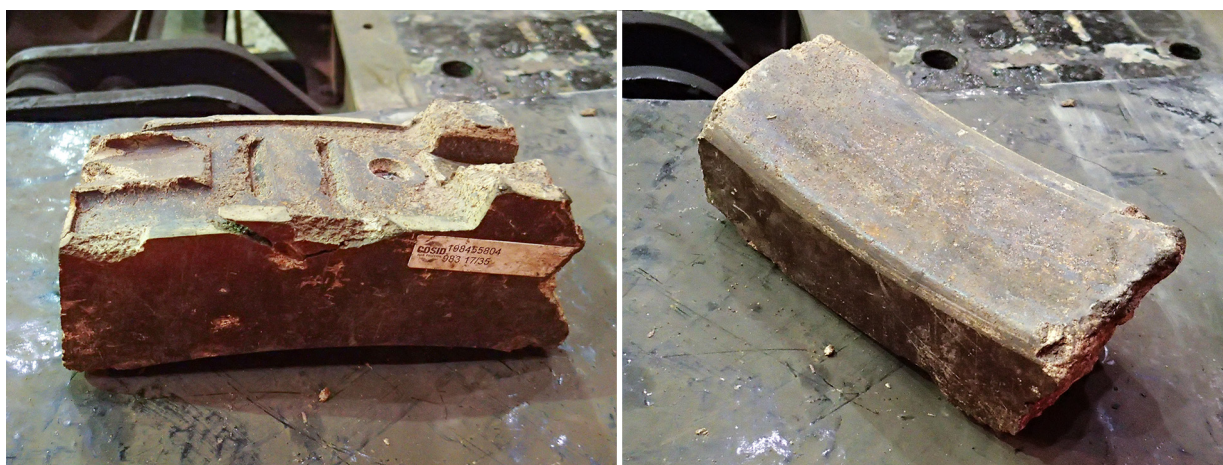
- D6 DB Cargo examined the wheelsets from bogie 2741 after the accident. In addition to the severe flats on the wheels at positions 5 and 6, there was also a small flat spot on the wheel at position 8 (figure D5). This was probably pre-existing and unrelated to the accident (paragraph 89).





*Figure D5: Flat on wheel at position 8 (courtesy DB Cargo)*

D7 The brake blocks were missing from all four wheels on bogie 2741, together with the keys and clevis pins (paragraphs 54 and 55). Part of a brake block was found 43.6 miles (70.2 km) from Robeston; this was 2.0 miles (3.2 km) after the start of damage to the rail head (paragraph 33). This was only lightly worn, indicating that it had recently been fitted to a vehicle (figure D6); the label records that it had been manufactured in the week commencing 28 August 2017. It is the same type of block as that fitted to wagon GERS89009 on 27 October 2017, which is not used on any passenger vehicles that operate in the Carmarthen area. No other brake blocks have been found that might have come from bogie 2741.



*Figure D6: Brake block fragment found 4 miles (7 km) east of Carmarthen*

D8 The corners of all block holders from both wheelsets were worn (figure D7). This indicates that the block holders had been in contact with the rotating wheels with no brake blocks present. Measurements of the wear made by Serco indicate that the block holders from the master brake beam were more severely worn than those from the slave beam, and the bottom of each block holder was worn more than the top.





Figure D7: Brake block holders from wheel positions 8, 7 (both courtesy DB Cargo), 6 and 5 with worn corners indicated

D9 The fixed retaining pins, that together with the clevis pin (figure 13) hold the brake block key in place, were missing from the damaged block holders on the second wheelset. The block holder from wheel position 6 had been torn in two, probably causing failure of the welded joints at the ends of the retaining pin. However, the retaining pin was also missing from the block holder at wheel position 5 (figure D8), which remained intact although distorted.

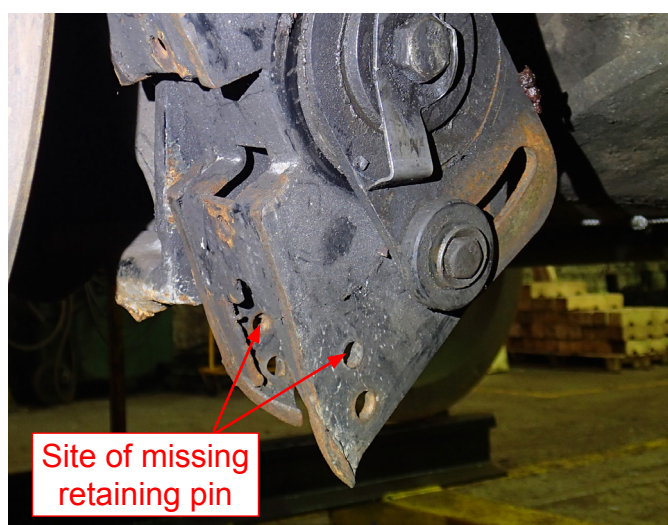


Figure D8: Brake block holder from wheel position 5

D10 The lower left-hand hanger pin (at wheel position 6) had sheared, and the corresponding shoulder of the hanger bush was damaged (figure D9). Only the outer half of the block holder has been found on the track, together with the tail of the hanger pin; the rest of the block holder and the head of the pin are missing.

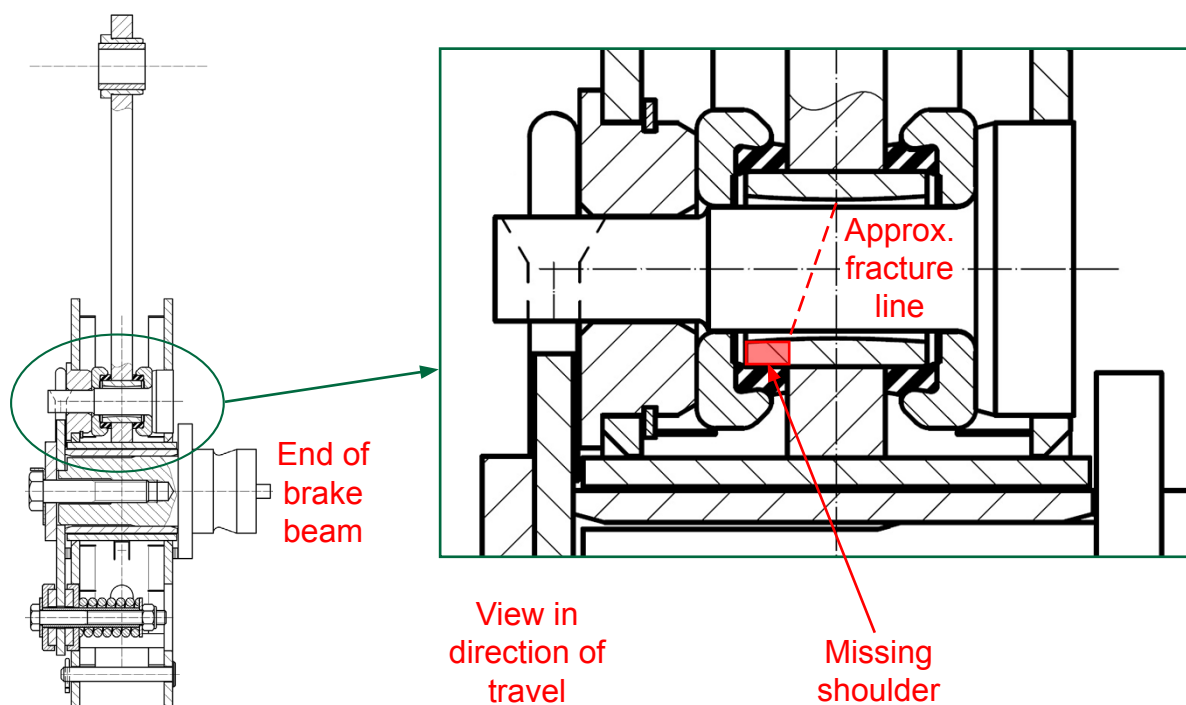


Figure D9: Section through brake hanger from wheel position 6; inset showing lower hanger pin (courtesy Wabtec Faiveley)

D11 Serco Rail Technical Services carried out a metallographic examination of the remains of the hanger pin. Serco concluded that, although the fracture surface of the pin was too badly damaged to determine the cause of the failure, the angled fracture (figure D10) indicated it had been overloaded in bending and shear. Conversely, failure due to fatigue would probably have resulted in a perpendicular fracture.

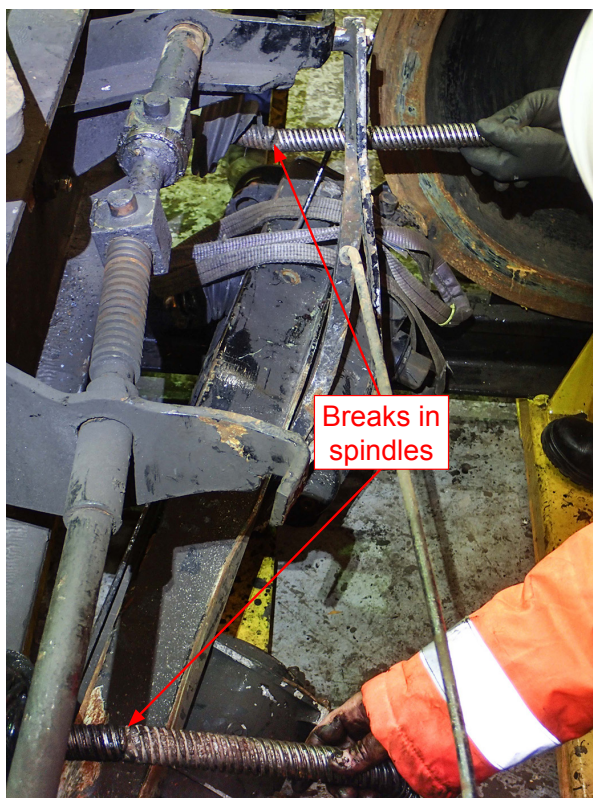


Figure D10: Remains of block holder from wheel position 6 and close up of fractured hanger pin

D12 The spindles connecting the brake beams had snapped, close to where the spindles project from the actuators (figure D11). Analysis of the fracture surfaces by Serco indicated that the spindles had been subject to severe reverse bending and their failure was probably due to low cycle fatigue<sup>27</sup>.

<sup>27</sup> Fatigue failure as a result of a low number of severe stress cycles.





*Figure D11: Reconstruction of bogie 2741; the visible part of the spindles would normally be hidden within the actuators mounted on the master brake beam (the detached brake beam is visible underneath)*

D13 The RAIB witnessed examination of the BFCB actuators by Wabtec Faiveley.

This revealed significant consequential damage, consistent with bouncing of the brake beam while it was being dragged at speed under the train. The left-hand actuator, which was at the free end of the brake beam, was more severely damaged than the right-hand one. Wabtec Faiveley also tested the brake distributor<sup>28</sup>, the empty / load changeover valve<sup>29</sup> and the relay valve<sup>30</sup>. The distributor had an air leak where a blanking plug had sheared off, probably due to being struck by a piece of ballast thrown up as the brake beam was dragging along the four foot. The testing revealed that the distributor had been fitted with an incorrect choke, which had the effect of slowing the rise in pressure delivered to the actuators when there was a brake demand<sup>31</sup>. No defects were identified in any of the air operated components that might have caused the failure of the braking system on wagon GERS89009.

<sup>28</sup> The control device that regulates air pressure to the brake cylinders in response to the changes of pressure in the brake pipe.

<sup>29</sup> An air system component that detects whether the wagon is empty or laden.

<sup>30</sup> A valve that reduces the pressure that reaches the brake actuators when the wagon is empty, depending on the position of the empty / load changeover valve.

<sup>31</sup> Touax Rail subsequently advised that the distributor had been supplied by Axiom Rail as a replacement for a missing unit. However, it was found to be configured incorrectly for use on a freight wagon and was sent to CFL (Société Nationale des Chemins de Fer Luxembourgeois) for conversion. On its return, it was fitted to another wagon before being swapped onto wagon GERS89009 in April 2017. It is unclear why the presence of the incorrect choke was not identified when the wagon received its annual VIBT in August 2017.

D14 The retaining bolt for the wheelset lift bracket at wheel position 5 was missing (figure D12). The bolt probably failed due to the dynamic loading caused by the wheel flats on this wheelset. The missing bolt has not been associated with any possible causal mechanism for the brake system failure on the wagon.



*Figure D12: Wheelset lift bracket at wheel position 5 hanging down after the accident (courtesy Network Rail)*

D15 The RAIB witnessed examination of the axle bearings by Timken Rail Services. The bearings were found to be in 'reasonable to good condition'. One of the bearings from the second wheelset of bogie 2741 had slight indentations to its rolling contact surface<sup>32</sup>; these were within the limit specified for an overhauled bearing. There was also a difference in the colour of the grease of the bearings from the two wheelsets, although there was no apparent significance to this. Timken concluded that all of the bearings were suitable for re-use.

D16 When DB Cargo examined the wheelsets after the accident (paragraph D6), it found scoring and rubbing on the trailing axle (figure D13). This was probably caused by contact with the master brake beam (paragraph D3) and other brake system components. There was also some paint loss from the abutments to the bearing journals.

<sup>32</sup> Such indentations are typically caused by impact loading and are sometimes referred to as 'brinell marking' or 'brinelling'.





*Figure D13: Evidence of rubbing contact adjacent to wheel position 5 (courtesy DB Cargo)*

## Appendix E - Extract from Rule Book Module TS1, General signalling regulations

### 19 Stop and examine train

#### 19.1 When this general signalling regulation must be used

You must carry out this regulation if you become aware of anything unusual or wrong such as:

- signals of alarm
- an insecure load
- a vehicle on fire
- a hot axle box
- a door open or on the catch
- a person has fallen from a train
- unusual noise coming from a train
- other mishaps.

You must also look for damage to the infrastructure which might have been caused by the train including:

- multiple or sequential track circuit failures, or
- multiple or sequential loss of detection of points.

#### 19.2 Anything unusual or wrong with a train

If you become aware of anything unusual or wrong with a train, or you receive **stop and examine train (7)**<sup>29</sup>, you must immediately:

- stop the train concerned
- stop trains on any adjacent lines from passing the train concerned
- stop trains proceeding on the same or any other line over the affected area
- tell the signaller who controls the area from which the train approached what has happened
- if necessary, carry out train signalling regulation 4<sup>30</sup>
- arrange for the train to be examined and dealt with as necessary.

If you cannot stop the train concerned before it enters the area controlled by another signaller, you must immediately tell that signaller what has happened.

You must first send the **emergency alarm** on a TCB or ERTMS line, or send **stop and examine train** on other lines where block bells are provided.

<sup>33</sup> ie Seven bells.

<sup>34</sup> eg Replacing a stop signal to danger.

## Appendix F - Network Rail signaller briefing note

### NATIONAL OPERATING PROCEDURES

TRANSFERRABLE LESSONS FROM SERIOUS OPERATIONAL INCIDENTS / INVESTIGATIONS

Form: F3.27A

Issue: 01

Date: 02/09/17

## Transferable Lessons from Serious Operational Incidents / Investigations



Issue No:	1	Date Issued:	5 December 2017
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Operational response to an incident involving a Collapsed brake frame



### Summary of Incident:

On the 30 October 2017 a freight train conveying dangerous goods caused several track circuits to remain occupied following its passage over a distance of approximately 25 miles. When the train was brought to a stand and examined it was found to have severe flat spots on one axle and the braking apparatus for the affected axle had become detached from the bogie and dragging underneath the train, this resulted in 9 broken rails, damage to several level crossings and other infrastructure.

### Learning points:

General Signalling Regulations 19 states that; you must apply the regulation if you become aware of anything unusual or wrong, such as:

- Signals of alarm • An insecure load • A vehicle on fire • A hot axle box
- A door open or on the catch • A person has fallen from a train • Unusual noise coming from a train
- Other mishaps.

You must also look for damage to the infrastructure which might have been caused by the train including:

- Multiple or sequential track circuit failures, or • multiple or sequential loss of detection of points.

### Points to consider and further actions and precautions:

Consider the meaning of multiple and sequential.

Multiple does not necessarily mean in a single signal box area. Sequential may not always mean consecutive.

**Talking point:** What else might cause you to use this regulation?

Briefed out to:

## Appendix G - Extracts from Touax Rail Maintenance Specification, Ref. DT-432

5.4.3 The following table is a guide to [the] facilities required for each job:

Exam	Facility
Traffic / daily / fitness to run	F1
Trip	F1
PPM	F3
VIBT	F4

5.4.1 Facilities for implementing this standard fall into the following broad categories:

- F<sub>1</sub>** Any line which may be protected for maintenance in accordance with rules. Examples being station sidings/loops, berthing roads, head shunts etc.
- F<sub>2</sub>** Any line which may be protected for maintenance in accordance with rules and offers facilities such as water supplies, electrical supplies and can make available consumables such as fuel, oil, filters etc. Examples being as F1 above but with suitable facilities or road access to enable items to be taken to the vehicle.
- F<sub>3</sub>** A flat and straight road, preferably concreted, (may or may not be covered) which may be protected for maintenance in accordance with rules and offers facilities as in F2 above.
- F<sub>4</sub>** As F3 above but offering lifting/jacking facilities and suitable component storage/handling. May offer pitted roads and other engineering equipment and tooling.
- F<sub>5</sub>** Fully equipped workshops conducive with the work being carried out. This level of facility is usually reserved for overhaul, and, components and sub-systems will be removed for attention to at many locations.

**Note:** The above categories may be recognised as the British Railways classification of maintenance facilities Levels 1 to 5. These are modelled on those categories but may be mixed to achieve a level of maintenance suitable for the location.



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