Rail Accident Investigation Branch

Rail Accident Report

Track damage between Pencoed and Llanharan, South Wales
6 March 2021

Report 03/2023
February 2023

This investigation was carried out in accordance with:

- the Railway Safety Directive 2004/49/EC
- the Railways and Transport Safety Act 2003
- 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.

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 RAIB has described a factor as being linked to cause and the term is unqualified, this means that RAIB has satisfied itself that the evidence supports both the presence of the factor and its direct relevance to the causation of the accident or incident that is being investigated. However, where RAIB is less confident about the existence of a factor, or its role in the causation of the accident or incident, RAIB will qualify its findings by use of words such as 'probable' or 'possible', as appropriate. Where there is more than one potential explanation 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 or incident but are associated with the underlying management arrangements or organisational issues (such as working culture). Where necessary, words such as '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 accident or incident 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 RAIB, expressed with the sole purpose of improving railway safety.

Any information about casualties is based on figures provided to RAIB from various sources. Considerations of personal privacy may mean that not all of the actual effects of the event are recorded in the report. RAIB recognises that sudden unexpected events can have both short- and long-term consequences for the physical and/or mental health of people who were involved, both directly and indirectly, in what happened.

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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Track damage between Pencoed and Llanharan, South Wales, 6 March 2021

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Summary

On the night between 5 and 6 March 2021, a wagon with severe wheel flats on one of its wheelsets fractured two rails within a mile of each other between Pencoed and Llanharan. The wagon was part of train 6A11 which was travelling from Robeston oil terminal, Milford Haven, to Theale oil terminal, near Reading.

The wheel flats occurred because a wheelset had stopped rotating (locked) while the train was moving during the journey. The investigation found that the wheelset had probably locked during braking in an area of very low railhead adhesion, when the train was travelling along the recently reopened Swansea District line. The rails on that line were rusty as it had not been used for several months. The environmental conditions were such that the rails were also wet, and it was the combination of rust and moisture which created the very low adhesion experienced by the train.

Network Rail had not taken any specific precautions to ensure that an adequate level of adhesion was available when reopening the line. This arose because Network Rail's focus when managing low adhesion was on the autumnal leaf fall season and it had not acted on the advice provided by a cross-industry working group on the adhesion-related precautions to take when reopening an unused line.

RAIB has made one recommendation to Network Rail to review its processes in light of the existing industry guidance to manage all occasions outside the leaf fall season which could result in very low levels of wheel/rail adhesion.

RAIB has also identified one learning point for signallers to remember that, in accordance with the Rule Book, they must arrange for a train to be stopped and examined if they become aware of an unusual noise coming from a wagon.

Introduction

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 report contains abbreviations. These are explained in appendix A. Sources of evidence used in the investigation are listed in appendix B.

The accident

Summary of the accident

3 On the night between 5 and 6 March 2021, a wheelset on a wagon forming part of a freight train, reporting number 6A11, stopped rotating while the train was moving and developed severe wheel flats (front cover). The freight train involved was the 21:25 hrs departure from Robeston oil terminal, Milford Haven, to Theale oil terminal, near Reading. Later in the journey, this wheelset restarted rotating, and the impact caused by the wheel flats subsequently fractured two rails on the South Wales main line between Pencoed and Llanharan. These fractures were situated within a mile of each other (figure 1).

4 Although the signallers who controlled the train's movements were aware that something was amiss with the train after the rails had been fractured, the train was allowed to continue its journey until it was stopped at Horfield Junction, on the approach to Bristol.

5 The train did not derail because of the rail fractures, and no one was injured in the accident. However, some damage was caused to the bogie-mounted braking equipment and wheelset involved (figure 10).

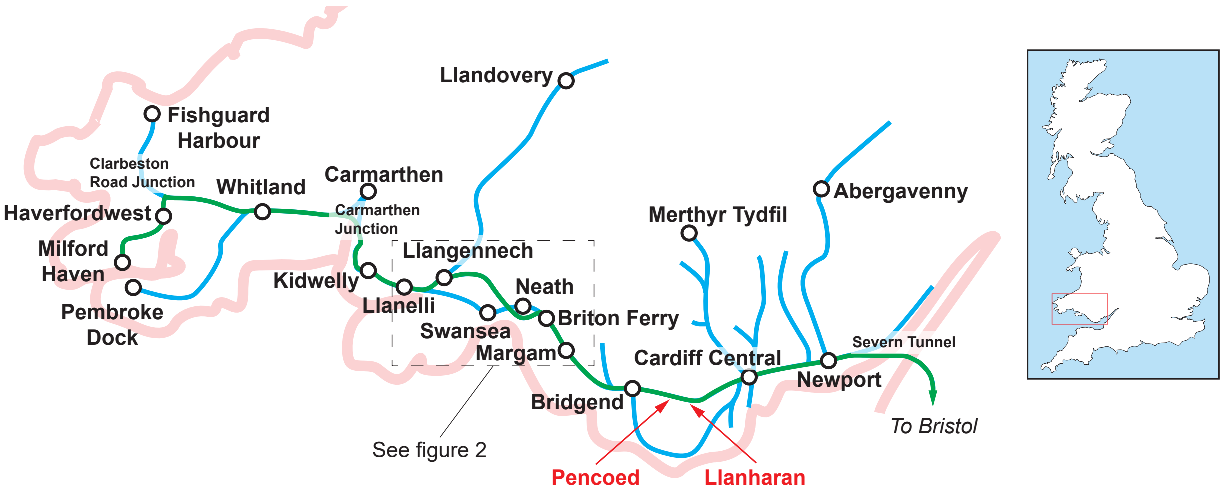

Figure 1: Route followed (in green) by train 6A11 along the South Wales main line.

Context

Route

6 After starting its journey at Robeston oil terminal, train 6A11 travelled to Haverfordwest, before continuing eastwards along the South Wales main line via Whitland and Carmarthen Junction, as far as Llandeilo Junction, which is situated beyond Llanelli (figures 1 and 2). At the junction, it was routed along the Swansea District line (shown in red on figures 2 and 3), turning east at Llangennech and taking the route towards Cardiff. It rejoined the South Wales main line at Briton Ferry and made a scheduled stop for a driver swap at Margam Knuckle Yard. Figure 3 shows the track gradient from Robeston to Briton Ferry while figure 4 shows the detail of the line between Llandeilo Junction and Briton Ferry.

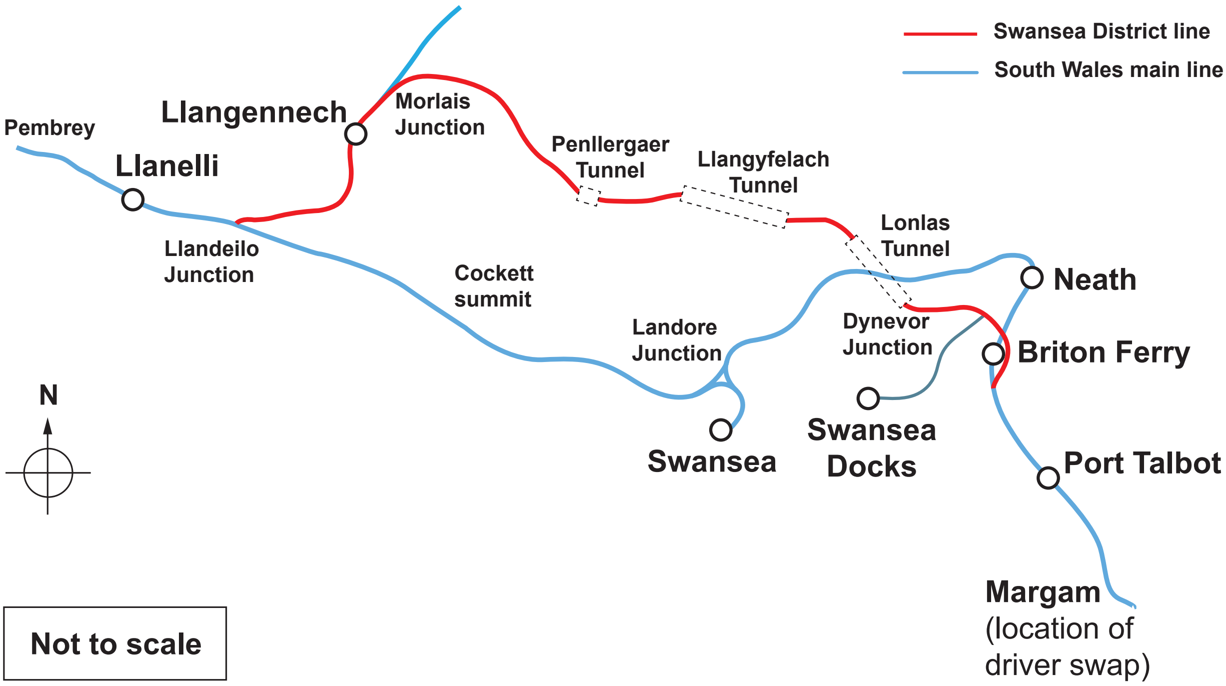

Figure 2: The Swansea District line.

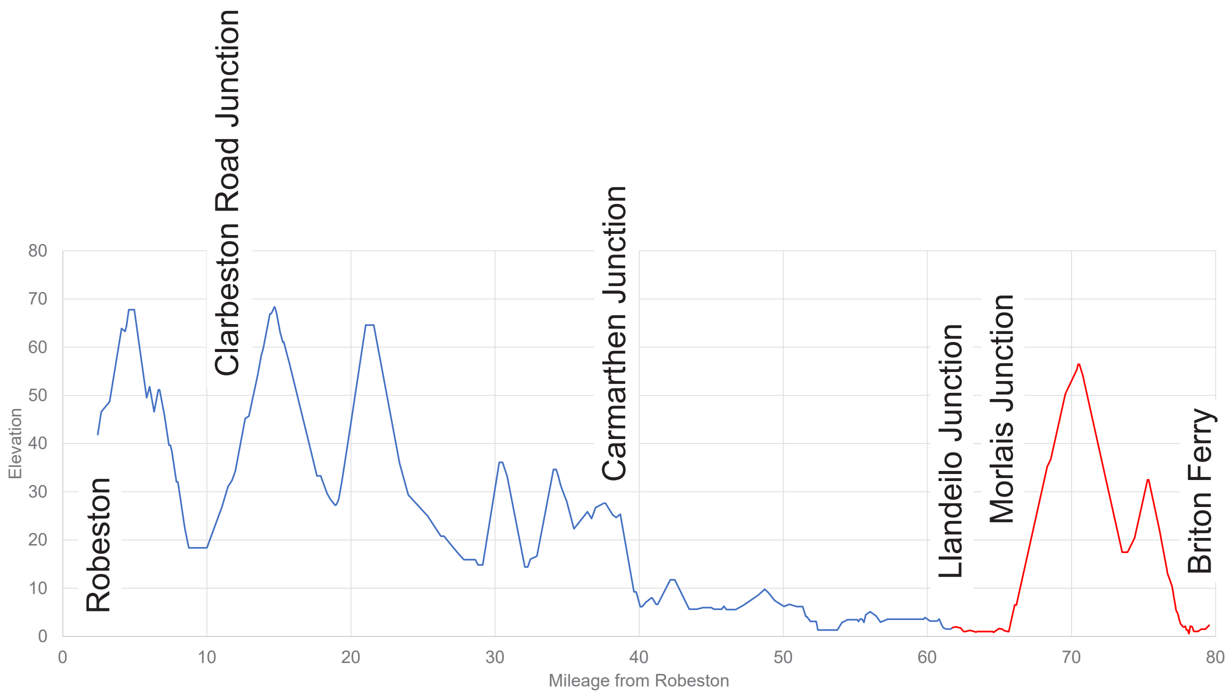

Figure 3: Gradient from Robeston to Briton Ferry.

7 After a driver changeover at Margam Knuckle Yard, train 6A11 passed Pencoed and then Llanharan on the South Wales main line before reaching Cardiff Central station, where the train temporarily stopped (see paragraph 37). The train then travelled through Marshfield, Newport and the Severn Tunnel. Having emerged from the tunnel, it continued towards Bristol Temple Meads and was eventually stopped on the approach to Bristol at Horfield Junction, between Filton Abbey Wood and Stapleton Road stations.

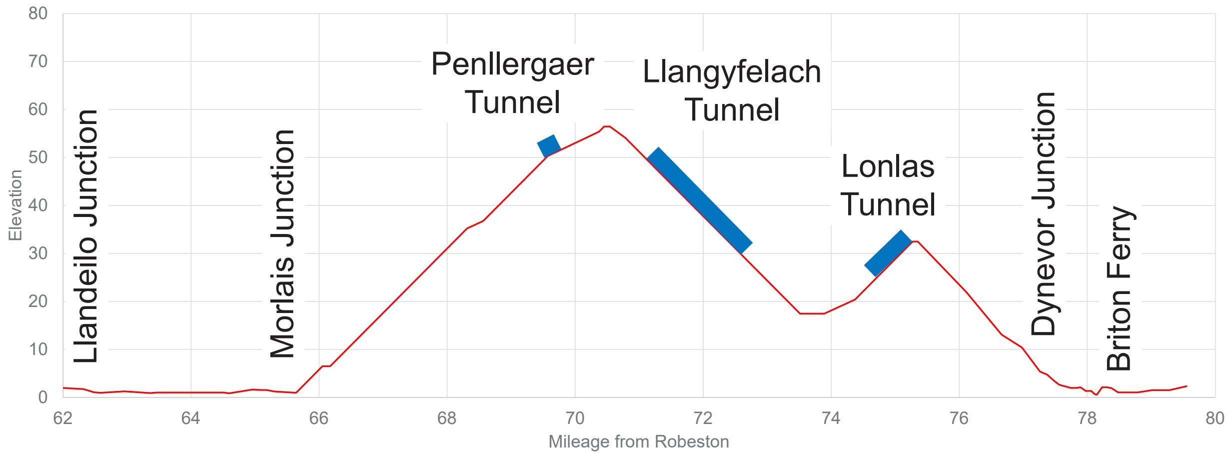

Figure 4: Gradient from Llandeilo Junction to Briton Ferry (the Swansea District line).

Organisations involved

8 Network Rail is the owner and maintainer of the railway infrastructure between Robeston oil terminal and Horfield Junction. It employs the signalling and control staff who managed the emerging situation with the train.

9 DB Cargo was the operator of train 6A11 on behalf of Puma Energy. It employs the drivers and ground staff who carried out the train preparation at Robeston oil terminal.

10 Puma Energy operates Robeston oil terminal and loaded the wagons with oil products.

11 Touax Rail is the owner and entity in charge of the maintenance of the wagon involved, number GERS89016. Maintenance of the wagon is undertaken by DB Cargo.

12 All parties involved freely co-operated with the investigation.

Train involved

13 Train 6A11 consisted of a class 60 locomotive, number 60015, and 23 bogie tank wagons and had a combined weight of 2,417 tonnes. All the wagons in the train were TEA type wagons, except for three TDA type wagons. Wagons 1 to 9, numbered from the front of the train, were carrying heating oil, while wagons 10 to 19 were carrying diesel oil for road vehicles. Wagons 20 to 23 were carrying gas oil.

14 The wagon on which the wheel flats developed was the eleventh wagon of train 6A11 (numbered from the front of the train in the direction of travel), number GERS89016. It was a TEA wagon loaded with diesel oil for road vehicles. It was built in 2001 by Arbel Fauvet Rail in Douai, France. The maintenance records for wagon GERS89016 indicate that it had received a planned preventative maintenance examination on 11 February 2021 and a yearly vehicle inspection and brake test examination on 5 November 2020.

Equipment involved

15 The train was fitted with a single-pipe air brake system, operating on all wheels of all wagons. A single train brake pipe connects all the wagons along the train, both supplying air to the wagons and controlling braking. Air pressure in the pipe is generated by a compressor on the locomotive, and the train driver controls the pressure in the pipe to control the brakes on the train. To release the brakes when running, air pressure is created in the train brake pipe. The pressure in the brake pipe when the brakes are fully released is normally 5 bar.

16 Each wagon carries a single ‘brake group’ and a separate auxiliary air reservoir fitted under the centre of the wagon body (figure 5). The brake group on a TEA wagon consists of a pipe bracket, distributor, control reservoir and relay valve. Reduction in the pressure in the train’s brake pipe causes the distributor within the brake group to operate and admit air from the auxiliary reservoir to the two brake cylinders on each bogie of the wagon. Air pressure in the brake cylinder moves a piston which, in turn, acts through a system of rods and beams to apply the brake blocks to the wheel treads. As with most freight wagons, TEA wagons are not fitted with a wheel slide protection[1] system.

Figure 5: Wagon GERS89016 and its brake group (auxiliary reservoir hidden by brake group).

17 The brake equipment fitted to the bogies of wagon GERS89016 is known as the block force compact bogie-mounted (BFCB) system. The BFCB system was developed by Faiveley Transport in Sweden (now part of Wabtec Corporation). It has been in use since 2001 and is widely used internationally.

18 The BFCB system fitted to both bogies of wagon GERS89016 consists of two transverse beams fitted between the axles (figure 6). The ends of both beams are attached to brake block holders, suspended from brackets on the bogie by hangers. The inner primary beam (the one nearest the centre of the wagon) carries a pair of brake cylinders that operate by extending longitudinal spindles, which pass through the bogie frame. These spindles push the primary and secondary beams apart, pressing the brake blocks against the wheels with equal force (figure 7). The system is self-adjusting, automatically taking up excessive slack (for example, caused by brake block wear) by means of a slack adjuster within the brake cylinders.

[1] A system which adjusts the braking effort on each axle to prevent the wheel sliding on the rail during braking. The system aims to make effective use of the available adhesion on the railhead to prevent wheels locking up and the consequent damage to the wheel tread.

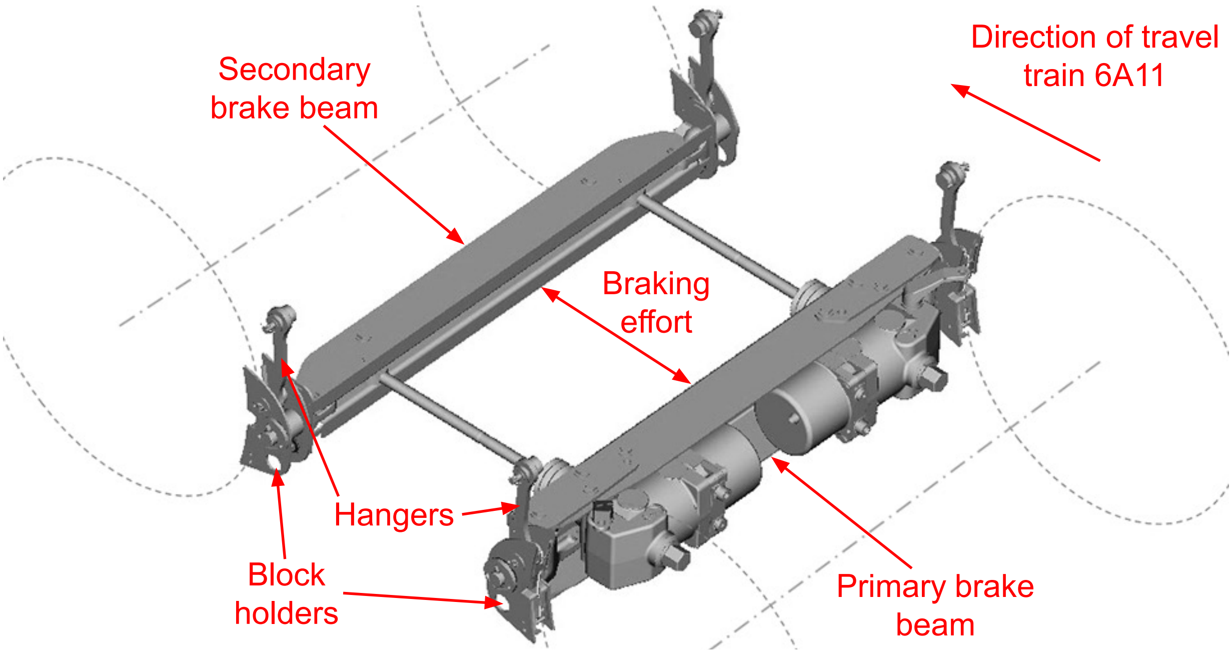

Figure 6: BFCB braking system for one bogie, brake blocks not shown.

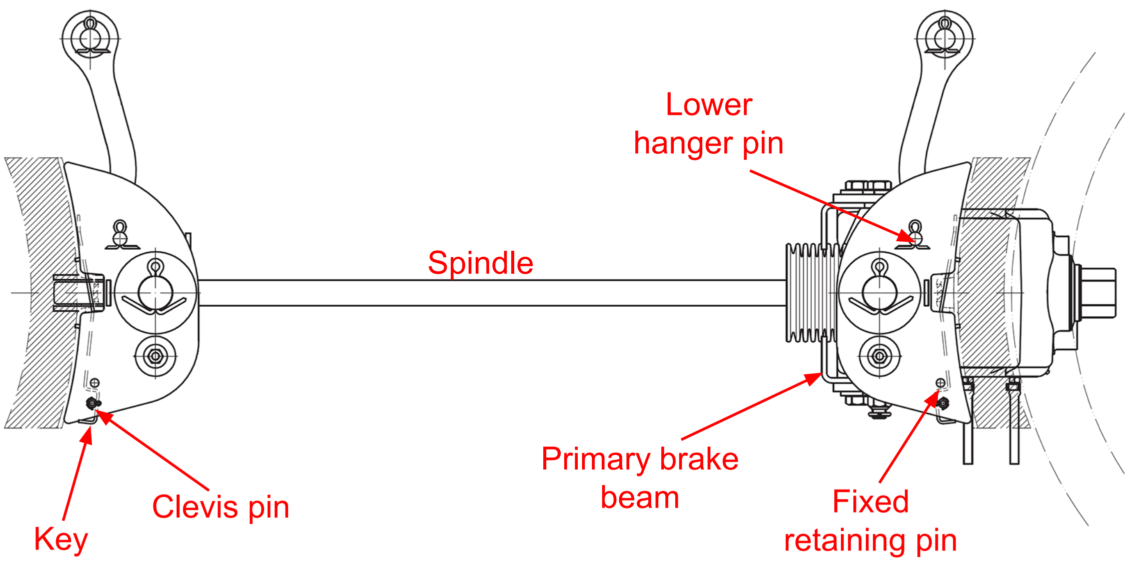

Figure 7: Side view of BFCB braking system.

Staff involved

19 The DB Cargo mobile operative at Robeston oil terminal who undertook the duties of train preparer before departure had approximately 14 years' experience on the railway, 2 of which at Robeston, and had achieved the grade of technical supervisor. He was certificated as competent to carry out train preparation activities in accordance with DB Cargo's competence management system.

20 The DB Cargo driver who took the train from Robeston oil terminal to Margam Knuckle Yard (driver 1) had approximately 25 years' experience as a locomotive driver and was based at Margam. He was certificated as competent to drive trains and as having the relevant route knowledge for the journey. The DB Cargo driver who took the train from Margam Knuckle Yard to Hornfield Junction (driver 2) had approximately 33 years' experience as a locomotive driver. He was certificated as competent to drive trains and as having the relevant route knowledge for the journey. He was also based at Margam.

21 The signaller at Port Talbot was the first to notice that something was amiss with the train. He had 42 years' experience as a signaller. The signalling team (Vale of Glamorgan signaller, main line signaller and shift signalling manager) at Cardiff Railway Operations Centre (ROC) each had between 12 and 20 years' signalling experience. The incident controller involved in the handling of the train as it passed through the Cardiff area was also based at Cardiff ROC. He had 20 years' experience on the railway, one year of which was as an incident controller. All of the signalling and incident control staff involved were Network Rail employees who had been certificated as competent in their roles in accordance with Network Rail's competence management system.

Weather

22 RAIB has reviewed records from weather stations along the route of the train and specifically at Robeston, Haverfordwest, Whitland, Llanelli and Morriston. The temperature during the journey of train 6A11 between Robeston and Margam varied between 0°C and 4°C and the weather was dry but humid, with no rain in the previous 24 hours and humidity levels of around 85%. The weather is likely to have contributed to the very low railhead adhesion (see paragraph 108).

The sequence of events

Events preceding the accident

23 At 17:29 hrs on Friday 5 March 2021, driver 1 booked on duty at Margam by telephone. His first duty was to take locomotive 60015, configured as a light engine (not coupled to another rail vehicle), from Margam to Robeston oil terminal. The journey, via Landore Junction, Cockett summit and Llandeilo Junction (figure 2), was uneventful. The locomotive arrived at Robeston oil terminal at 20:15 hrs.

24 At the oil terminal, and under the guidance of the DB Cargo train preparer, train 6A11 was formed with 23 wagons being coupled up to the locomotive. The train then waited at the exit gate, in preparation for the pre-departure checks. These checks, once carried out by the driver and train preparer, proved that the brake pipe was complete up to the end of the train, by confirming that the brakes applied and released on the rearmost wagons when commanded.

25 Train 6A11 departed Robeston oil terminal at 21:17 hrs. As the train was pulling out of the oil terminal, the DB Cargo train preparer conducted the required roll-by examination[2] of the train under the headlights of his van, which was parked at the terminal gate. He noted that nothing was amiss during the examination and that all wheelsets were rotating correctly.

26 Earlier that evening at 21:00 hrs, a possession[3] covering the Swansea District line had been handed back to the signaller at Port Talbot signal box, meaning that trains could now be routed over the line. At around 21:45 hrs, the Port Talbot signaller routed the first train, comprising a single locomotive, returning from Robeston oil terminal to Margam over the reopened section of line. This was the first time that a train had passed over the line since the possession was taken as a result of the accident at Llangennech in August 2020 (RAIB report 01/2022, see paragraph 128).[4]

Events during the accident

27 The first part of the journey of train 6A11, to Llanelli via Haverfordwest, Clarbeston Road, Whitland, Ferryside and Kidwelly, was uneventful. The train passed the track-mounted equipment for the hot axlebox detector (HABD) site at Pembrey at 22:59 hrs (see paragraph 78).

28 On the approach to Llanelli West level crossing, the Port Talbot signaller contacted driver 1 to inform him that the train would be routed over the Swansea District line. The train had originally been booked to remain on the main line heading towards Swansea. However, before the accident at Llangennech, the Swansea District line had been the normal route for oil trains such as train 6A11.

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[2] A planned visual check that the rail wheels of wagons passing an observer at slow speed are all rotating correctly and that there are no wheel flats, overheating bearings or other issues (from Ellis's British Railway Engineering Encyclopaedia © Iain Ellis. www.iainellis.com).

[3] A period during which a section of railway line is blocked to service trains so that engineering work, such as maintenance, repair or renewal activities, can be safely carried out.

[4] Other than some limited movement of engineering trains in the intervening months.

29 At 23:08 hrs, train 6A11 entered the Swansea District line at Llandeilo Junction, heading towards Llangennech and Morlais Junction. At 23:21 hrs, driver 1 brought the train to a stop at Morlais Junction. This was because of an existing track circuit failure which prevented the signal protecting the junction from being cleared (showing an aspect other than red). Driver 1 spoke to the signaller who authorised him to pass this signal at danger (red). The train was on the move again shortly afterwards, heading towards Neath and Briton Ferry. It passed Briton Ferry HABD at 23:52 hrs (see paragraph 79) before arriving at Margam Knuckle Yard at 00:13 hrs on Saturday 6 March 2021. Driver 1 secured the train and left Margam Knuckle Yard shortly afterwards.

30 At 01:20 hrs, driver 2 booked on duty at Margam by telephone. His duty was to take train 6A11 to its final destination at Theale. He made his way to the train and started getting ready to depart.

31 Train 6A11 restarted its journey towards Theale at 01:35 hrs. It passed Bridgend station at 02:02 hrs, Pencoed at 02:07 hrs and Llanharan at 02:12 hrs.

32 By the time the train reached Llanharan, the signaller at Port Talbot signal box had become aware that something was potentially amiss. He could hear an alarm sounding in the signal box, which drew his attention to the fact that two track circuits[5] had remained showing occupied after the passage of train 6A11. As the train was leaving his area of control at Llanharan, the Port Talbot signaller contacted the next controlling signaller, who was the Vale of Glamorgan signaller at Cardiff ROC. The Port Talbot signaller advised the Vale of Glamorgan signaller that train 6A11 had left two track circuits showing occupied after its passage. This call took place at 02:13 hrs.

Events following the accident

33 At 02:14 hrs, the Vale of Glamorgan signaller spoke to driver 2 on the Global System for Mobile communications – Railway (GSM-R) radio system to inform him that two track circuits continued to show occupied after the passage of his train through the Llanharan area. In this conversation, driver 2 confirmed to the signaller that his train was travelling through the Pontyclun area and that it was complete as his train still had a continuous brake pipe. One of the possible reasons for an occupied track circuit is the presence of one or more wagons left behind by the train, which would manifest itself to a driver by a drop in brake pipe pressure resulting in an automatic brake application.

34 At 02:14 hrs, the Vale of Glamorgan signaller called the Port Talbot signaller back to say that he had spoken to the driver who had confirmed that the train was complete. In this conversation, the Port Talbot signaller queried whether anything was being dragged or hanging off the train.

35 At 02:21 hrs, train 6A11 passed over the HABD site at Pontsarn, and soon after, St George’s CCTV level crossing. The Vale of Glamorgan signaller observed the passage of the train using the level crossing CCTV monitor. He did not notice anything amiss with the train. The Vale of Glamorgan signaller called the Port Talbot signaller at 02:24 hrs to confirm that the train was complete and that there did not appear to be anything being dragged or hanging off the train.

[5] A device used to detect the absence of a train on a defined section of track using the running rails as an electrical circuit.

36 At 02:30 hrs, train 6A11 passed in front of Cardiff ROC, located to the west of Cardiff Central station. By that point, the train had left the area of control of the Vale of Glamorgan signaller to enter the area of control of the South Wales main line signaller at Cardiff ROC. As the train passed the ROC, staff inside the building knew that something was amiss because of the loud repetitive banging noise made by the train.

37 The main line signaller immediately started making arrangements to bring the train to a controlled stop and sent a message on the GSM-R system for driver 2 to contact him. At 02:32 hrs, driver 2 contacted the main line signaller who asked him to bring the train to a stand and wait for further instructions. Train 6A11 came to a stand at Cardiff East Junction, just outside Cardiff Central station at 02:33 hrs.

38 The shift signalling manager and incident controller at Cardiff ROC had heard the banging noise made by the train as it passed them. They agreed that the noise was most likely to have been caused by the presence of wheel flats on a wagon and decided that the most suitable course of action was to allow the train to continue towards the wheel impact load detector (WILD) site at Marshfield, approximately 6.5 miles (10.4 km) away. Equipment at WILD sites measures the impact loads on the rails to detect abnormalities with wheels, including wheel flats. The expectation of the shift signalling manager and incident controller was that the WILD site would confirm the presence of any wheel flats. In this case, their intention was then to route the train to Alexandra Dock sidings for examination. This course of action was conveyed to the South Wales main line signaller.

39 At 02:43 hrs, the main line signaller spoke to driver 2 to instruct him to continue towards Marshfield and to then expect a further call. Train 6A11 moved off a few minutes later and passed the Marshfield WILD site at 02:56 hrs. The incident controller was remotely monitoring the passage of the train over the WILD site expecting to receive an alarm. However, no alarm came. As a result of this, the train was allowed to continue on its journey.

40 Train 6A11 passed Newport station at 03:05 hrs and Bishton HABD at 03:12 hrs. It arrived at Severn Tunnel Junction at 03:19 hrs. Having emerged from the tunnel, it then passed Pilning station at 03:32 hrs. As the train passed the train maintenance depot at Stoke Gifford, staff heard loud noises and saw sparks coming from one wagon on the train. They reported this to the signaller at the Thames Valley Signalling Centre (TVSC).

41 The TVSC signaller contacted driver 2 and asked him to stop and examine his train. Train 6A11 came to a stop at signal BL1587 on the down Filton main line beyond the disused Horfield station at 03:48 hrs. Upon examining his train, driver 2 noticed evidence of ‘scaling’ on the wheels of three wagons (7th, 17th and 23rd) and that the trailing bogie of GERS89016 (11th) was feeling warmer than its leading bogie. He did not immediately identify the collapsed brake rigging (figure 10, bottom left).

42 Train 6A11 was then authorised to move at slow speed to the nearby Bristol East depot for inspection.

43 At 02:45 hrs, in accordance with the Rule Book, the Port Talbot signaller had arranged for the line to be examined by the next train passing through the Pencoed and Llanharan area. At 03:31 hrs, the driver of the examining train reported that there was no issue with the line. The Port Talbot signaller started to allow drivers of subsequent trains to pass the signals being held at red by the track circuit failures. Subsequent investigation by Network Rail identified at 09:32 hrs that the track circuit faults observed by the Port Talbot signaller were the results of two rail breaks (figure 8) and the line was closed at this point.

Figure 8: The rail break at Pencoed, in-situ (left-hand image) and its fracture face (right-hand image) (photos courtesy of Network Rail).

44 The inspection of train 6A11 at Bristol East depot took place on 11 March 2021 (figure 9). Wagon GERS89016 was inspected, and the accident wheelset was found to have flats measuring about 185 mm in length on both wheels.

45 As well as damage to the trailing wheelset of the leading bogie of wagon GERS89016 (figure 10), wheelset damage was also identified on another eight wagons, as described in table 1. Figure 10 shows the damage witnessed on wagon GERS89016 as well as wagon VTG88111 (the fifth wagon from the front of the train) and wagon 7077920143 (the seventeenth wagon).

Summary of damage to train 6A11			
Order	**Wagon identification**	**Tread damage**	**Comments**
1	VTG 88099		Brake group had air pressure, but the brake cylinders did not
2	VTG 88095	Y	4th wheelset (both wheels)
3	TIPH 78264	Y	3rd wheelset (one wheel)
4	TIPH 78224		
5	VTG 88111	Y	2nd wheelset (both wheels)
6	TIPH 78203		
7	7077920259	Y	1st and 2nd wheelsets (four wheels)
8	VTG 85315		
9	VTG 88106		
10	7077920267		
11	GERS 89016	Y	Broken spindles on leading bogie (x2) At trailing end of leading bogie: • Collapsed brake beam • Missing brake blocks, retaining keys and associated pins (x2) • Missing friction devices (x2) • Wheelset with large flats Trailing bogie: • Tread damage to 3rd and 4th wheelsets
12	7077920093		
13	VTG 88158		
14	VTG 88108		
15	GERS 89011		
16	7077920119		
17	7077920143	Y	1st wheelset has tread damage for 45° Also 3rd wheelset (both wheels)
18	GERS 89017		
19	VTG 88103	Y	4th wheelset (one wheel)
20	VTG 88094		
21	GERS 89019		Brake cylinder on 2nd wheelset (one wheel) leaking air from brake group
22	VTG 88096	Y	3rd wheelset (one wheel)
23	GERS 89021	Y	1st and 2nd wheelsets Air leaks from relay valve and distributor mounting flange on brake group

Table 1: Summary of damage to train 6A11 as observed at Bristol East depot.

Figure 9: Wagon GERS89016 at Bristol East depot after the accident (photo courtesy of DB Cargo).

Wagon GERS89016 Trailing wheelset of leading bogie

Wagon VTG88111 Trailing wheelset of leading bogie

Wagon 7077920143 Leading wheelset of leading bogie

Figure 10: Example of wheelset damage on train 6A11 (photos courtesy of DB Cargo).

Events during the days following the accident

46 On the same morning (6 March 2021), train 6B26, the 06:40 hrs DB Cargo freight service from Margam to Trostre works, slipped to a stand on the rising gradient between Dynevor Junction and Lonlas Tunnel on the Swansea District line. The train was made up of a class 66 locomotive and 20 loaded wagons. This was the next loaded train to pass over the Swansea District line after train 6A11 and the second train to undertake this journey in that direction after the line reopened (paragraph 26).

47 On 7 March, Network Rail completed the repairs to the rail breaks. On 9 March, three days following the accident with train 6A11, a train carrying the same reporting number of 6B26 again slipped to a stand past Dynevor Junction. On arrival at Trostre works, a wagon in this train (number BLA 910558) was found to have developed wheel flats on its leading wheelset, with scaling observed on other wheelsets.

48 Later that day, at 23:17 hrs, the driver of train 6B17, the 21:00 hrs DB Cargo freight service from Robeston to Westerleigh, reported that his train was struggling to make progress along the Swansea District line in the Penllergaer Tunnel area. The train was made up of a class 60 locomotive and 23 loaded tank wagons. On arrival at Margam, three TEA wagons from the train were found to have developed wheel flats and scaling marks on some of their wheelsets.

49 On 10 March, the locomotive of train 6B13, the 05:00 hrs Robeston to Westerleigh DB Cargo freight service, activated the Marshfield WILD site. It was found on inspection to have developed wheel flats. Later that same day, DB Cargo instructed Network Rail to stop routing its trains along the Swansea District line until further notice.

Analysis

Identification of the immediate cause

50 The damage to the infrastructure between Pencoed and Llanharan was caused by impact loading from the rotation of a wheelset with severe wheel flats on train 6A11.

51 As train 6A11 left the area between Pencoed and Llanharan, the signaller received an alarm indicating that two track circuits had been left showing occupied. There was no evidence of these track circuit failures existing before the train's passage. Subsequent investigation identified that the failures were the result of two rail breaks in the area (paragraph 43).

52 The high impact forces generated by a rotating wheelset with a wheel flat is a known cause of rail breaks, particularly if the impact occurs near a rail joint, where the strength of the rail is reduced. The repeated impact on the track of a wheel flat also produces a characteristic noise that can be heard as a train passes. The sound is generated as the edges of the wheel flat impact on the rail and is cyclic in nature.

53 The subsequent inspection at Bristol East depot identified damage to the wheels of several vehicles of train 6A11, including the presence of severe wheel flats on the trailing wheelset of the leading bogie of wagon GERS89016 (paragraph 44). RAIB has concluded that the damage to the infrastructure between Pencoed and Llanharan was caused by impact loading from these severe wheel flats.

Identification of causal factor

54 The trailing wheelset of the leading bogie of wagon GERS89016 developed severe wheel flats during its journey from Robeston to Pencoed.

55 The departure of the train at 21:17 hrs from Robeston depot was witnessed by the DB Cargo train preparer as he conducted the required roll-by examination (paragraph 25). Witness evidence indicated that all wheelsets were seen to be rotating as expected during this examination and that there was no indication of the characteristic cyclic noise made by a wheelset rotating with wheel flats.

56 However, by the time the train passed Cardiff ROC at 02:30 hrs, staff within the building immediately recognised the noise made by the train as being characteristic of a vehicle travelling with wheel flats.

57 In order for wheel flats to develop, a wheelset must stop rotating under a wagon that is still travelling along the track. In this condition, the large contact forces at the wheel/rail interface are sufficient to rapidly generate large flats[6] which will continue to grow in size if the wheelset continues to slide.

58 A wheelset may not be rotating under a wagon that is travelling along the track for a variety of individual reasons which include:

- a handbrake being left on before departure (paragraph 60)

[6] Jergeus et al, 'Full-scale railway wheel flat experiments', Proc. IMechE 213 part F (1990) 1-13, states that a wheel flat between 20 and 60 mm long will be created within seconds of the start of sliding.

- an uncommanded brake application following a malfunction within the air braking system (paragraph 62)
- an uncommanded brake application following an object becoming caught within the brake rigging (paragraph 66)
- an object becoming jammed between the brake rigging and wheels (paragraph 67)
- one or more seized bearings on the wheelset (paragraph 69)
- the influence from the other wagons in the rake (paragraph 71)
- a brake application made during normal operation, but in conditions of low wheel/rail adhesion (a causal factor in the accident, paragraph 73).

59 These factors and their potential relevance as a cause of the wheel flats found on wagon GERS89016 are discussed in the following paragraphs.

The handbrake on wagon GERS89016 being left on

60 Wagon handbrakes that have been left on have been the cause of previous accidents investigated by RAIB (such as the freight train derailment at Hatherley on 18 October 2005, RAIB report 08/2006). Detecting handbrakes that have been left on is one of the purposes of the roll-by examination undertaken before departure of a freight train (paragraph 25).

61 On this type of wagon, only one of the two bogies is fitted with a handbrake. The bogie fitted with a handbrake can be identified as it has a large handwheel fitted to the side of the bogie frame. It is the manual operation of this handwheel which applies and releases the handbrake. As shown on figure 9, the bogie with the handbrake on wagon GERS89016 was the trailing bogie which is not the bogie with the wheelset that developed the wheel flats. This allows a handbrake being potentially left on to be discounted as the cause of the wheel flats found on wagon GERS89016.

An uncommanded brake application (malfunction within the air braking system)

62 The braking system of wagon GERS89016 was tested at Bristol East depot on 11 March 2021 and then again at Margam on 22 April 2021. On both occasions, the braking system responded to the changes in brake pipe pressure as expected. The brakes were applied and released as commanded, albeit with a slightly higher than expected force at the block/wheel interface (see paragraph 99). The testing also showed that overcharging[7] the brake pipe did not result in high air pressures being inadvertently trapped in the control reservoir, which could potentially create a dragging brake condition.

63 Following the testing at Margam, both the brake group (paragraph 16) and the BFCB system from the leading bogie of wagon GERS89016 were taken to Faiveley Transport (Birkenhead) for further testing and disassembly. The spindles, which were found after the accident to be broken, were sent for metallurgical examination.

[7] Overcharging is a process where the brake pipe pressure is temporarily increased to more than 5 bar and then slowly reduced to 5 bar. This is to reset the balancing pressure in the control reservoir to 5 bar.

64 None of the testing and detailed examination revealed anything untoward with the braking equipment other than post-accident damage. The metallurgical examination of the spindles concluded that they were likely to have broken as a result of the impact forces generated by the wheelset with wheel flats rotating and imparting large shock loads to the equipment attached to the bogie frame. The spindles normally keep the primary beam in a levelled position. With the spindles broken, the primary beam was free to adopt a more natural position under the weight of the brake cylinders, which is how it was found post-accident.

65 RAIB has therefore concluded it is highly unlikely that a malfunction within the wagon braking system could have potentially created the wheel flats found on wagon GERS89016.

An uncommanded brake application (object caught within the brake rigging)

66 RAIB has considered if an object might have become caught between the brake beam and bogie frame. Witness evidence suggests that train 6A11 did not strike any lineside equipment, vegetation or objects that had been left on the track, such as track maintenance tools. The inspection of the wagon post-accident did not identify any object that had become detached from the wagon and that was also large enough to wedge itself between the brake beam and bogie frame. The inspection of the other wagons in the rake did not identify any missing components meeting these criteria either.

An object jammed between the brake rigging and wheels

67 RAIB's investigation into the accident at Ferryside (see paragraph 123) identified a brake block falling and becoming caught between one of the wheels and the adjacent brake block holder as a probable cause of the wheelset becoming locked. The accident at Ferryside occurred during the wagon's first journey following bogie maintenance, when the brake blocks had been replaced. The blocks were considered to have come loose due to the split pins not being fitted to the block holders following the maintenance.

68 The last brake block replacement on wagon GERS89016 was undertaken on 11 February 2021, almost a month before this accident. RAIB considers that it is likely that any maintenance deficiencies which could have caused a wheelset to lock would have been revealed before the day of the accident. In addition, the roll-by examination carried out before the train departure from Robeston on the night of the accident (paragraph 25) did not identify anything amiss with the train such as displaced or hanging braking components. RAIB has therefore concluded that there was no evidence that an object had become caught between the brake rigging and the wheels.

Seized bearings

69 A wheelset is connected to a bogie frame by an axlebox fitted at each end of the wheelset. These axleboxes house the bearings that enable the wheelset to rotate freely. A seized bearing could potentially prevent a wheelset from rotating.

70 The accident bogie was examined post-accident and the wheels were found to be able to rotate freely, without any evidence that the bearings had seized. Bearing faults usually manifest themselves with evidence of overheating. The axleboxes did not exhibit any such signs when inspected. Evidence from the HABD sites (figure 11) shows that the axleboxes of the accident wheelset were running at similar temperatures to the other axleboxes on the wagon. RAIB has therefore concluded that a seized bearing was not a cause of the wheel flats found on wagon GERS89016.

The influence from other wagons in the rake

71 The inspection of train 6A11 at Bristol East depot after the accident revealed that the leading wagon in the rake (VTG88099) did not have effective brakes (table 1). While the presence of an unbraked wagon in the rake will extend the distance required for the train to come to a stand, it will not increase the propensity of a wheelset on another wagon to lock up and develop wheel flats.

A normal brake application in low adhesion conditions

72 Overall, no failure conditions could be postulated and supported by evidence to explain the generation of the wheel flats. RAIB therefore concluded that they probably have been generated as a result of the train operating in conditions of very low adhesion.

Low adhesion during normal braking

73 It is probable that the wheelset locked up and developed wheel flats during a normal braking event because of very low railhead adhesion along the Swansea District line.

74 A wheelset will stop rotating if, under braking conditions, the retarding moment generated by the braking system is greater than what the wheelset can transfer to the track at the wheel/rail interface. Sliding is therefore a function of four parameters: the brake block force, the friction at the block/wheel interface, the vertical load on the wheel and the friction at the wheel/rail interface.

75 Rail vehicles require a certain level of adhesion at the wheel/rail interface to be able to decelerate without sliding. This is normally expressed as a coefficient of friction.[8] The available adhesion at the wheel/rail interface can vary greatly depending on the time of year, the time of day, the presence of contaminants, the weather conditions, and other factors.

76 The mean adhesion on the rail network was measured in the 1970s by British Rail[9] as having a coefficient of friction of 0.27. But the range of adhesion levels available varied then and still varies considerably from very low (less than 0.05) to very high (greater than 0.4).

[8] Symbol μ. The lower the value of μ, the lower the adhesion between wheel and rail.

[9] BR report TN-TRIB-9 ‘A twelve-month adhesion survey on a 280km route’, June 1976.

77 In 1995, the railway industry established a cross-industry Adhesion Working Group (now renamed as the Seasonal Challenge Steering Group as its remit now also includes other seasonal weather). Its sole objective was to research and develop initiatives to combat the effects of low railhead adhesion. Table 2 shows the range of adhesion encountered on the railway as defined by the Adhesion Working Group in its guidance.[10]

Range of railhead adhesion on the rail network		
Adhesion level	**Typical coefficient of friction**	**Description**
High	> 0.15	Clean rail wet or dry
Medium	0.10 to 0.15	Damp rails with some contamination
Low	0.05 to 0.10	Typical autumn mornings due to dew / dampness often combined with light overnight rust
Very low	<0.05	Severe rail contamination often due to leaves but sometimes other pollution

Table 2: Range of railhead adhesion on the rail network as defined by the Adhesion Working Group.

Journey of train 6A11

78 Train 6A11 passed the HABD located in Pembrey at 22:59 hrs. RAIB reviewed the trace recorded for wagon GERS89016 on the HABD and concluded that there was no indication of any wheelset sliding as all wheels and axleboxes on the wagon were measured at very similar temperatures (figure 11 – left). This is confirmed by the CCTV footage of the train passing Llanelli station at 23:02 hrs which does not show any evidence of sparks being generated at the wheel/rail interface (figure 12) as would be expected if a wheelset had locked up.

79 Train 6A11 subsequently passed the HABD located at Briton Ferry at 23:52 hrs (figure 11 – right). The trace recorded for wagon GERS89016 on the HABD shows that the wheels of the trailing wheelset of the leading bogie were now running significantly hotter than the other wheels and that the axleboxes for that wheelset were cooler than the other axleboxes on this wagon. When a wheelset is sliding, the axlebox bearings will not be generating heat as they are not rotating, and significant heat will be generated in the wheels at the wheel/rail interface through friction. RAIB therefore interpreted these traces as indicating that, by the time the train passed Briton Ferry, the trailing wheelset of the leading bogie of wagon GERS89016 was, or had recently been, sliding.[11]

[10] 'Managing low adhesion', 6th edition, January 2018.

[11] The investigation of the accident at Llangennech (see paragraph 128) identified the lack of monitoring by Network Rail of the data recorded by the HABD system as a causal factor in the accident. RAIB considered whether this was also a factor in the Pencoed accident but concluded that it was not, on the basis that, unlike at Llangennech, the temperatures measured on the accident wheelset were unlikely to have been sufficiently high to reach temperatures that other European countries use as alarm levels.

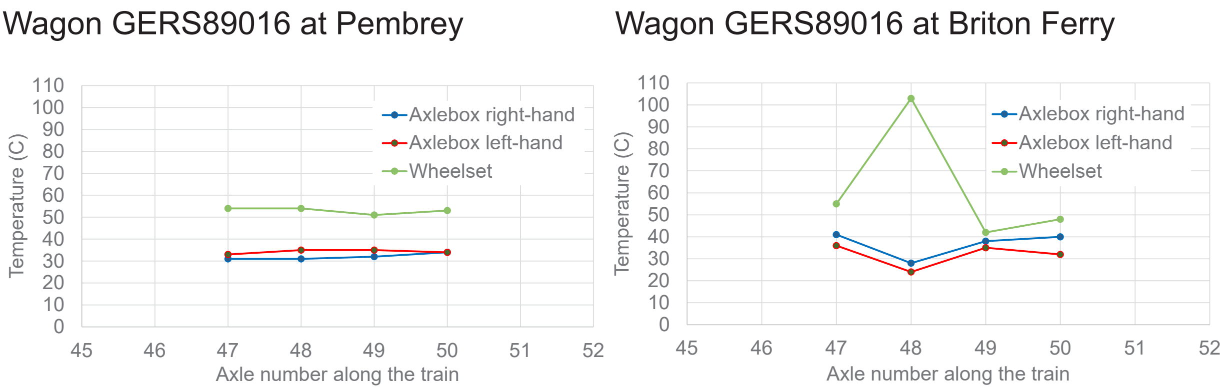

Figure 11: HABD records.[12]

Figure 12: Wagon GERS89016 at Llanelli station.

Identification of the likely location where sliding took place

80 The on-train data recorder (OTDR) from the locomotive forming train 6A11 indicated that there were a number of braking events during the trip from Llandeilo Junction to Briton Ferry (figure 13). RAIB commissioned a study[13] of the trip from Llandeilo Junction to Briton Ferry over the Swansea District line to determine whether any of the braking events along that line could have resulted in a wagon wheelset locking up and sliding.

81 The study concluded that there were braking events along the Swansea District line which could have been sufficient to lock up a wheelset, provided that the adhesion level was very low (0.05 or less). In particular, the study concluded that the braking event which took place as the train was descending from Lonlas Tunnel towards Dynevor Junction was the most likely source of the wheel slide as this was the largest brake application.

[12] The results for the wheelset temperature sensor at Briton Ferry have been corrected following advice received from Network Rail that the wheel sensor at Briton Ferry applied a constant offset to all wheelset readings.

[13] The study was commissioned from nC² Engineering Consultancy, which is a group of experts in material science, mechanical engineering and tribology affiliated with the University of Southampton.

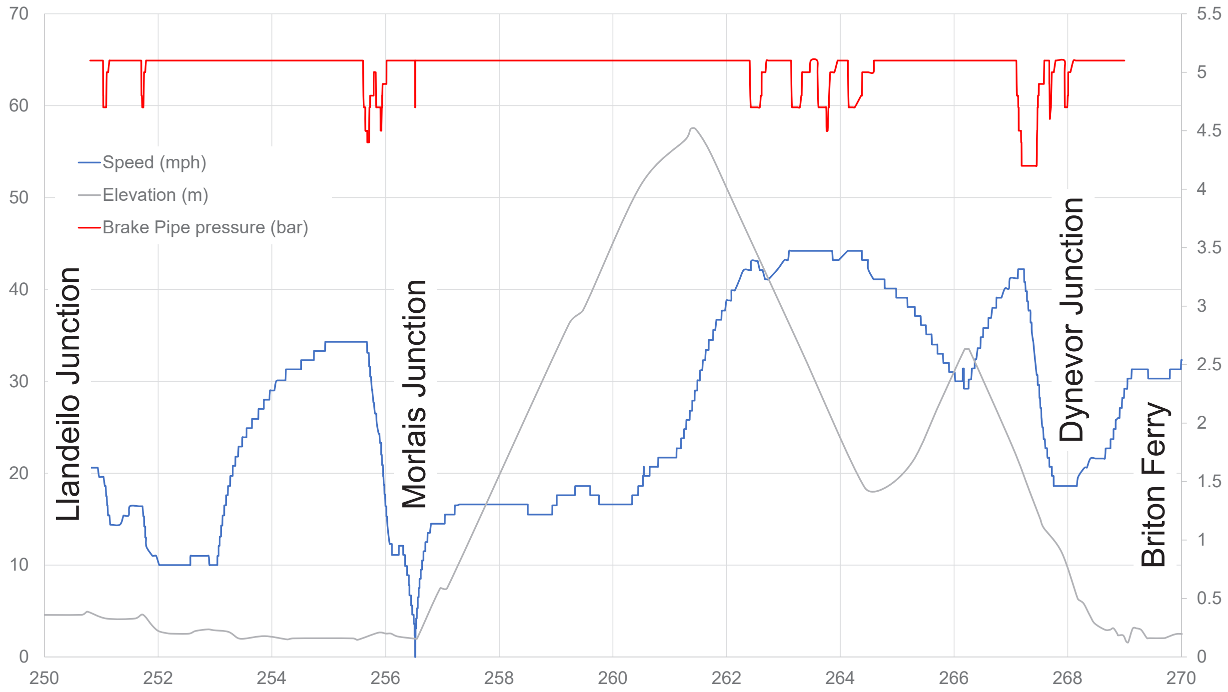

Figure 13: Brake applications along the Swansea District line.

Sliding and development of initial wheel flats under braking

82 Train 6A11 was hauled by a class 60 locomotive (paragraph 13). The traction control system of a class 60 locomotive is fitted with an anti-slip function to prevent the wheelsets of the locomotive slipping when the driver is demanding traction from the locomotive. Slipping is defined as a wheelset rotating but without the corresponding longitudinal movement of the locomotive taking place. This anti-slip function automatically detects if a wheelset is slipping and, if detected, rapidly reduces the electrical current provided to the traction motor and hence the torque applied on that wheelset until the wheelset stops slipping. Once the applied torque has reduced sufficiently so that it matches with the available adhesion at the wheel/rail interface, the wheelset will stop slipping.

83 When slipping is detected by the system, the locomotive will also automatically deposit sand on the rails in front of the wheelset to try to locally increase the available adhesion. This sanding activity is recorded on the OTDR.

84 Where the combined effect of the anti-slip function and the deposition of sand on the rails has failed to control a slip because levels of adhesion are so low, the ‘wheel slip’ channel of the OTDR will record the event. A ‘wheel slip’ event on the OTDR is hence an indication of very poor adhesion being experienced by the locomotive.

85 Figure 14 shows the OTDR data as recorded on locomotive 60015 on 5 March 2021 for the trip from Robeston to Margam. Figure 14 shows:

- the speed trace in mph
- the power demanded by the driver
- the power achieved by the locomotive
- the sanding activity
- the ‘wheel slip’ channel as recorded by the OTDR.

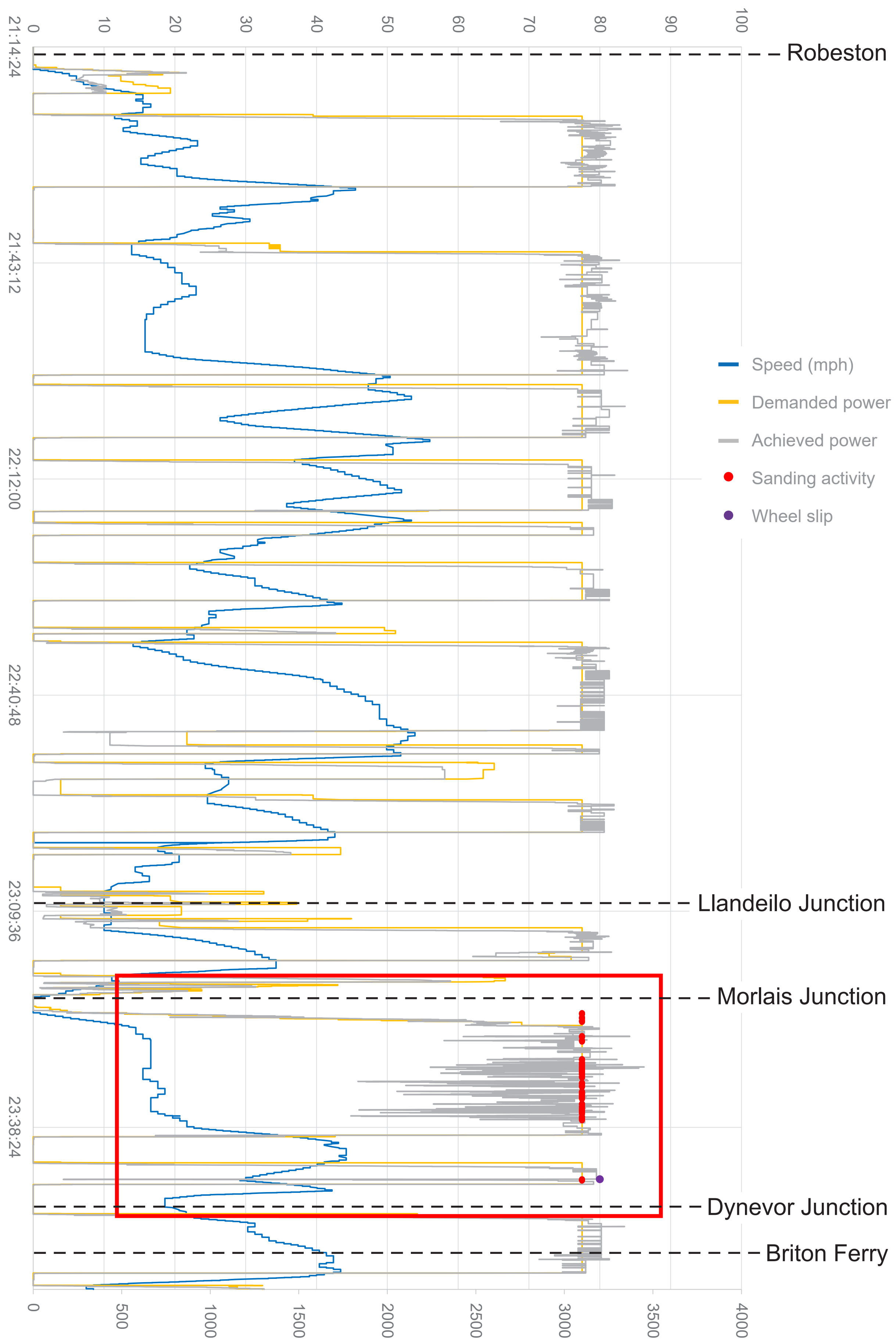

Figure 14: OTDR data for locomotive 60015 on 5 March 2021.

86 The activity of the anti-slip function of the traction control system can be recognised on OTDR data when there is a large fluctuation of the power achieved by the locomotive against a constant power demand by the driver. This usually coincides with a significant sanding activity on the OTDR. In extreme cases concurrent 'wheel slip' activity data will also be recorded by the OTDR.

87 OTDR data shows that the journey from Robeston to Morlais Junction was uneventful and that, whenever the driver commanded traction power, the traction control system was able to deliver this without any apparent intervention from the anti-slip function. This section of the trip included several steep gradients (figure 3).

88 From Morlais Junction to Llangyfelach Tunnel, the driver commanded full traction on the locomotive but train 6A11 initially struggled to increase its speed on the rising gradient and the anti-slip function of the traction control system had to intervene. OTDR data (identified by the red box on figure 14) showed that the torque applied to the wheelset was repeatedly reduced to match the available adhesion and that sanding was automatically activated.

89 RAIB used the OTDR data along the Swansea District line to calculate the tractive effort at the rail which, when combined with wheel slip data, allowed the adhesion levels to be estimated (figure 15).

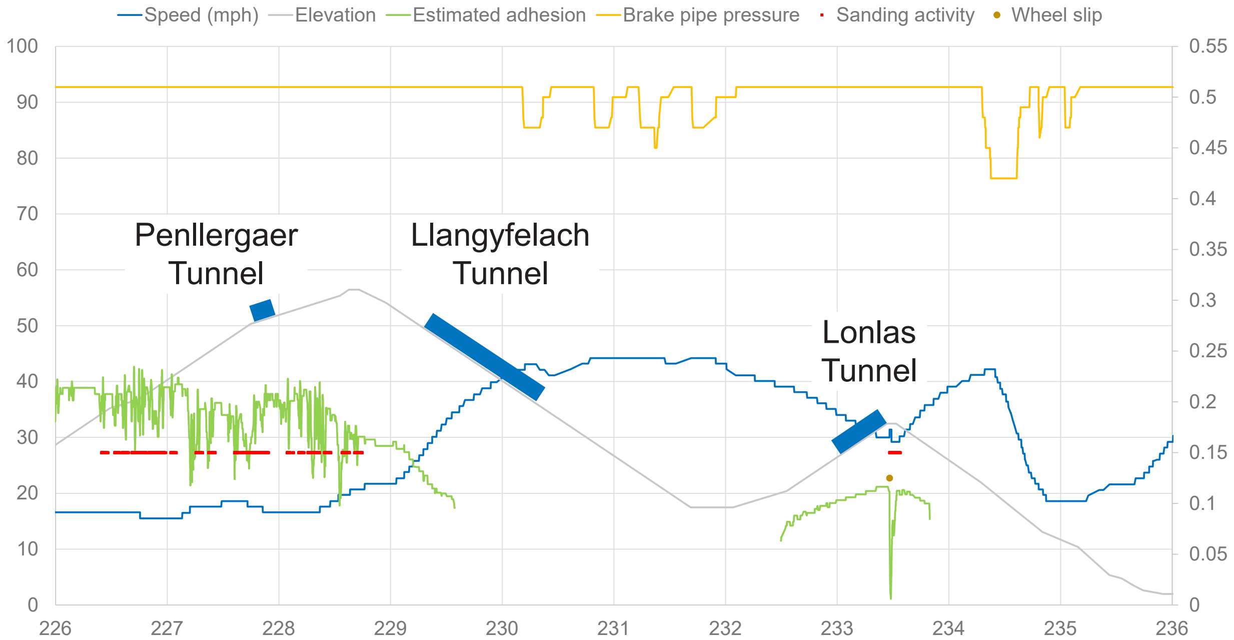

Figure 15: Results of analysis of the OTDR data for locomotive 60015 on 5 March 2021 to estimate adhesion.

90 This analysis found that the estimated level of adhesion along the stretch of line from Morlais Junction to the start of the descent towards Llangyfelach Tunnel was between 0.15 and 0.2 (figure 15). This was a time when the locomotive was repeatedly depositing sand on the rails and hence this estimated level of adhesion accounts for the effects of sand. A detailed examination of the adhesion curve (figure 16) shows that some of the lowest points of the adhesion curve occur immediately before sanding takes place. These lowest points of the adhesion curve give an instantaneous estimate of the adhesion that was present before sanding, and indicate that adhesion was as low as 0.1 along the stretch of line from Morlais Junction to the start of the descent towards Llangyfelach Tunnel.

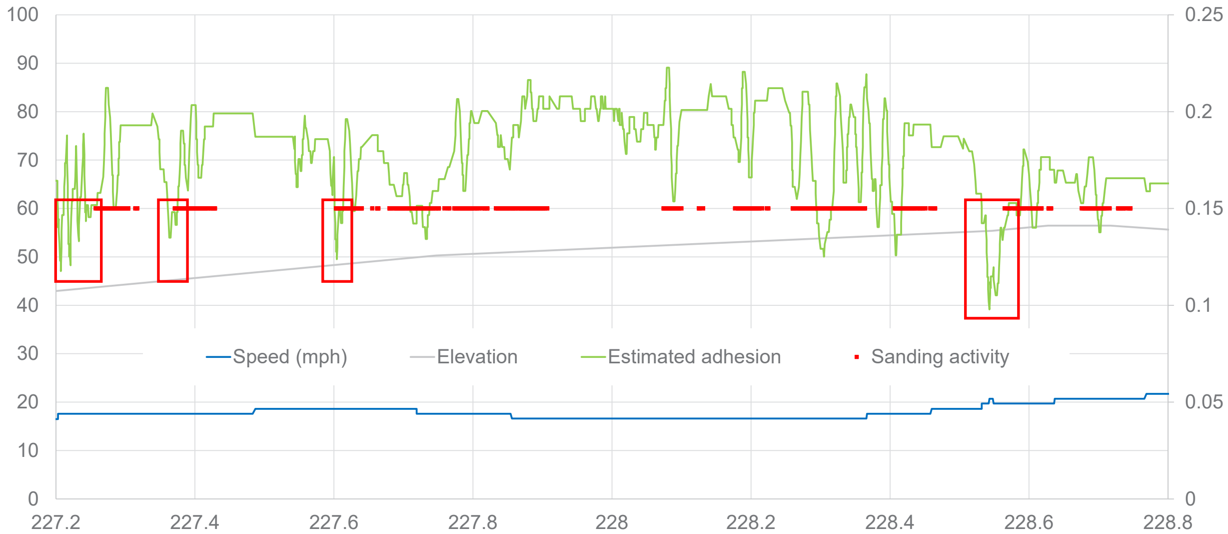

Figure 16: Detailed analysis of the adhesion curve for locomotive 60015.

91 From Llangyfelach Tunnel to the start of the ascent towards Lonlas Tunnel, the driver did not apply traction and hence the anti-slip function did not have to intervene. It is not possible therefore to estimate the level of adhesion that was present on this stretch of line.

92 The train then ascended the 1 in 120 gradient towards Lonlas Tunnel with the driver again commanding traction. The level of adhesion along that stretch was estimated to be around 0.1 (figure 15). As the train exited Lonlas Tunnel and started the descent towards Briton Ferry, the train recorded a ‘wheel slip’ indication on the OTDR. This indicates that the adhesion level in that area was very low as the traction system was not able to generate sufficient adhesion through its sanding and anti-slip function. The lowest point of the adhesion curve on figure 15 suggests an instantaneous un-sanded adhesion less than 0.05 (that is to say, very low).

93 During the descent towards Briton Ferry, the driver did not apply traction and hence the anti-slip function was not required. There is therefore no means of estimating the adhesion along that stretch of line on the day, other than by assuming that it would have been similar to that which the train experienced as it was about to start the descent (very low adhesion).

94 No further activation of the anti-slip function was recorded after the train rejoined the South Wales main line at Briton Ferry.

Wheel flat growth post-braking

95 The study commissioned by RAIB (paragraph 80) calculated that the wheel flats would have grown to around 70 mm in length by the end of the brake application from Lonlas Tunnel towards Dynevor Junction. Figure 17, developed as part of the study, shows that with a wheel flat length of 70 mm, adhesion would have needed to be greater than 0.08 to get the wheelset to start rotating after the brakes were released. This suggests that the wheelset involved would have stayed locked after the brakes were released, assuming that the adhesion levels remained in a similar range, and that the wheel flats would have continued to grow.[14]

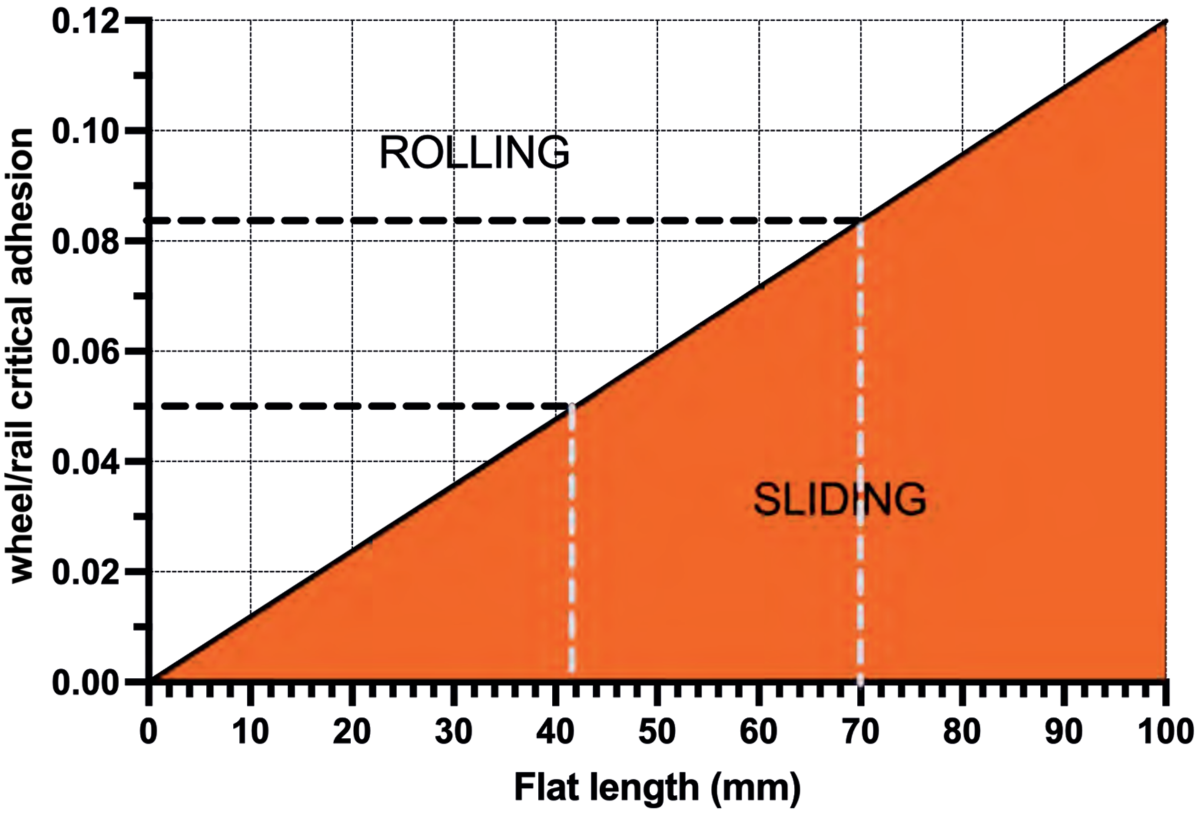

Figure 17: Plot showing the relation between wheel/rail critical adhesion and the flat length.

96 Once the train returned to the main line at Briton Ferry (about 2.5 miles (4 km) after the start of the braking event), the adhesion level is likely to have been different. The study concluded that, although it is possible that the wheelset started to rotate again at this location, it is more likely that it continued to slide. It is also possible that the accident wheelset, which by now had substantial wheel flats, rotated and then locked up again during subsequent brake applications on the approach to Margam.

[14] The work by Jergeus et al referred to in footnote 7 suggests that, by the time a wheelset has started to slide, the rate at which the flats will grow is mostly related to the contact forces and less dependent on the friction at the wheel/rail interface. In their experiments, the low adhesion conditions had been artificially created with soapy water. The paper concluded that it is uncertain whether real-life sources of low adhesion would show the same results.

97 By the time the train stopped at Margam for the planned driver swap, the flats would have likely reached the size found after the accident (paragraph 44). The train stood still at Margam for 1 hr 22 mins. The static adhesion on departure from Margam would likely have been sufficient for the accident wheelset to restart rotating as the train departed.

98 In summary, RAIB has concluded that the wheel flats on the trailing wheelset of wagon GERS89016 were probably generated when the wheelset locked during a braking event on the Swansea District line in conditions of very low railhead adhesion.

99 Several other wagons showed signs that their wheelsets had been either sliding or on the cusp of sliding (paragraph 45 and table 1). RAIB interpreted this as further evidence that the whole train had been running in conditions of very low adhesion at times. When tested, the brake forces generated at the block/wheel interface of wagon GERS89016 were found to be slightly above the expected range (paragraph 62) which might explain why this wagon was slightly more susceptible to developing wheel flats than others.

100 The Swansea District line was closed to rail traffic on 26 August 2020, following the accident at Llangennech (see paragraph 128). There had been significant damage to the railway and environmental pollution in the surrounding area. The line remained closed to rail traffic until the day of the accident on 5 March 2021 when it reopened at 21:00 hrs (paragraph 26). The reason that adhesion on the Swansea District line was very low is discussed below.

Low adhesion on the Swansea District line

101 Network Rail had not taken any precautions to ensure an adequate level of railhead adhesion was available when reopening the Swansea District line.

102 Network Rail manages the reopening of unused lines using its internal standard NR/L2/MTC/CP008 module 04.[15] None of the actions mentioned in this standard discuss controlling levels of railhead adhesion when reopening a line.

103 During the closure of the Swansea District line and before its reopening, Network Rail undertook the following activities in accordance with its track maintenance standards:

- basic visual inspections in accordance with track maintenance standards to assure itself that the lines were fit for purpose
- inspections for railhead wear
- ultrasonic testing to confirm the absence of rail internal defects in accordance with its ultrasonic testing regime (performed manually)
- track-mounted flange lubricator maintenance (servicing the lubricators and topping up grease in the days before the reopening of the line).

None of these activities were focused on assessing and controlling the level of railhead adhesion on the line.

[15] NR/L2/MTC/CP008/04 issue 1 ‘Returning to a full operational service’ dated 30 November 2020.

104 The Swansea District line is also fitted with traction gel applicators. Traction gel applicators are designed to increase the adhesion on the top of the railhead by applying a traction enhancing material. However, Network Rail only uses them on this line during leaf fall season and the accident took place outside of that season (see paragraph 113).

105 Network Rail undertook a visual inspection of the line on 14 March 2021 to assess its condition. This was nine days after the accident involving train 6A11. Figure 18 shows the condition of the railhead on that day at a location between Lonlas Tunnel and Dynevor Junction. The photograph shows a lack of a running band (where the repeated passage of trains normally leaves a shiny band on the railhead as shown, for example, on figure 8). Where the running band would normally be located, the photograph shows rust.

Figure 18: Railhead condition on the line between Lonlas Tunnel and Dynevor Junction (courtesy Network Rail).

106 Results from analysis of swabs of the railhead taken by Network Rail during the 14 March 2021 track inspection showed:

- evidence of large amounts of brown dirt/debris and a trace of metallic particles (this is to be expected from a railhead surface but is also consistent with the presence of rust)
- no visual evidence of sand/sandite[16] or intact leaf material/vegetation. A microscopic examination revealed elevated levels of silicon, which confirmed the presence of crushed sand
- trace amounts of hydrocarbon material similar to that of hydrocarbon wax but no evidence of natural alcohols or hydrocarbons associated with leaf/vegetation matter
- traces of amines and acid esters.

107 The samples were taken nine days after the accident, at a time when some rail traffic, including passenger trains, had restarted using the line. The presence of crushed sand can therefore be expected and is not necessarily an indication that sand was present at the time of the passage of train 6A11 on 5 March 2021.

108 The presence of rust and hydrocarbon materials on the railhead is important as these are known to be potential sources of low adhesion. Rust, in particular when combined with a small amount of water, is known to lead to low or very low adhesion levels. In its guidance on managing low adhesion (paragraph 77), the Adhesion Working Group gives the following advice when reopening a line previously out of use:

Opening lines previously out of use	Rails not used for periods of time can accumulate detritus as well as forming surface rust. When used for the first time, and particularly if combined with damp or wet rail conditions, adhesion levels can be significantly reduced. The risk to safety is dependent on the features of the line, but particular consideration should be given by Network Rail to advising drivers of the first train(s) over a re-opened route where signals at danger or buffer stops may present a particular hazard.

Figure 19: Advice from the Adhesion Working Group on reopening out-of-use lines.

109 Train 6A11 passed Morlais Junction at 23:21 hrs and Briton Ferry at 23:52 hrs. Table 3 shows the weather report including the air temperature, the dew point and humidity levels, between 22:59 hrs and 23:59 hrs, at a weather station[17] located between Llangyfelach Tunnel and Lonlas Tunnel.

Time	Air temperature	Dew point	Humidity levels
22:59	0.6°C	-1.8°C	84%
23:09	0.8°C	-1.8°C	83%
23:19	0.9°C	-1.7°C	83%
23:29	0.9°C	-1.7°C	83%
23:39	0.9°C	-1.7°C	83%
23:49	0.9°C	-1.7°C	83%
23:59	1.0°C	-1.6°C	83%

Table 3: Weather report at local weather station on 5 March 2021.

[16] A substance made of sand, antifreeze and steel shot that is deposited on the rails to improve railhead adhesion.

[17] https://www.wunderground.com/dashboard/pws/ISWANSEA13/graph/2021-03-5/2021-03-5/daily.

110 The air temperature at the time was cold, close to freezing, and the humidity levels were high. In cold weather, the rail temperature can be lower than the air temperature.[18] With the rail temperature being near the dew point, it is likely that the metal rail would have caused the humid air to condense, and that dew would have formed on the railhead. This means that the rails on the Swansea District line would have been wet at the time train 6A11 travelled over them.[19] RAIB concluded that it was the presence of rust and water which led to the very low adhesion conditions on the Swansea District line. The presence of rust was a result of Network Rail not acting to control adhesion levels when reopening a line closed for a long period.

Identification of underlying factors

Network Rail's management of low adhesion

111 Network Rail's adhesion-related standards only consider the management of railhead adhesion during the leaf fall season.

112 Network Rail's standard dealing with the management of low adhesion is NR/L2/OPS/095. It is titled 'High risk sites for wrong-side track circuit failures (WSTCF) in leaf areas and for low rail adhesion'. Despite its title suggesting that it deals with low rail adhesion in general, its purpose explicitly states that it relates to the leaf fall season, which is defined by Network Rail as running from 1 October to 13 December each year. This standard references other standards including GO/RT3208[20] (which has been superseded by RIS-3708-TOM[21]) for the actions to take at high-risk sites. Again, these standards apply only during the leaf fall season.

113 RAIB analysis and witness evidence showed that the Swansea District line had a history of adhesion-related incidents during the leaf fall season. In response, Network Rail would commission the traction gel applicators (paragraph 104) and run the railhead treatment train[22] once a day, six days per week along the line during the leaf fall season. However, at the end of a leaf fall season, these activities would stop, and the equipment would be decommissioned until required again the following year.

114 This focus on the leaf fall season in standards meant that Network Rail did not apply any specific measure to ensure adequate railhead adhesion when it reopened the Swansea District line in March 2021.

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[18] See figure 14 in 'A study into the effect of the presence of moisture at the wheel/rail interface during dew and damp conditions' by B.T. White et al from the University of Sheffield (2017).

[19] While it is also possible that ice was present on the railhead, this will melt under the passage of the train wheels, leaving a small amount of water on the rails, similar to dew.

[20] GO/RT3208 issue 3 'Arrangements concerning the non-operation of track circuits during the leaf fall contamination period' dated August 2007.

[21] RIS-3708-TOM issue 2 'Arrangements concerning the non-operation of track circuits during the leaf fall contamination period' dated September 2017.

[22] A multi-purpose vehicle used to apply sandite or high pressure water jets to combat rail head contamination during leaf fall season.

115 The Adhesion Working Group has issued guidance regarding the reopening of unused lines and the risk associated with rust and water creating poor adhesion levels (paragraph 108). However, Network Rail advised RAIB that its standard for reopening an unused line, NR/L2/MTC/CP008, did not refer to the guidance, nor did it mention the risk of low adhesion when reopening an unused line. Network Rail further advised that the guidance provided by the Adhesion Working Group is intended to be non-binding. As such, Network Rail considered that there was no need to cascade its content into its standards.

Observation

116 The train was allowed to continue in service from Cardiff to Bristol, despite the presence of wheel flats having been detected.

117 As train 6A11 passed Cardiff ROC at 02:30 hrs, Network Rail's staff inside the building realised that one of the wagons was travelling with wheel flats (paragraph 36). The South Wales main line signaller immediately called the driver to bring the train to a stop, following the instructions within general signalling regulation 19 of the Rule Book.[23] The next step, if actions were taken in accordance with the Rule Book, would have been to 'arrange for the train to be examined and dealt with as necessary'. This would normally mean instructing the driver to examine his train and report back to the signaller any findings.

118 In this instance, this did not happen. Instead, the shift signalling manager and the incident controller formulated a plan for the train to move forward to the Marshfield WILD site. The expectation was that the wagon with wheel flats would trigger the WILD site and the train would then be directed towards Alexandra Dock.[24] As a result, the train driver set off towards Marshfield without examining his train, expecting a call shortly after passing the WILD site.

119 The shift signalling manager and incident controller have immediate access to a report showing the measurements for a train passing a WILD site. In this case, the report for train 6A11 did not indicate a problem with any of the wagons on the train. As a result, the shift signalling manager and incident controller allowed the train to continue on its journey. The train was only stopped an hour later near Bristol. Although no further infrastructure damage occurred, the infrastructure and the train were exposed to an increased risk of sustaining damage during this period.

120 The report produced by the WILD site did not raise any concern with any of the wagons on train 6A11 because the measurements of the impact loads generated by the flats on wagon GERS89016 were so extreme that the software discounted them as false readings. If it suspected a false reading, the software would default to returning the wheel weight measurements only for the entire train (no impact measurement). When this happened, there was no obvious message provided by the software to advise the reader of the report that this default had occurred.

[23] GERT8000 TS1 'General signalling regulations', Section 19 'Stop and examine train', issue 14, December 2020.

[24] Network Rail's National Operating Procedure NR/L3/OPS/045/3.21 issue 2 'Asset monitoring systems wheel impact load detector (WILD) and hot axlebox detector (HABD)' allows for a train that has triggered an alarm at a WILD site to be moved at a reduced speed to the next available location.

121 Had the software reported the measurements of the impact loads, the shift signalling manager and incident controller would have realised that the train needed to be stopped as at least two wagons, including wagon GERS89016, had measurements in excess of the alarm limits.

Previous occurrences of a similar character

122 RAIB has previously investigated similar accidents involving similar trains travelling along the same route resulting in a similar outcome.

Ferryside investigation

123 On 30 October 2017, train 6B13, 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 on the Swansea District line, the driver found that there had been a catastrophic failure of the braking system on one of the wagons. This accident was investigated by RAIB (RAIB report 17/2018).

124 The investigation found that one of the wheelsets on the damaged wagon had locked up and entered a slide, causing severe wheel flats, before it started to rotate again. Impacts from these wheel flats caused damage to 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.

125 RAIB's investigation found that the wheelset involved had probably 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 a few days before the accident.

126 RAIB reanalysed the OTDR data of the locomotive involved in the Ferryside accident to determine whether there were also signs of very low adhesion being experienced during the journey.

127 Figure 20 shows the analysis of the OTDR data from the locomotive involved in the Ferryside accident, presented in the same way as in figure 14, which shows data from the locomotive involved at Pencoed. Figure 20 shows numerous activities of the anti-slip function of the traction control system and associated sanding, combined with several instances of wheel slip activities being recorded. This suggests that the Ferryside locomotive (number 60001) was struggling for adhesion throughout its journey on the day of the accident and hence that very low adhesion was a possible causal factor to the Ferryside accident. RAIB's report into this accident has been updated accordingly by inclusion of an addendum.

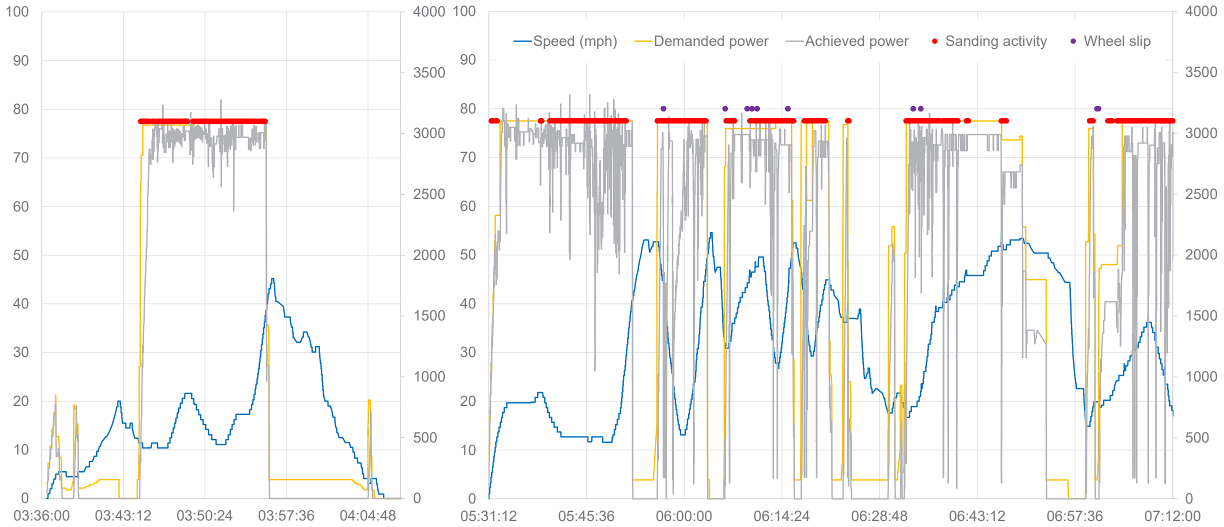

Figure 20: Analysis of the OTDR data for locomotive 60001 on 30 October 2017.

Llangennech investigation

128 On 26 August 2020, train 6A11, the 21:52 hrs service from Robeston (Milford Haven) to Theale, conveying 25 wagons carrying oil-based products, derailed near Llangennech, on the Swansea District line. The derailment and the consequent damage to the wagons resulted in a significant spillage of fuel and a major fire. The driver, who was unhurt, reported the accident to the signaller. Subsequent examination of the site found that ten wagons (positioned third to twelfth in the train) had derailed, and that around 446,000 litres of fuel had escaped. This accident was investigated by RAIB (RAIB report 01/2022).

129 The derailment occurred because one wheelset on the third wagon in the train stopped rotating during the journey. The wheelset had become locked, probably because of a defect in the braking system on the third wagon, arising from deficiencies in the design and maintenance of components. The sliding of the locked wheelset along the railhead caused damage to the profile of the wheel treads. This meant that the wheels were unable to safely negotiate Morlais Junction, near Llangennech, damaging the pointwork and causing the third wagon to become derailed. The following wagons derailed on the damaged track. Some of the derailed wagons were ruptured in the accident, and the spilling fuel ignited.

130 RAIB revisited the OTDR data of the locomotive (number 60062) involved in the Llangennech accident to determine whether there were signs of low adhesion being experienced during the journey. Figure 21 shows the analysis of the OTDR data presented in the same way as in figures 14 and 20. Figure 21 shows a very small amount of activity of the anti-slip function of the traction control system on departure from a standstill, combined with sanding activity. This suggests that the locomotive was not experiencing conditions of very low adhesion on its journey.

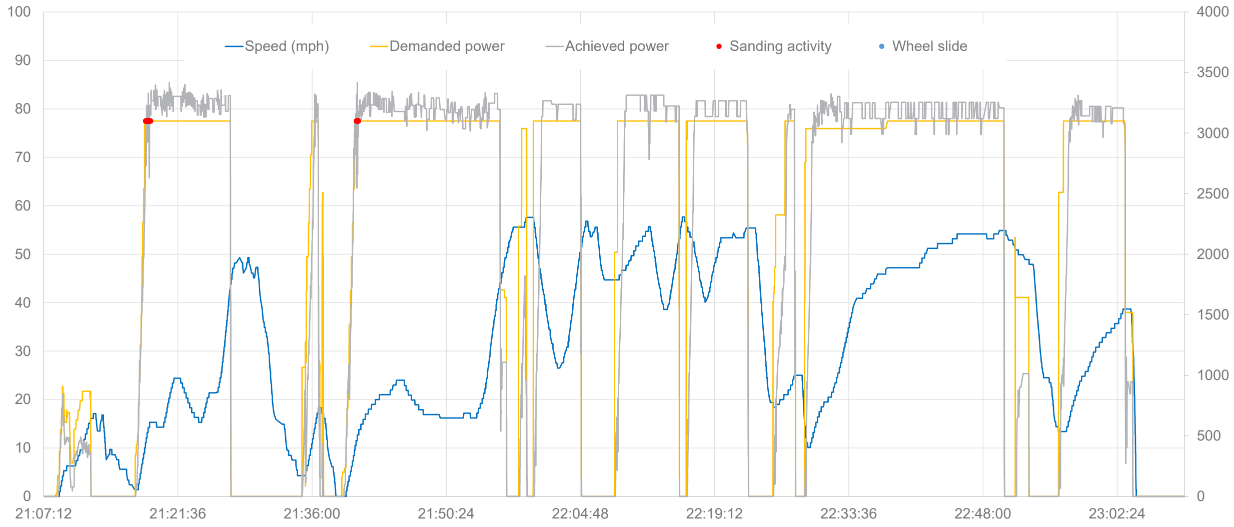

Figure 21: Analysis of the OTDR data for locomotive 60062 on 26 August 2020.

Summary of conclusions

Immediate cause

131 The damage to the infrastructure between Pencoed and Llanharan was caused by impact loading from the rotation of a wheelset with severe wheel flats on train 6A11 (paragraph 50).

Causal factor

132 The causal factor was that the trailing wheelset of the leading bogie of wagon GERS89016 developed severe wheel flats during its journey from Robeston to Pencoed (paragraph 54). This happened probably because:

1 The wheelset locked up and developed wheel flats during a normal braking event because of very low railhead adhesion along the Swansea District line (paragraph 73). This happened because:

i. Network Rail had not taken any precautions to ensure an adequate level of railhead adhesion was available when reopening the Swansea District line (paragraph 101, **Recommendation 1**).

Underlying factor

133 The underlying factor was that Network Rail's adhesion-related standards only consider the management of railhead adhesion during the leaf fall season (paragraph 111, **Recommendation 1**).

Observation

134 The train was allowed to continue in service from Cardiff to Bristol, despite the presence of wheel flats having been detected (paragraph 116, **Learning point 1**).

Previous RAIB recommendations relevant to this investigation

135 None of the recommendations made by RAIB as a result of its previous investigations into the Ferryside and Llangennech accidents are relevant to this investigation.

136 RAIB's Ferryside report contained a learning point relevant to this investigation. This learning point reads:

> '*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'*.

Actions reported that address factors which otherwise would have resulted in an RAIB recommendation

137 In April 2021, Network Rail advised RAIB that it has modified the software that controls the output of the wheel impact load detection systems so that it raises an automatic alert in the case when the impact force measurements have been discarded by the software (paragraph 120).

138 In May 2022, the Seasonal Challenge Steering Group issued a new document[25] setting out the approach of the rail industry to the management of railhead adhesion. The document lists a range of control measures that can be considered by duty holders to manage railhead adhesion. The main focus of the document remains on the leaf fall season.

Other reported actions

139 On 9 May 2021, DB Cargo advised Network Rail that it could restart routing DB Cargo's freight trains over the Swansea District line.

[25] 'GB rail industry approach to railhead adhesion management' version 1.0, dated 31/05/22.

Recommendation and learning point

Recommendation

140 The following recommendation is made:[26]

1 *The intent of this recommendation is to ensure that adequate levels of wheel/rail adhesion are available to allow the safe operation of trains.*

Network Rail should review the guidance provided by the Adhesion Working Group and other industry good practice to identify all occasions outside the leaf fall season which could result in very low levels of wheel/rail adhesion. Following its review, Network Rail should revise its existing processes and standards to acceptably control the risks associated with very low levels of wheel/rail adhesion. Network Rail should appropriately brief those staff responsible for implementing these processes and standards on any changes made (paragraphs 132 and 133).

Learning point

141 RAIB has identified the following important learning point:[27]

1 General signalling regulation 19 of the railway Rule Book (GERT8000 Module TS1, Section 19) requires signallers to arrange for a train to be stopped and examined if they become aware of an unusual noise coming from a wagon. Delaying such an examination until the train is at a more convenient location introduces additional risk to the train and infrastructure and, as such, great care is needed when considering doing so (paragraph 134).

[26] 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 (ORR) 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.

[27] 'Learning points' are intended to disseminate safety learning that is not covered by a recommendation. They are included in a report when RAIB wishes to reinforce the importance of compliance with existing safety arrangements (where 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.

Appendices

Appendix A - Glossary of abbreviations and acronyms

BFCB	Block force compact bogie-mounted
CCTV	Closed-circuit television
GSM-R	Global System for Mobile communication - Railway
HABD	Hot axlebox detector
OTDR	On-train data recorder
RAIB	Rail Accident Investigation Branch
ROC	Railway Operations Centre
TVSC	Thames Valley Signalling Centre
WILD	Wheel impact load detector

Appendix B - Investigation details

RAIB used the following sources of evidence in this investigation:

- information provided by witnesses
- information taken from the train's on-train data recorder (OTDR)
- CCTV recordings taken from the stations along the route of train 6A11
- data from the WILD at Marshfield
- data from the HABD systems along the route
- site photographs and measurements
- weather reports and observations at the site
- a report commissioned by RAIB from nC² titled 'Investigation into a braking incident on train 6A11 on 5/6 March 2021'
- data from Network Rail's control centre incident log
- a review of previous RAIB investigations that had relevance to this accident.

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