Rail Accident Investigation Branch

Rail Accident Report

Freight train derailment at Petteril Bridge Junction, Carlisle
19 October 2022

Report 10/2023
October 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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Freight train derailment at Petteril Bridge Junction, Carlisle, 19 October 2022

Contents

Summary

At 19:53 hrs on Wednesday 19 October 2022, five tank wagons in a freight train that was conveying cement powder from Clitheroe, Lancashire, to Mossend, near Glasgow, derailed near Petteril Bridge Junction in Carlisle. A number of wagons were damaged and there was significant damage to the track and to the bridge over the River Petteril. This resulted in closure of the routes from Carlisle to Newcastle-upon-Tyne and to Settle for seven weeks. No one was injured.

The derailment occurred because one set of wheels on the ninth wagon in the train stopped rotating during the journey. These wheels had stopped rotating up to 55 miles (88 km) before the derailment and continued to slide along the railhead causing considerable damage to the profile of the wheel treads. This meant that the wheels were unable to safely negotiate a set of points just before Petteril Bridge Junction, damaging them and causing the ninth wagon to become derailed. Five of the wagons derailed due to the consequent track damage and two of them fell off the side of the bridge where the railway crosses the River Petteril. The ninth tank wagon was ruptured and landed upside down in the river, although very little of the cement powder was spilled.

The initial wheel slide was probably the result of a normal brake application made in low adhesion conditions that were not abnormal for the route at the time of year. The wheel slide continued because the adhesion between the wheels and the rails was then insufficient for the wheels to restart rotation.

The non-rotating wheels were not identified by the signallers on the route, nor by the train driver or any engineered system, meaning that the train was not stopped before it reached Petteril Bridge Junction.

RAIB has made one recommendation to the railway industry to undertake work to understand the specific risks to freight trains in low adhesion conditions. RAIB has also made two recommendations to the railway industry relating to reviewing the railway Rule Book requirements for stopping and examining trains and the requirements relating to drivers looking back along their trains.

RAIB has also identified one learning point for signallers, reminding them of the circumstances in which they should stop trains for examination.

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 and acronyms, which are explained in appendix A. Sources of evidence used in the investigation are listed in appendix B.

The accident

Summary of the accident

3 At 19:53 hrs on Wednesday 19 October 2022, five wagons in a freight train, reporting number 6C00, derailed as it was passing through 679A points, close to Petteril Bridge Junction, south-east of Carlisle station (figure 1). The train was approaching from the Settle direction and travelling at around 17 mph (27 km/h) when the derailment occurred. Two of the derailed wagons fell from the bridge which takes the railway over the River Petteril, with one landing in the river and the other on the riverbank (figure 2).

4 No one was injured in the accident, but there was significant damage sustained to the railway infrastructure which resulted in the closure of the routes from Carlisle towards both Newcastle-upon-Tyne and Settle for seven weeks. Immediately after the derailment, it was identified that the leading wheelset of the ninth wagon of the train (number VTG12455) had a very large wheel flat (a flat spot on the wheel tread) on each wheel (figure 3).

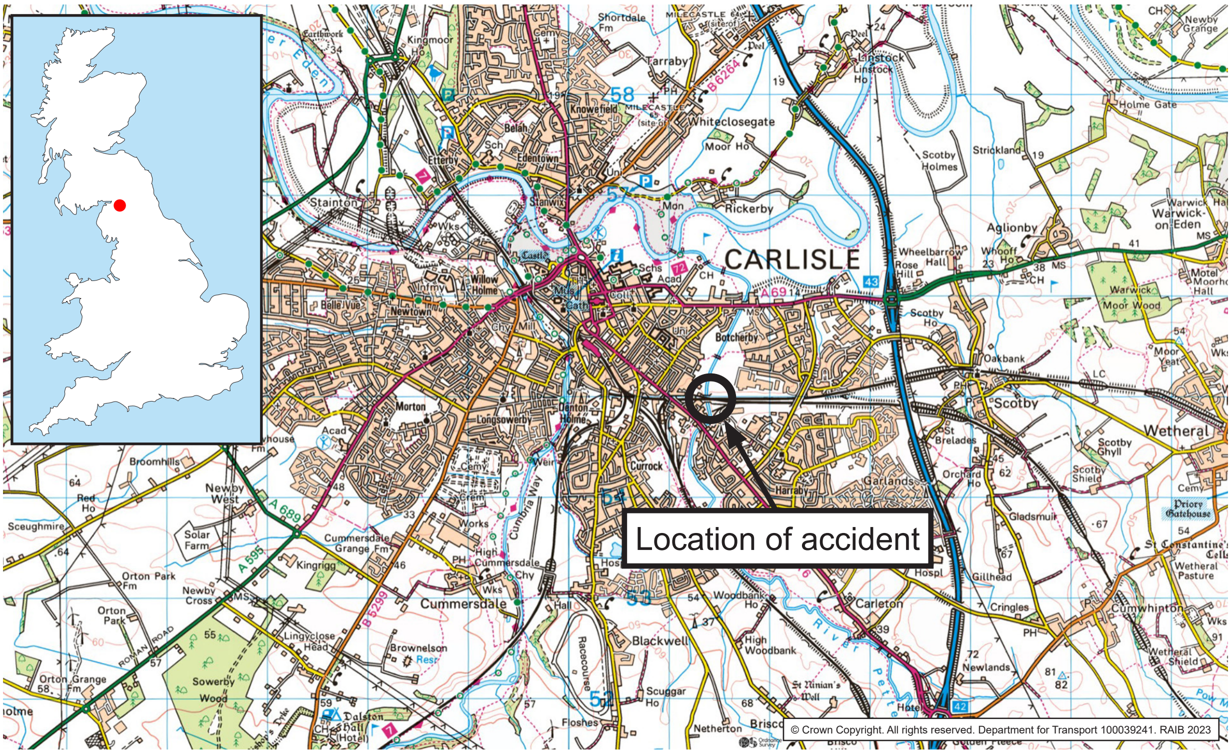

Figure 1: Extract from Ordnance Survey map showing location of accident at Petteril Bridge Junction.

Figure 2: Overview of derailed wagons at Petteril Bridge Junction.

Figure 3: *Wheel flat observed on the leading wheelset of the ninth wagon immediately after derailment.*

Context

Location

5 The derailment occurred at a set of trailing points, in the direction of travel of the train, (numbered 679A) which is located at 307 miles 10 chains from London St Pancras[1] (figure 4). This set of points provides access to the sidings for a disused oil depot, on the Down (northbound) Settle to Carlisle line, about 50 metres to the east of Petteril Bridge Junction. The Settle to Carlisle line remains double tracked as it passes through Petteril Bridge Junction.

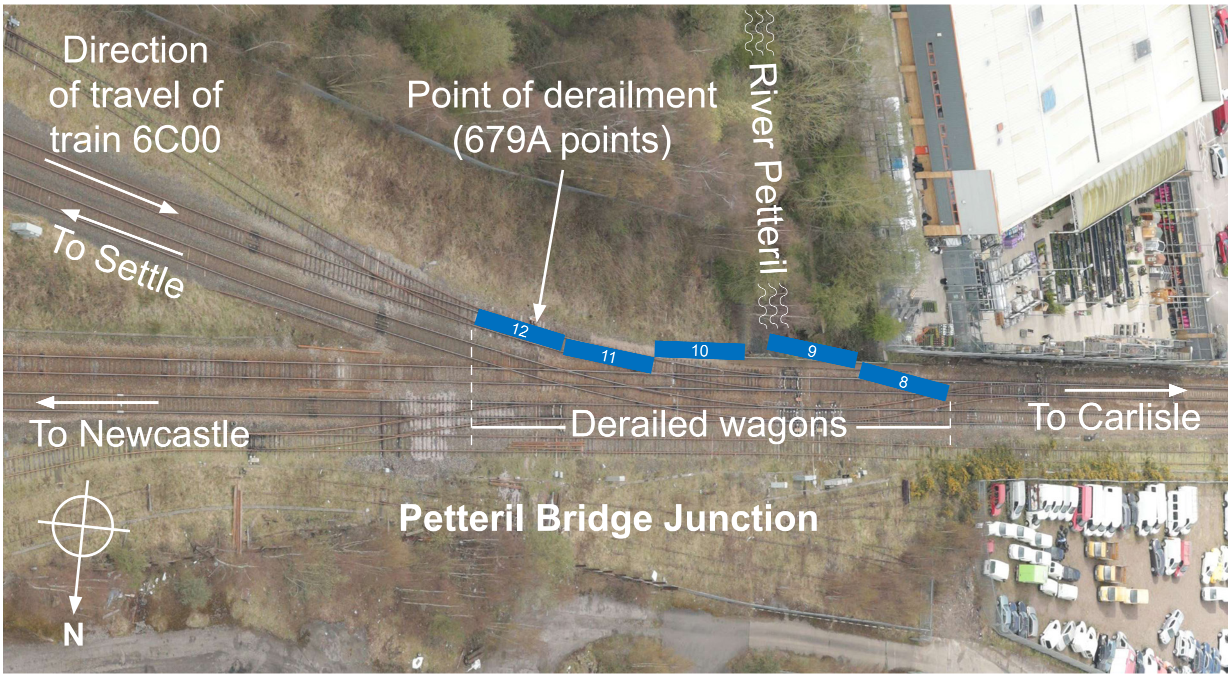

Figure 4: Aerial view of the derailment site, showing positions of derailed wagons (background image courtesy of Network Rail).

6 The permissible speed at the point of derailment, and through Petteril Bridge Junction, is 20 mph (32 km/h). The permissible speed on the route of the train before the point of derailment is 60 mph (96 km/h), reducing about 140 metres before Petteril Bridge Junction. At the point of derailment, the gradient is level after a long descent from the north Pennine hills.

7 The signalling at the derailment location was controlled from the signal box at Carlisle. However, the rest of the journey of the train over the Settle to Carlisle line was controlled from a series of signal boxes operating under the 'absolute block' system.[2]

Organisations involved

8 GB Railfreight Limited (GBRf) was the operator of train 6C00 and the employer of the train driver. It was also the employer of the ground staff operator who prepared the train at Clitheroe.

[1] This mileage is referenced to a zero point at the original buffer stops in London St Pancras station, via the Erewash valley route, the 'Old Road' via Beighton Junction, and the now closed route via Cudworth.

[2] The operating principle of the absolute block signalling system is to only allow one train to occupy a defined 'block section' of line between two signal boxes at any time.

9 VTG Rail UK Limited is the owner of the wagons involved in the accident. It is the entity in charge of maintenance for the wagons, with the maintenance work itself being contracted out to DB Cargo Limited at Clitheroe.

10 Network Rail is the owner and maintainer of the railway infrastructure, and the employer of the signallers along the route. It is also responsible for the seasonal management of rail adhesion along the route.

11 Wabtec Faiveley UK[3] and Knorr-Bremse Rail Systems UK are the respective manufacturers of the brake cylinders and the brake distributor on the wagons.

12 GBRf, VTG and Network Rail all freely co-operated with the investigation. Wabtec Faiveley and Knorr-Bremse Rail both freely provided technical assistance during testing of the components from the wagons.

Train involved

13 The train consisted of a class 66 diesel-electric locomotive (number 66739) hauling 14 JPA tank wagons that were fully loaded with powdered cement. Each JPA wagon was carrying a load of approximately 80 tonnes of cement, with the loaded wagons each weighing about 101 tonnes. The maximum permissible speed of the loaded train was 60 mph (96 km/h).

14 Train 6C00 was the 17:15 hrs freight service from Clitheroe Castle Cement sidings to Carlisle Network Yard (located to the north of Carlisle station). The train was scheduled to continue to Mossend, near Glasgow, the following day for unloading. The same locomotive had brought the empty wagons south from Carlisle to Clitheroe that morning.

15 The wagons were part of a sub-fleet that was operationally constrained to the Clitheroe to Mossend traffic flow. Other sub-fleets of similar JPA wagons operated on different traffic flows out of Clitheroe, Hope (Derbyshire), Padeswood (Flintshire) and Dunbar (East Lothian) cement terminals.

Equipment involved

16 Each of the JPA wagons was fitted with two TF25 type bogies. One bogie on each wagon was fitted with a manually operated handbrake acting on both wheelsets in that bogie (see paragraph 90).

17 The train was fitted with a single-pipe air brake system, operating on all the wheels of all the 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 driver regulates the pressure in the pipe to control the brakes on the train. To release the brakes when running, air pressure is created in the brake pipe. The pressure in the brake pipe when the brakes are fully released is normally 5 bar. Reducing the air pressure in the brake pipe proportionally increases the force of the brake application. Once the brake pipe pressure decreases to 3.3 bar, ‘full service’ braking is applied.

[3] A trading name of Faiveley Transport Birkenhead Ltd, which is part of the Wabtec Group.

18 Each wagon is fitted with a single brake distributor (figure 5) and a separate auxiliary air reservoir located under the centre of the wagon body. A reduction in the pressure in the train's brake pipe causes the distributor 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 then 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, JPA wagons are not fitted with a wheel slide protection system. Such systems, common on passenger trains, detect wheelsets starting to slide when braking and automatically reduce the brake force being applied to the sliding wheelset until the system determines that they are no longer sliding.

Figure 5: A JPA wagon and the location of its distributor (auxiliary reservoir hidden under wagon).

19 The brake equipment fitted to the bogies of a JPA wagon 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 both within the United Kingdom and internationally.

20 The BFCB system 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 rods, 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 slack adjusters within the brake cylinders.

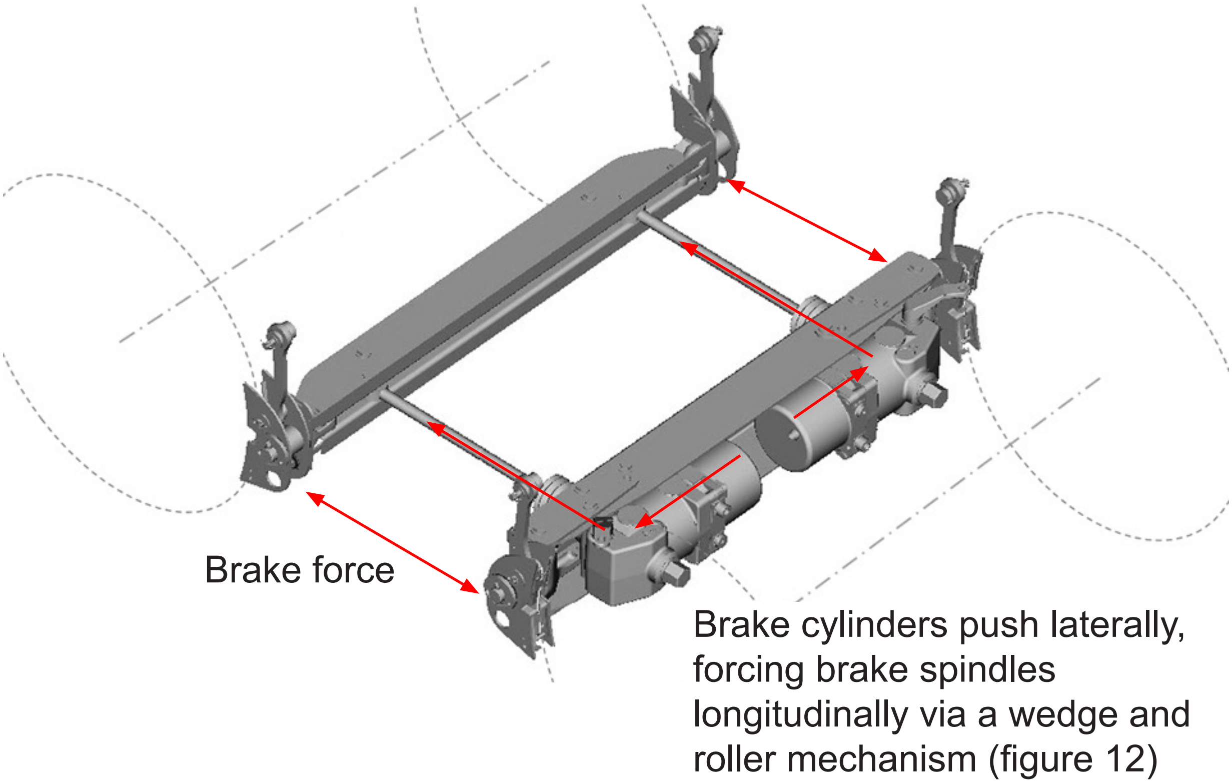

Figure 6: BFCB braking system for one bogie (brake blocks not shown).

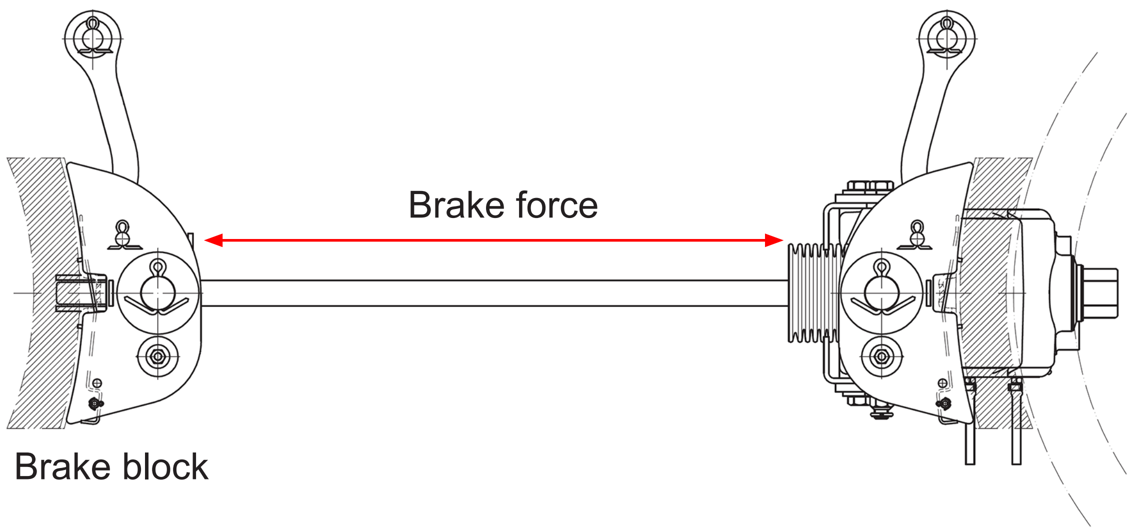

Figure 7: Side view of BFCB braking system.

Staff involved

21 The driver had worked on the railway for 39 years, with the last 22 of those driving freight services. The driver regularly drove class 66 locomotives, and often drove this service over the Settle to Carlisle route. The driver held the relevant competencies for driving class 66 locomotives and had up-to-date route knowledge for the route from Clitheroe to Carlisle. GBRf stated that there was no record of this driver having been involved in any relevant safety-related incidents.

22 The ground staff operator who helped prepare the train at Clitheroe had worked in that role for three years and was acting as a mentor for a new trainee. Before that the operator had worked on the railway in another role for eight years. GBRf stated that there was no record of this staff member having been involved in any safety-related incidents.

23 The signaller at Culgaith signal box (figure 8) had been a signaller for 20 years and had operated Culgaith signal box for most of that period. This signaller held the relevant competencies required to operate Culgaith signal box at the time of the accident. Network Rail stated that there was no record of this signaller having been involved in any relevant safety-related incidents.

24 The signaller at Low House signal box (figure 8) had worked as a relief signaller for 23 years, covering several signal boxes on the Settle to Carlisle line, including both Low House and Culgaith. This signaller held the relevant competencies required to operate these signal boxes. Network Rail stated that there was no record of this signaller having been involved in any relevant safety-related incidents.

External circumstances

25 Records from local weather stations along the route of the train, between Settle and Carlisle, recorded no rainfall on the evening of 19 October 2022. However, witness evidence was that the rails were damp at both Culgaith and Low House signal boxes.

26 Weather stations at Dent and Garsdale recorded the average wind speeds as being between 15 and 20 mph (24 and 32 km/h). This, combined with the time of year, meant that there was a high risk of leaves falling from trees and being blown around.

27 The recorded average air temperatures at Garsdale were around 9°C, very close to the recorded dew point of about 8°C. Temperatures at lower altitudes on the Settle to Carlisle route were a little warmer at up to 12°C.

28 It was dark at the time of the derailment, although the train had left Clitheroe during daylight, with dusk falling on the initial climb towards Blea Moor.

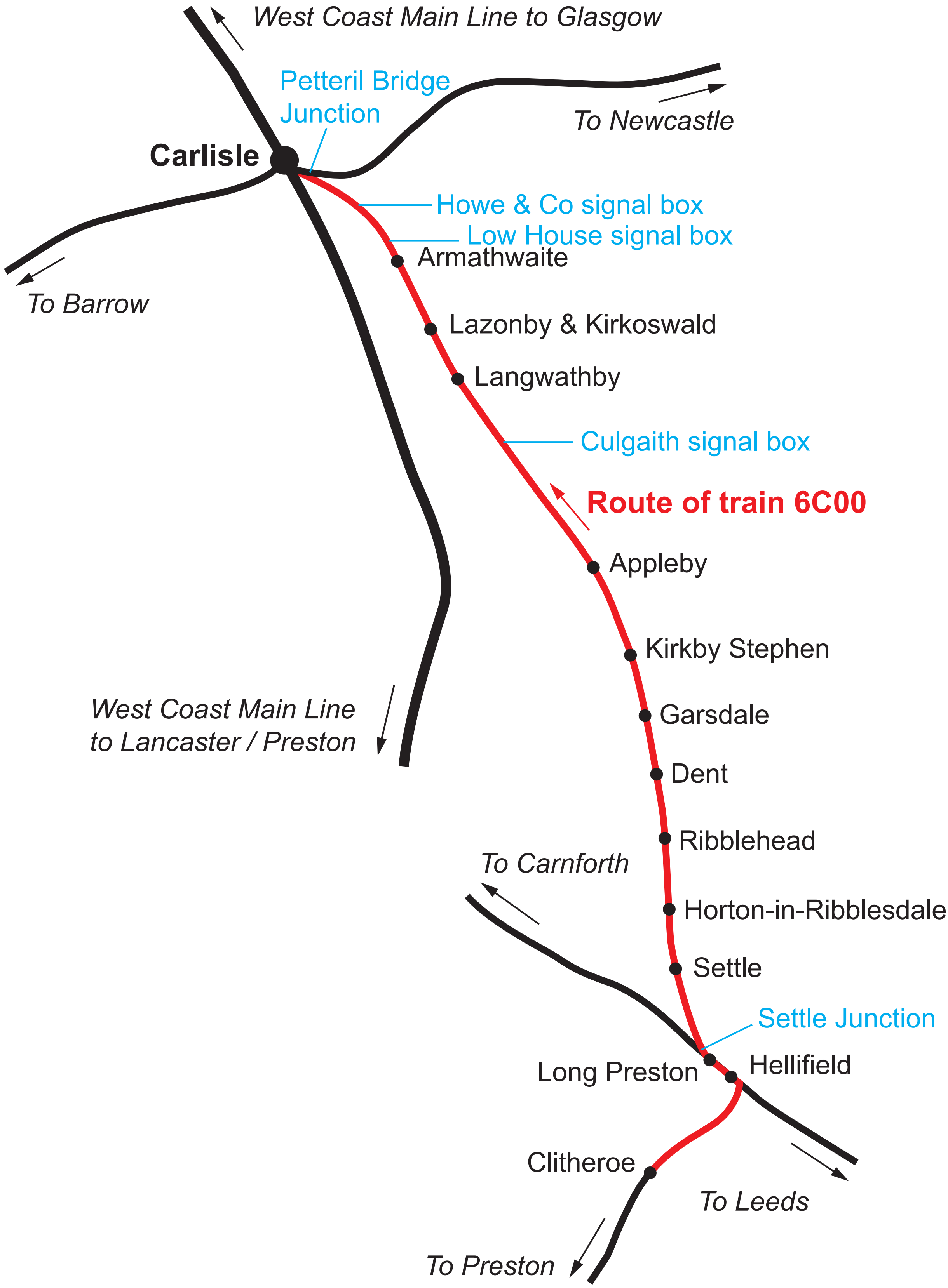

Figure 8: Route of train 6C00.

Background information

Route of the train

29 After departing from Clitheroe cement terminal, train 6C00 started its journey from Horrocksford Junction over the (primarily freight-only) route which runs from there to Hellifield. This route was mostly on rising gradients, with a maximum permissible speed of 30 mph (48 km/h) for freight trains.

30 At Hellifield, the train joined the route via Settle Junction to Carlisle (the Settle to Carlisle line). After a gentle climb, the route includes a long, steep ascent into the north Pennine hills, with a 15 mile (24 km) stretch at an average gradient of 1 in 107. There is then a flatter 10 mile (16 km) long stretch along the top of the hills before a 15 mile (24 km) long descent at an average gradient of about 1 in 120, followed by a gentler descent towards Petteril Bridge Junction. Figures 8 and 9 show the route and gradient profile for the journey of train 6C00 from Clitheroe to Carlisle.

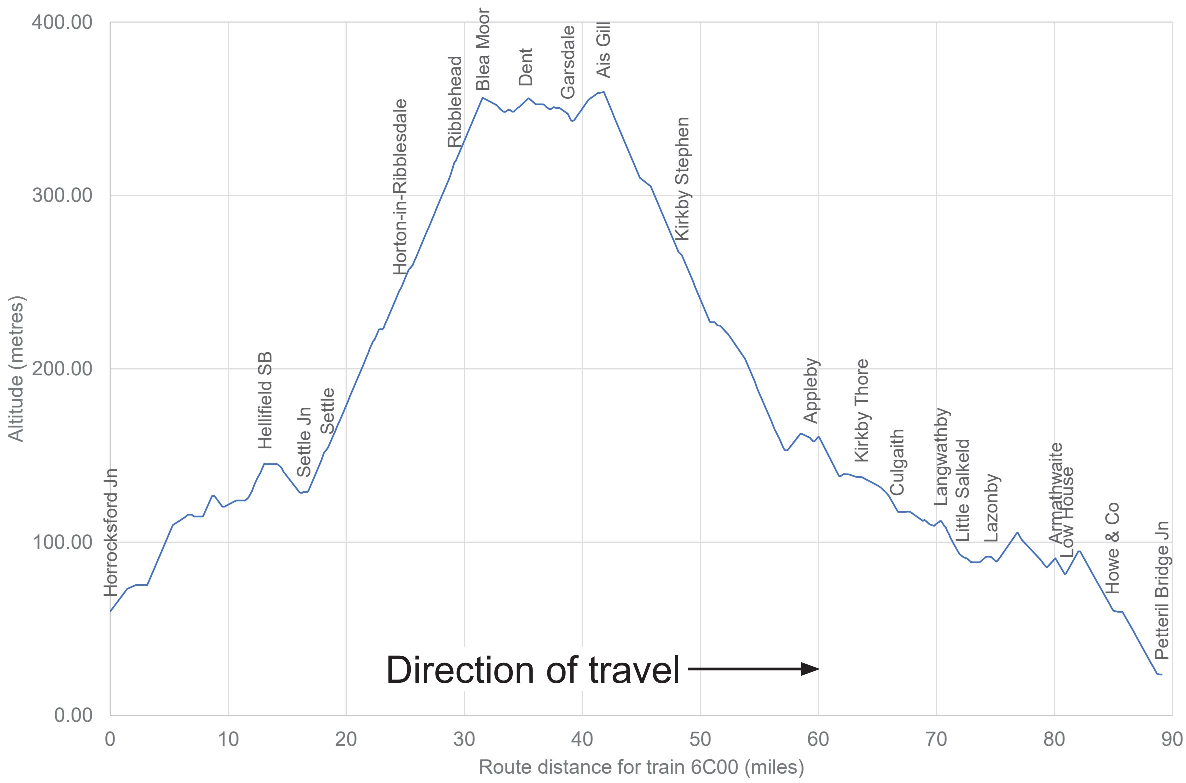

Figure 9: Gradient profile for the route of train 6C00.

Pre-existing wheel flats on the train

31 Eleven of the wagons in train 6C00, including the ninth wagon, had passed a wheel impact load detection site (known as a 'Gotcha' site) at Braidwood, near Motherwell, on 13 October 2022, six days before the derailment. This site recorded small impact forces on the rails from two wagon wheelsets. These were consistent with wheel flats on the rotating wheels, usually caused by the wheels having previously slid along the railhead without rotating for a short distance. These forces were small and well below the level that would have required any alarm to be raised or any action to be taken.

32 These flats were recorded on the fourth (rear) wheelset of wagon VTG12459 (the eighth wagon from the front of train 6C00) and the third wheelset of wagon VTG12450 (the eleventh wagon from the front). No wheel flats were recorded in the 13 October data for wagon VTG12455 (the ninth wagon from the front).

33 Examination of the eighth and eleventh wagons after the derailment showed that these pre-existing wheel flats were still visible (figure 10). RAIB has no evidence to suggest that the existence of either of these wheel flats contributed to the derailment on 19 October 2022.

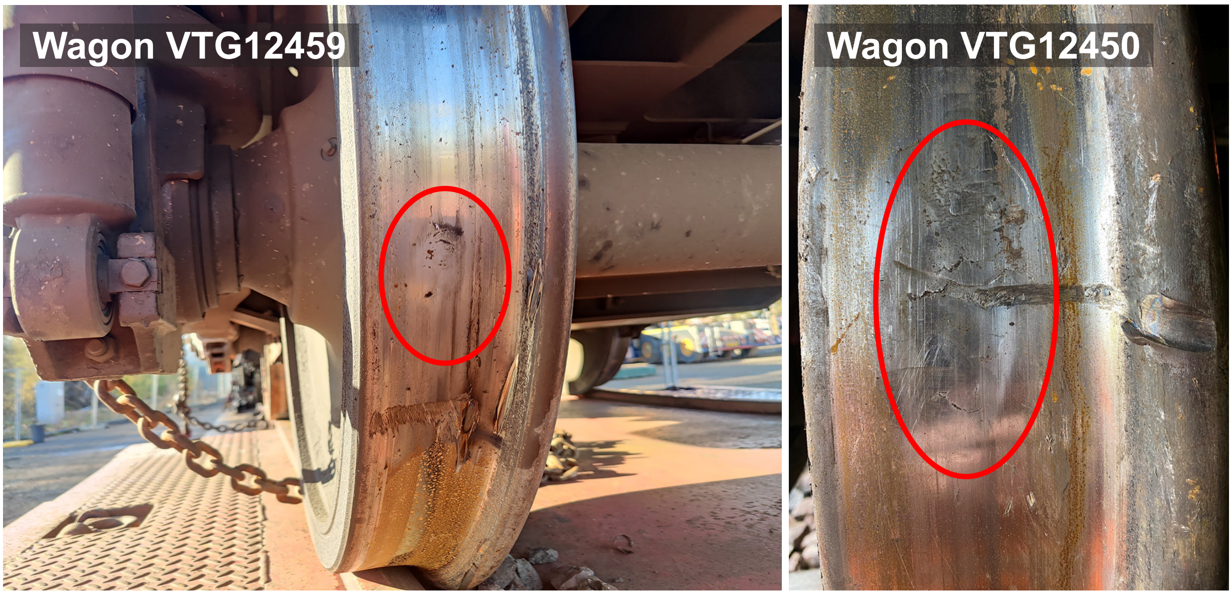

Figure 10: Pre-existing wheel flats on wagons in train 6C00.

The condition of the ninth wagon before the derailment

34 The JPA wagons were subject to an annual vehicle inspection and brake test (VIBT), and a four-monthly planned preventative maintenance (PPM). All the wagons in train 6C00 were found to have been maintained within the required periodicity. The ninth wagon had undergone its last VIBT five months before the derailment and its last PPM one month before the derailment, with no relevant faults or defects found. Before departure on the day of the derailment, the brake blocks on the sixth wagon were replaced due to wear, and the whole train was subject to an in-service inspection, with no defects found.

Brake system testing

35 Following the accident, the ninth wagon was recovered from the River Petteril and transported to a secure storage site (figure 11). Examination of the braking system showed that all the main components were still intact, although several air pipes had become dislodged due to the distortion in the wagon's underframe caused by the accident and the wagon's recovery. Reconnection of the dislodged pipework made the brake system airtight, and able to be pressurised and tested. A series of functional tests was then undertaken on the wagon's braking system in conjunction with VTG and DB Cargo.

Figure 11: The ninth wagon (VTG12455) after recovery.

36 The wagon's brakes were tested using a portable test rig. This simulated the brake pipe connection from a locomotive and allowed the wagon's brakes to be applied and released in line with the requirements of the VIBT procedure. The brake system was seen to operate as intended and the brakes applied in accordance with the criteria required by the testing.

37 It was noted that the time the brakes took to release when commanded was longer than required by the VIBT (35 seconds compared to the 20 seconds specified), although the brakes did release fully. Subsequent examination showed that water contamination had entered the air system, probably during the five-week period between the derailment and reconnection of the dislodged pipework (see paragraph 40).

38 During the brake tests, the forces applied by the brake blocks on the wheels were measured using instrumented brake blocks. These showed that the brake block forces on the eight wheels on the ninth wagon were relatively uniform and in line with the expected design values. This demonstrated that excessive brake force was not being applied to the leading wheelset that had slid and developed the wheel flats.

Brake distributor testing

39 The brake distributor was subsequently removed from the wagon and bench tested, with the assistance of its manufacturer, Knorr-Bremse. These tests showed that it was functioning as designed, with the air pressure being applied to the brake cylinders responding correctly to changes in the brake pipe pressure. The slow brake release time observed during the brake system testing (paragraph 37) was also found during the bench test.

40 Subsequent dismantling and examination of the brake distributor found water inside the air chambers and corrosion in a choke used to control the speed of the brake release. The last VIBT before the derailment (paragraph 34) found the brake release timings to be correct, suggesting that the corrosion was not present then. It is likely that the corrosion was initiated by water getting into the air system of the wagon after the derailment, when the air system pipework was disturbed and open to the atmosphere and the rain. No other defects were found during the examination of the distributor.

41 If the brake release timings had been extended from 20 seconds to 35 seconds (paragraph 37), the effect would have been to extend the brake application on all the wheelsets of the ninth wagon by a few seconds during each brake application. RAIB found no evidence of abnormal brake wear on this wagon to support this possibility.

42 It is likely, therefore, that the slow brake release times were a result of water ingress which occurred after the derailment and that the brakes on the ninth wagon were working within specification at the time when the wheel slide was initiated.

Brake cylinders testing

43 The brake cylinders were removed from the BFCB beams (paragraph 20) and tested in conjunction with the manufacturer, Wabtec Faiveley. All four cylinders from the ninth wagon were found to pass bench tests for force and stroke length, as per their design. The brake cylinders were also dismantled and inspected to identify any defects.

44 One of the brake cylinders on the leading bogie was found to have a broken piston spring and a bent guide plate (figure 12). This spring was intended to maintain alignment of the brake piston in its cylinder. Although the piston spring also assists the piston to return to its position after application of the brakes, the main return spring, which was still intact, was configured to do this on its own if necessary. Wabtec Faiveley stated that failure of a piston spring was very rare, although not entirely unknown.

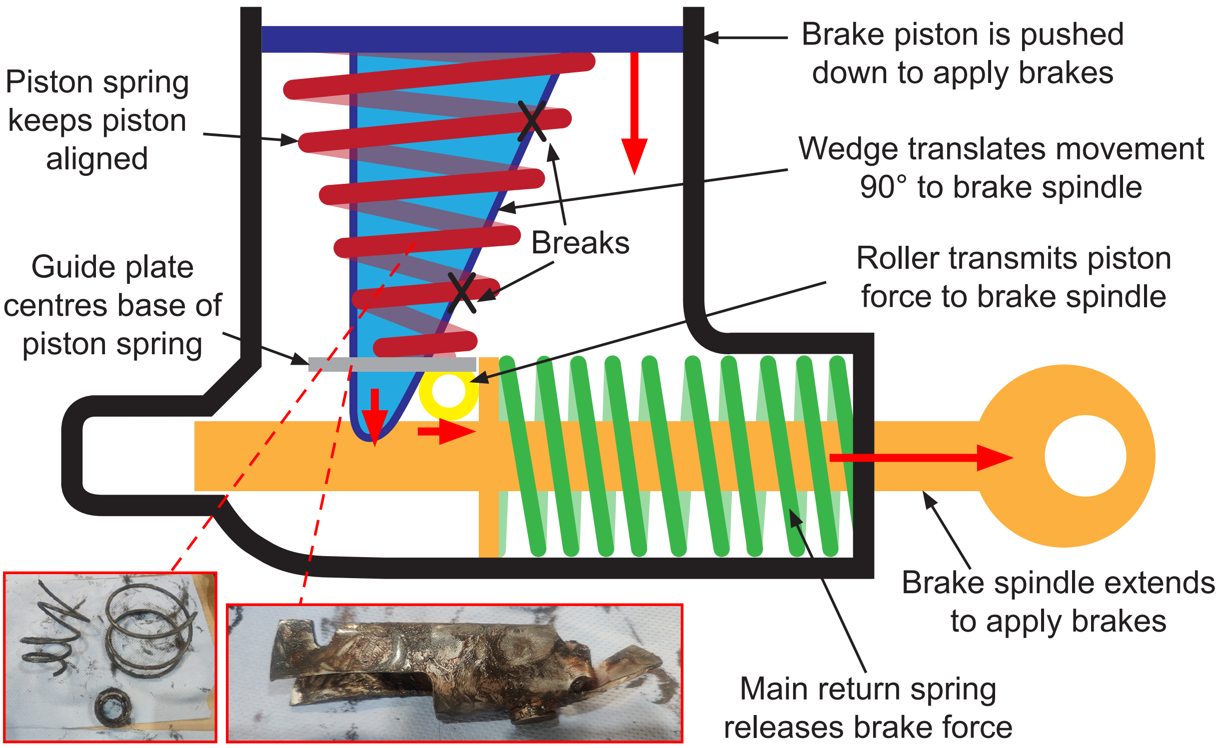

Figure 12: Internal arrangement of the brake cylinders.

45 The piston spring had broken in two locations and RAIB commissioned a metallurgical examination of it to determine the nature of the breaks. This found that the first break showed signs of fatigue cracking that would have developed over many cycles of operation in normal service. The second of the breaks was due to the dislodged spring being trapped in the brake cylinder mechanism and being crushed. The conclusion of the examination was that fatigue had initially led to the spring failing and becoming dislodged, resulting in the spring and its guide plate becoming loose in the mechanism and subsequently becoming crushed during service operations. The metallurgical report concluded that it was likely that the cracking, and both the resulting breaks, had occurred during normal service, before the derailment.

46 If the dislodged spring and guide plate had become wedged in the brake cylinder mechanism, it is possible that it could have resulted in the brake force on that bogie not being fully released after a brake application. The maximum force that could have been applied would have been a normal full service brake application. However, this would have resulted in the brakes being applied to both wheelsets in the bogie, and not just to the wheelset that slid, which would also cause additional brake wear on the brake blocks for both wheelsets. Examination of the wagon after the derailment did not show any significant difference in the brake block wear between the two bogies on the ninth wagon, nor any evidence of excess heat having been generated, suggesting that any possible abnormal brake force from this brake cylinder had a minimal effect.

The sequence of events

Events preceding the accident

47 At 12:27 hrs on 19 October 2022, train 4N00 (figure 13) arrived in the loading sidings at Clitheroe cement terminal from Carlisle, after reversing into the terminal from Horrocksford Junction (figure 14). Train 4N00 conveyed twelve of the empty wagons that would later form train 6C00, as well as an additional thirteenth empty wagon that was to be detached at Clitheroe for maintenance.


Figure 13: Train 4N00 on its southbound journey at Appleby (courtesy of Paul Berry).

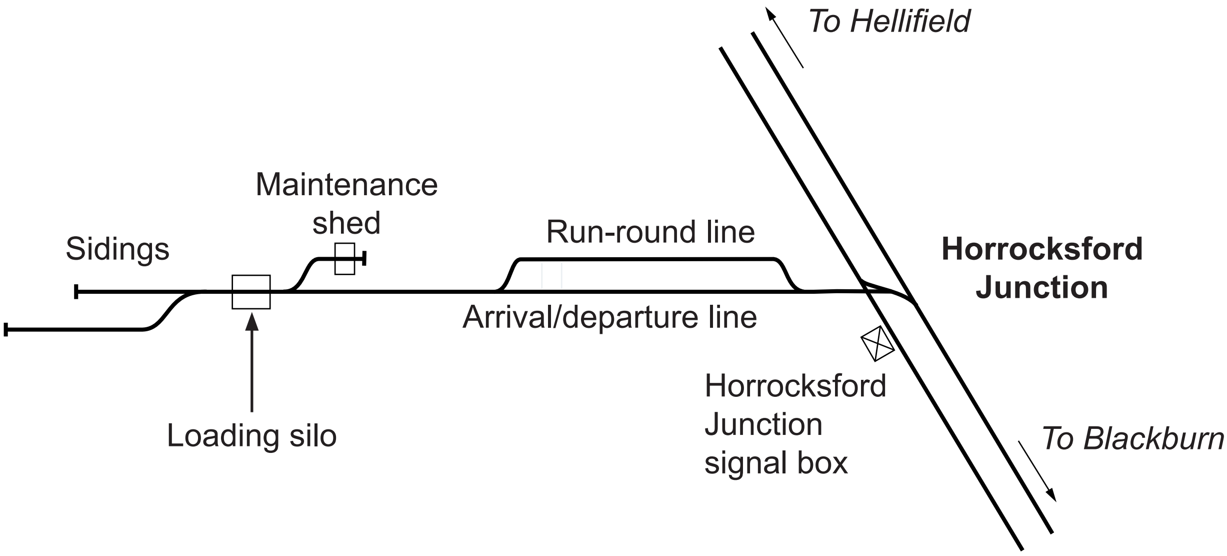

Figure 14: Track diagram of the cement terminal at Clitheroe.

48 Between 12:35 hrs and 16:40 hrs, 12 wagons were loaded one-by-one as the train drew forward through the loading hopper building. During this process, two already-loaded wagons were attached to the end of the train, and the empty wagon next to the locomotive was detached and taken away by the terminal's shunting locomotive. Once all the wagons were loaded, the driver overcharged the train's brake pipe as part of the train's pre-departure process. This admits a higher pressure than required in normal operation to allow the control pressures in the wagons' brake distributors to normalise, thus reducing the risk of the train setting off with a dragging brake. GBRf procedures required the overcharge to be carried out on the arrival/departure line (figure 14) after the locomotive had run round the train rather than before, but RAIB has no evidence to suggest that this minor non-compliance contributed to the derailment.

49 From 16:40 hrs to 17:25 hrs, the now-loaded train of 14 wagons drew forward to the arrival/departure line. The locomotive was detached and ran round to the opposite end of the train ready for the journey north. After getting authority from the signaller at Horrocksford Junction, the driver propelled the train out on to the main line, while the ground staff operator carried out the pre-departure roll-by observational checks. A public webcam[4] at Horrocksford Junction, combined with bodycam footage from the ground staff operator, showed that all the train's wheels were freely rotating at this location.

50 At 17:25 hrs, train 6C00 departed from Horrocksford Junction towards Hellifield and Carlisle. Eight minutes later, at 17:33 hrs, the driver carried out a running brake test, as required by the railway Rule Book,[5] and achieved a speed reduction of 11 mph (18 km/h). The driver applied the brake for 17 seconds during the running brake test.

51 Between Horrocksford Junction and Hellifield, the driver made two very short (6 seconds each) and light (<25% of full service) brake applications to manage the train's speed within the 30 mph (48 km/h) permissible speed limit. At 18:00 hrs, the driver made another similar brake application to regulate the train's speed to 15 mph (24 km/h) at Hellifield.

52 From Hellifield to Settle Junction, the driver increased the train's speed towards the maximum permissible line speed of 60 mph (96 km/h) before starting the climb up towards Blea Moor (figure 9). On that climb, the driver kept the locomotive's power handle in its maximum position. Despite this, the train's speed slowed to around 20 mph (32 km/h) due to the weight of the train, the rising gradient and low levels of wheel/rail adhesion.[6] At 18:22 hrs, the train passed a public webcam at Horton-in-Ribblesdale station (figure 15), and an audible wheel flat can be heard on the recording around the middle of the train. Due to the absence of significant braking up to this point, RAIB considers it likely that this wheel flat was one of those that were pre-existing on the train before the day of the accident (paragraph 31).

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[4] RAIB has sourced footage from several public webcams on the route of train 6C00, at Horrocksford Junction, Horton-in-Ribblesdale and Garsdale. These were courtesy of Railcam UK Ltd and the Friends of the Settle to Carlisle Line.

[5] GERT 8000 Rule Book Module TW1, 'Preparation and movement of trains', issue 17, September 2021.

[6] The coefficient of friction (μ) between the rail and the wheels of a train.

Figure 15: Train 6C00 passing Horton-in-Ribblesdale (courtesy of Railcam UK and the Friends of the Settle-Carlisle Line).

53 After Blea Moor, the gradient levelled out and the train was able to increase speed again. No brake applications were made after Hellifield until the train approached a 30 mph (48 km/h) permanent speed restriction through Dent station. At this point, the driver made a brake application of approximately 35% of full service, lasting a maximum of 32 seconds, which reduced the train's speed by 19 mph (31 km/h).

54 At 18:50 hrs, the train passed another public webcam at Garsdale (figure 16), by which time it was getting dark. A review of this footage by RAIB did not identify any visual or audible signs of a problem with the train.

55 At 18:55 hrs, the train passed Ais Gill and the driver made the first of many short brake applications to control the train's speed on the long, steep descent to Appleby. Most of these brake applications were considerably less than 20 seconds long.

56 At 19:03 hrs, the train passed Kirkby Stephen and left marks on the railhead at sets of points there showing that a non-rotating wheelset had passed over them (see paragraph 79). Similar marks were left at every subsequent set of points along the route of the train between this location and the point of derailment.

57 At 19:09 hrs, train 6C00 passed a southbound passenger service on the opposite line (train 2H97, the 18:24 Northern service from Carlisle to Leeds). Rear-facing closed-circuit television (CCTV) footage from this service (figure 17) momentarily showed a small amount of sparking at the wheel/rail interface on one wheelset of train 6C00. This sparking was only visible once the contrast of these CCTV images had been altered and it is unlikely that the driver, or any other railway staff, on train 2H97 would have been able to see it as train 6C00 passed.

Figure 16: Train 6C00 passing Garsdale (courtesy of Railcam UK and the Friends of the Settle-Carlisle Line).

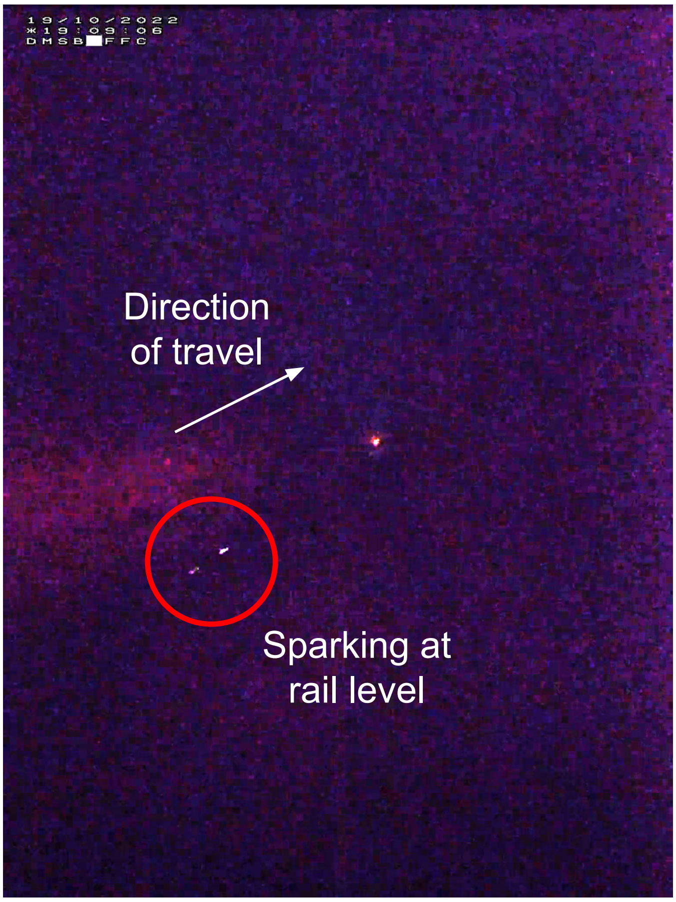

Figure 17: Rear-facing CCTV image from train 2H97 showing sparking at a wheelset on train 6C00 (courtesy of Northern Trains).

58 At 19:31 hrs, train 6C00 passed a private residence at Little Salkeld. CCTV footage from this residence, which was fitted with a night vision system, showed sparking from the leading wheelset on the ninth wagon (figure 18). This sparking would not have been as visible to the naked eye as it appears in the night vision images.

Figure 18: Sparking from the ninth wagon in train 6C00 at Little Salkeld (courtesy of Mike England).

59 At 19:37 hrs, train 6C00 passed Lazonby & Kirkoswald station. Here the train left the last of three track sections whose status were displayed in Culgaith signal box (train 6C00 had passed Culgaith signal box at 19:26 hrs). The status of each track section is determined by axle counters. These count the number of wheels that enter and then leave a section of track and provide an indication to the signaller to show whether a train is present in that section. After train 6C00 had left the last track section, all three sections continued to show as occupied (that is to say, a train was indicated to be present). The signaller at Culgaith contacted the next signaller at Low House signal box to check on the progress of train 6C00 (see paragraph 141).

60 At 19:42 hrs, train 6C00 passed Armathwaite station, where the station CCTV footage showed a small amount of sparking at the leading wheelset on the ninth wagon (figure 19). One minute later it passed Low House signal box. The signaller watched the train pass to check that it was complete after the contact from Culgaith signal box. The signaller at Low House did not see or hear anything wrong with the train as it passed by (see paragraph 142).

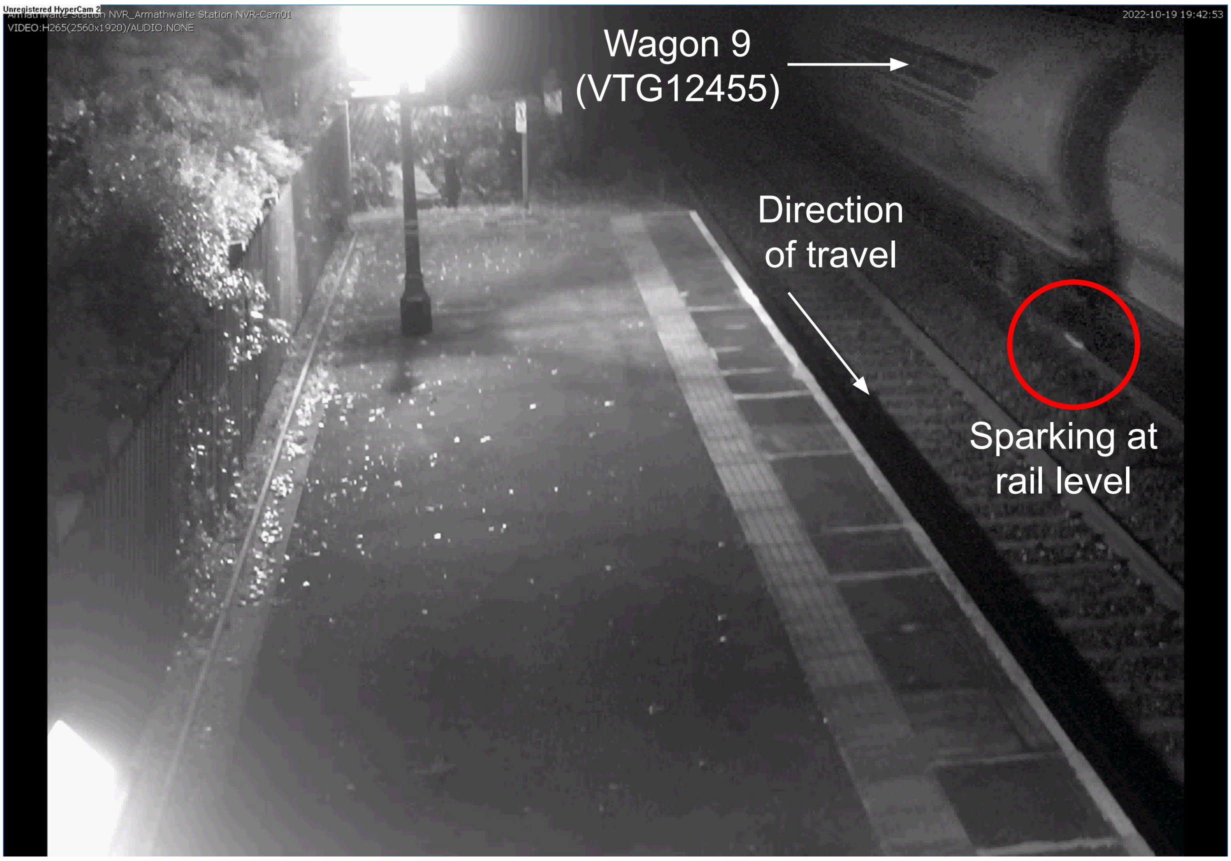

Figure 19: Sparking from the ninth wagon in train 6C00 at Armathwaite station (courtesy of Northern Trains).

Events during the accident

61 By 19:53 hrs, train 6C00 had slowed to 20 mph (32 km/h) as it approached Petteril Bridge Junction. As the train passed over 679A points in the trailing direction (figure 4), the leading wheelset of the ninth wagon derailed to the left and started to severely damage the track as both of its wheels ran along the sleepers instead of the railhead. This damage led to subsequent wheels of the following wagons becoming derailed to the left.

62 The derailed wagons destroyed the set of points at Petteril Bridge Junction, which was located on top of the bridge over the river. The derailed wagons, which were running to the left of the track, ran against the side of the bridge parapet wall, resulting in the wall and part of the railway formation falling into the river. This led to the ninth and tenth wagons falling off the left side of the bridge, coming to a rest with the ninth wagon upside down in the river and the tenth wagon on its side on the riverbank (figure 20). The rear of the eighth wagon also derailed to the left as it was dragged sideways by the front of the ninth wagon.

Figure 20: Damage to the track and bridge at Petteril Bridge Junction.

63 The coupling between the fifth and sixth wagons separated as the ninth and tenth wagons fell off the bridge, resulting in the brake pipe becoming separated and the train's brakes applying automatically.

Events following the accident

64 The automatic brake application stopped the train, and the driver contacted the signaller, thinking that the train could have become divided. Although the adjacent line to the right of the train was still open to traffic, it was unlikely to have been obstructed because the wagons had primarily derailed to the opposite side. At the same time, the controlling signaller in Carlisle power signal box received indications that some track detection equipment had failed. This was because of the track damage caused by the derailment.

65 The driver got out of the locomotive to look back along the train and saw that some of the wagons had become derailed and that the train had become divided. The driver immediately informed the signaller, who took steps to block all lines to traffic.

66 Due to difficulties with erecting a suitable crane close enough to the derailed wagons, it took three and a half weeks for all of them to be recovered from the site. It was seven weeks after the derailment before the lines to both Newcastle and Settle could be reopened to traffic after extensive rebuilding work to the side of the bridge over the River Petteril.

Analysis

Identification of the immediate cause

67 Train 6C00 derailed, while travelling through 679A points in the trailing direction, due to a large false flange that had developed on the leading wheelset of the ninth wagon during the journey and this had not been detected.

68 Immediately after the derailment, the leading wheelset of the ninth wagon was found to have a large wheel flat on each of its wheels (figure 3). These wheel flats had worn approximately 25 mm into the tread surface of the wheels, resulting in a large false flange on the outside edge (figure 21). The wheel flats were approximately 290 mm long (figure 22).

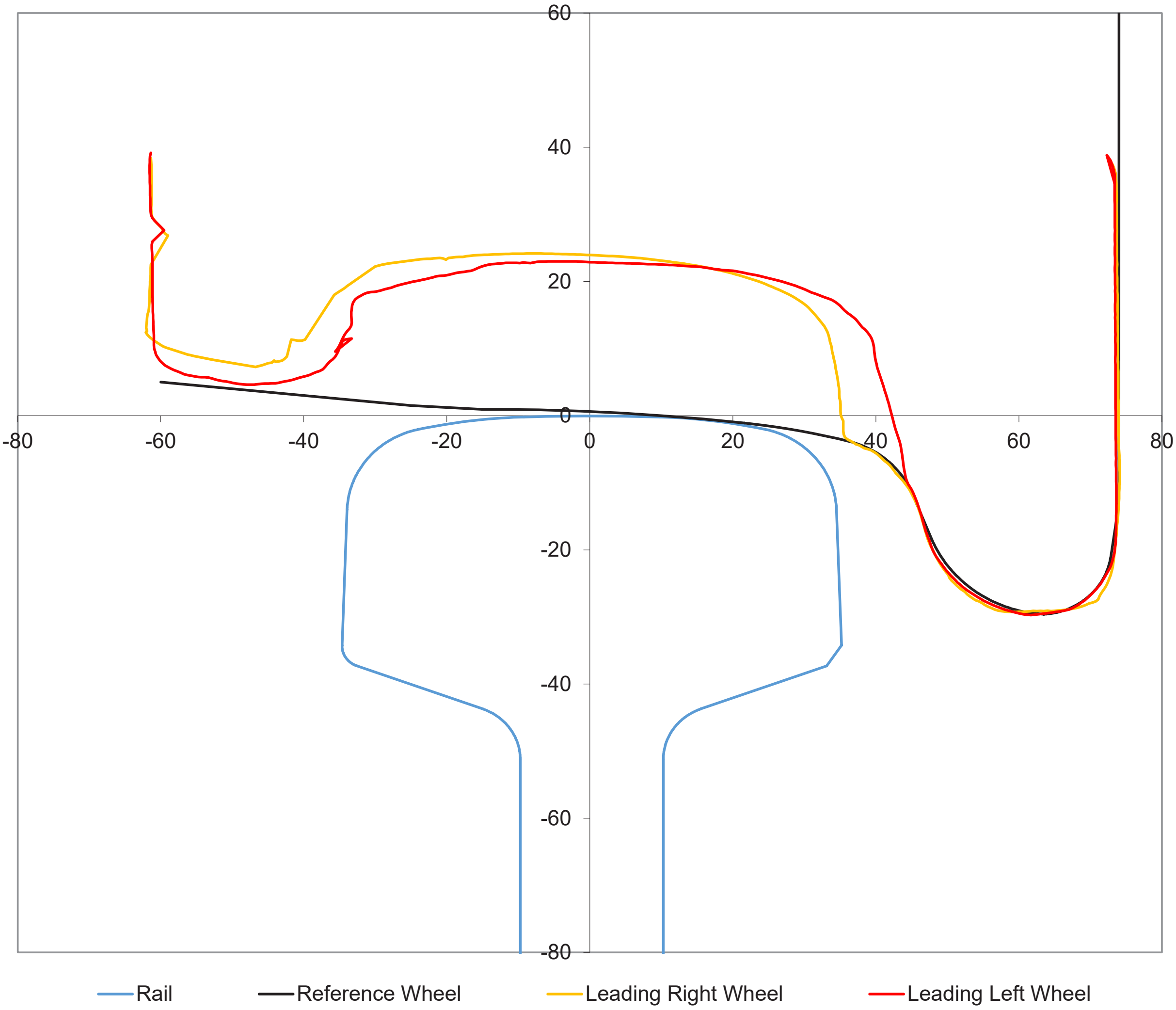

Figure 21: Wheel profile of the worn wheels, compared to the reference wheel profile.

Figure 22: The length of the wheel flats.

69 Marks at the site showed that, during the initial stage of the derailment, the outer edge of the false flange on the leading left wheel of the ninth wagon had become trapped between the converging stock rail and switch rail at 679A points (figure 23). In the absence of a false flange, the outer edge of the wheel would have passed over the top of the converging rails, with the contact surface of the wheel transitioning from the switch rail to the stock rail. Figure 24 shows the marks on the inside of the stock rail as the outer edge of the trapped false flange on the leading left wheel ran along the inside of it at the tip of the switch rail as the wheel dropped into the four-foot (the gap between the running rails).

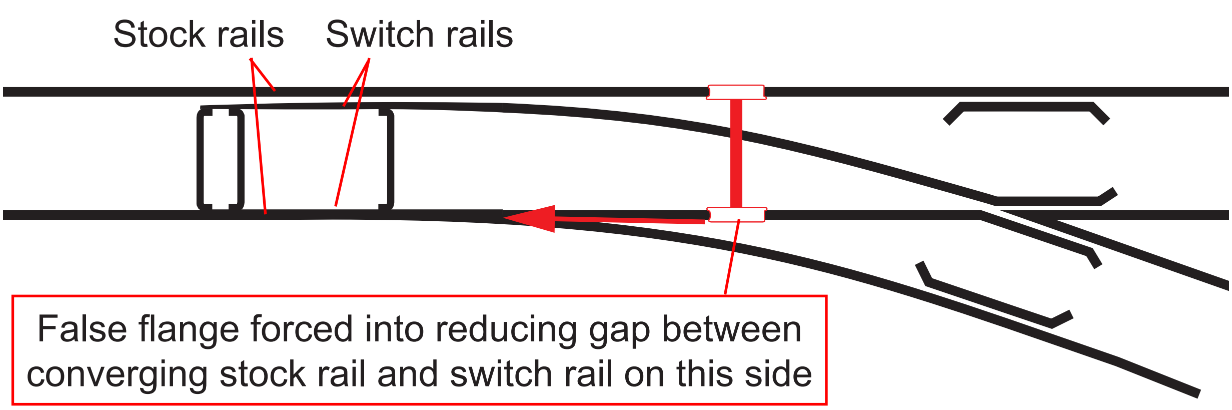

Figure 23: Route of the false flange at trailing points.

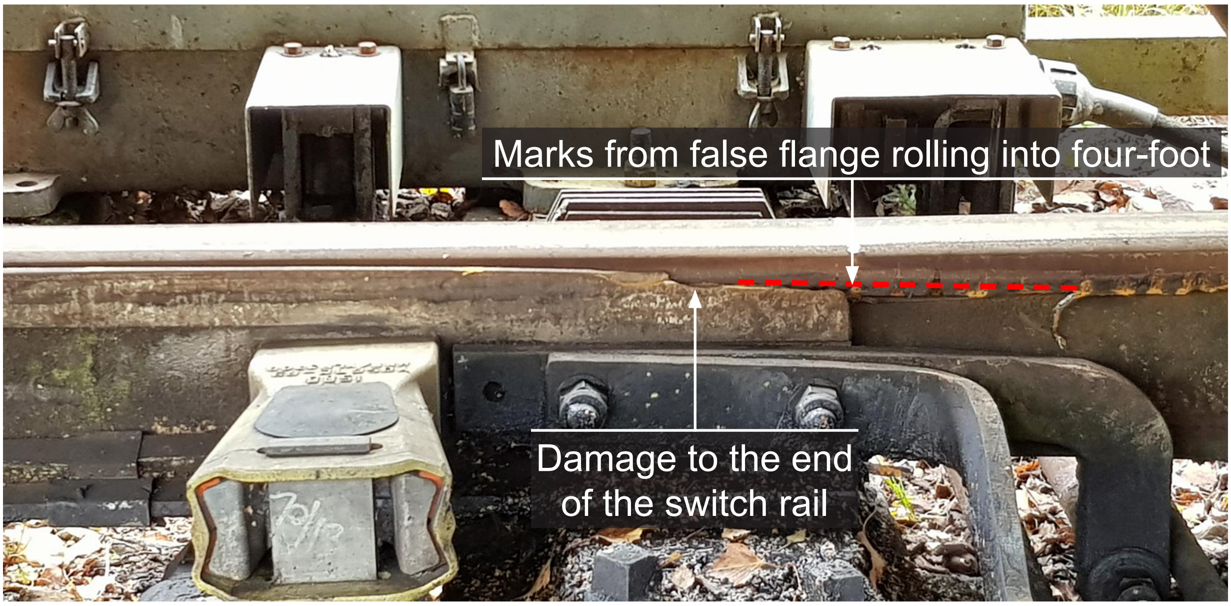

Figure 24: Switch rail at 679A points.

70 This event, and the subsequent stage of the derailment mechanism is illustrated in figure 25. The left wheel dropped inside the left rail after it passed the end of the switch rail, with its outer face then pushing the left rail outwards, while the flange of the right wheel was pushing against the right rail and trying to climb up onto it. The track fixings holding the left rail in position then gave way and the rail shifted laterally and started to roll over. A few metres further on, the left wheel collided with a check rail that was mounted inside the left rail as part of the next set of points. This caused the left wheel to climb over the left rail, and the right wheel to drop into the four-foot.

71 This derailment mechanism, where a wheel with a false flange on the outside edge derails at a set of trailing points has been seen at a number of previous derailments. Examples include Hatherley (RAIB report 08/2006), Dunkeld & Birnam (RAIB safety digest 01/2019), and Llangennech (RAIB report 01/2022).

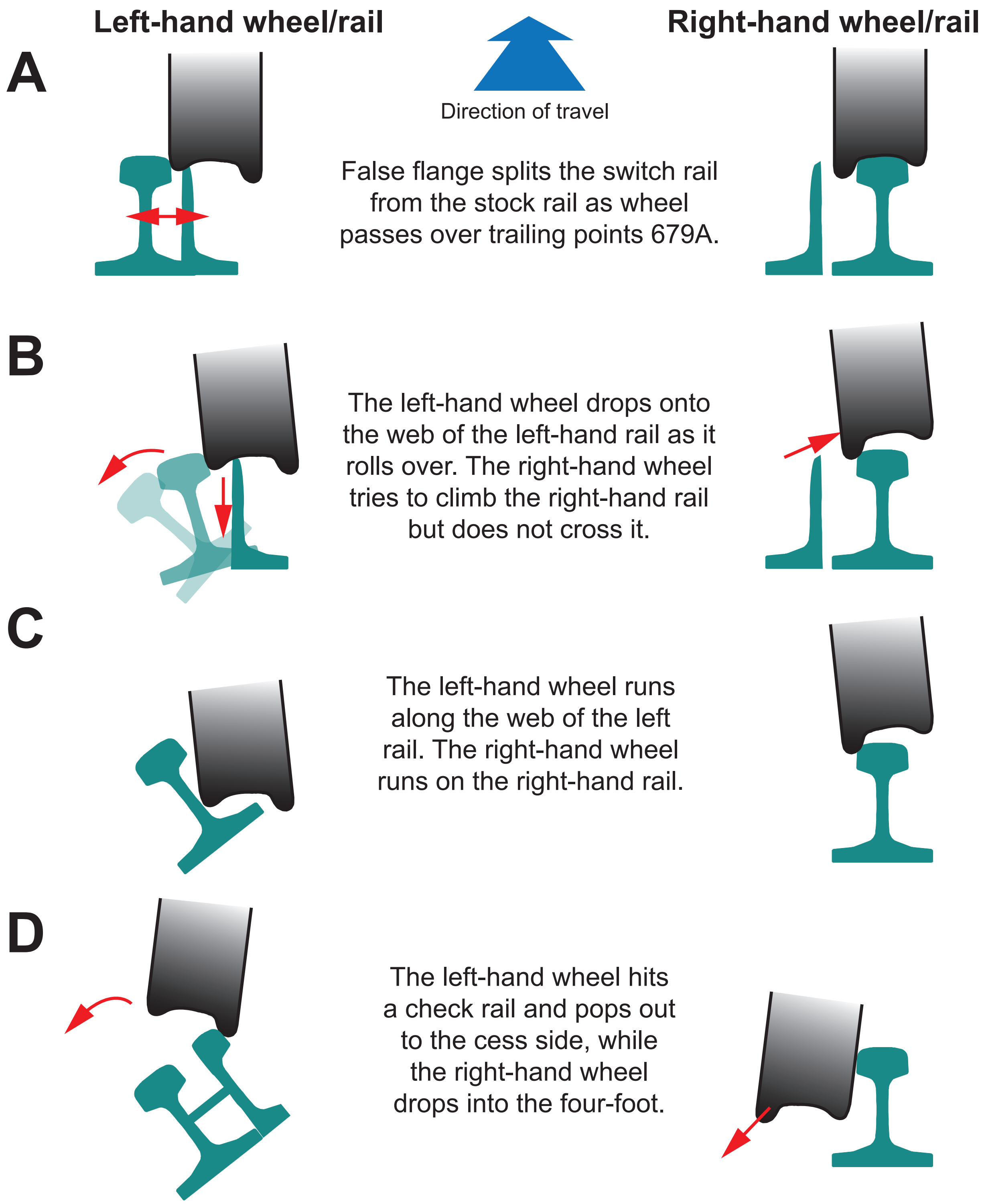

Figure 25: Derailment mechanism.

Identification of causal factors

72 The accident occurred due to a combination of the following causal factors:

a. The ninth wagon developed very large wheel flats, and consequent false flanges, on its leading wheelset as a result of that wheelset sliding along the railhead for between 48 and 55 miles (paragraph 73).

b. Train 6C00 was not stopped before reaching Petteril Bridge Junction, after the wheelset on the ninth wagon had stopped rotating (paragraph 135).

Each of these factors is now considered in turn.

Cause of the wheel flats

73 The ninth wagon developed very large wheel flats, and consequent false flanges, on its leading wheelset as a result of that wheelset sliding along the railhead for between 48 and 55 miles.

74 There was no audible indication of any significant wheel flats while the train was at Clitheroe, including during its departure from Horrocksford Junction, on any of the available video recordings. There was no physical damage to either the wagon or the track consistent with a large, rotating wheel flat. Similarly, there were no reports of audible wheel flats from the signallers that the train had passed on its southbound journey that morning. These are all evidence that the very large wheel flats on the ninth wagon were not present before the journey from Clitheroe to Petteril Bridge Junction started. However, it is known that two of the other wagons had pre-existing, small wheel flats, which were still present after the derailment (paragraph 33).

75 If the wheelset had been rotating for some distance after a significant wheel flat had been generated, the resulting vibration would likely have caused damage to other components on the wagon or its bogies. The absence of this type of damage to the brake blocks and to the brake rigging on the ninth wagon demonstrates that the wheelset had not been rotating for most of the time after the very large wheel flats had been generated. That means that the circumstances for this accident are different to previous incidents at Ferryside (RAIB report 17/2018), Llangennech (RAIB report 01/2022) and Pencoed (RAIB report 03/2023), where wheelsets had been rotating after wheel flats had been generated, resulting in damage to the wagon and/or the track.

76 Because there were false flange marks at every set of points from Kirkby Stephen to Petteril Bridge Junction (paragraph 56), RAIB has concluded that it is very likely that the wheelset slid continuously from the point that it first stopped rotating until just before the derailment, probably for a distance of up to 55 miles (88 km) (see paragraph 84). However, it was observed that there were discrete contact marks on the outside of the left rail from a false flange on the final 20 metres leading to the point of derailment, with each mark spaced by the circumference of a wagon wheel. This indicated that the leading wheelset on the ninth wagon had possibly been rotating just before 679A points (see paragraph 117), although the wheelset was not rotating as it slid through the points and derailed.

77 The size of the wheel flats generated over this length of slide is consistent with the wheel flats and slide distances observed in the investigations described in paragraph 75, and with that recorded during an additional derailment at Hatherley (RAIB report 08/2006). The graph in figure 26 shows the observed relationship between wheel flat length and likely slide distance.

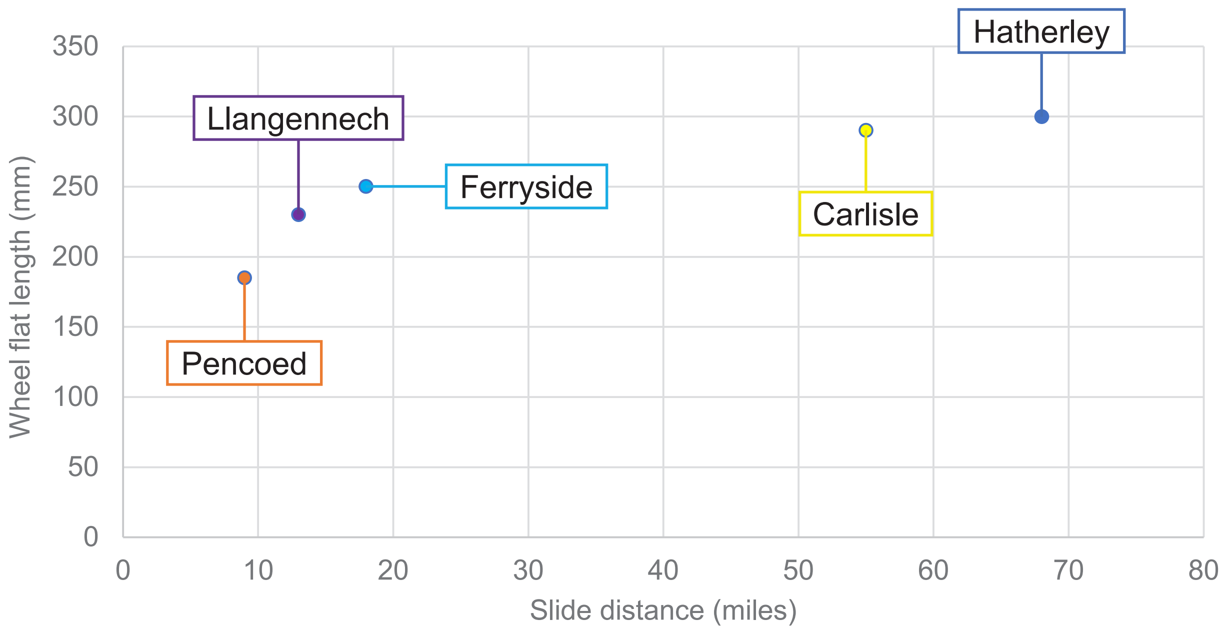

Figure 26: Wheel flat lengths and slide distances during previous incidents.

Distance of the wheel slide

78 The wheel flats that resulted in the initial derailment of the ninth wagon were sufficiently deep that a false flange had been created on the outside of the wheel, that protruded below the level of the railhead (figure 27). When a sliding wheel with a false flange passes over a set of points, the false flange on the outside of the rail comes into contact with the converging and diverging rails and leaves marks as it is dragged over the top of them without derailing (figure 28). If the false flange is sufficiently big, the speed is sufficiently low, and the angle of the converging rail is shallow enough, then the false flange can become trapped between the converging rails at trailing points and result in a derailment, as described in paragraph 70.

79 After the derailment, RAIB surveyed each set of points from Petteril Bridge Junction back along the route of the train, in turn, until no false flange marks were visible. Marks were clearly visible at the last set of points that train 6C00 passed, at Howe & Co's Siding, as shown in figure 29. False flange marks were then found at every set of points that the train had previously passed over, all the way back to Kirkby Stephen (figure 30). No easily recognisable false flange marks were found at the previous set of points from Kirkby Stephen, which were at Garsdale. That meant that the first location where there was clear evidence of the leading wheelset on the ninth wagon sliding with a large enough false flange to leave marks on the railhead was at Kirkby Stephen.

80 Figure 31 shows that a wheel flat with a depth of at least six millimetres would be required before a false flange sufficient to leave marks on converging rails at points could exist. That would require the wheel to have slid for some distance, probably several miles, before it would leave evidence of false flange marks. This suggests that the slide was initiated somewhere between Blea Moor and Ais Gill (figure 8).

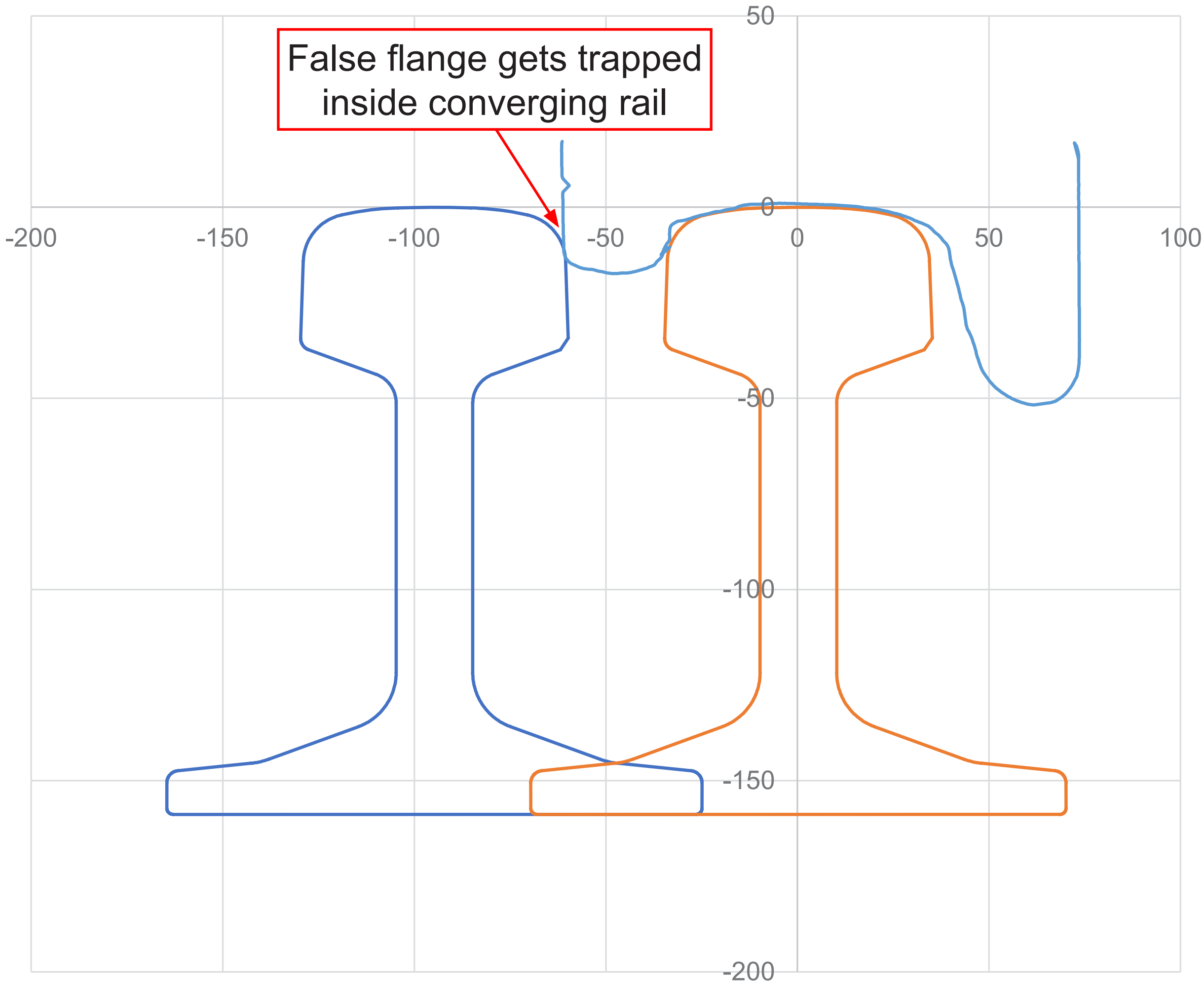

Figure 27: False flange protruding below railhead level.

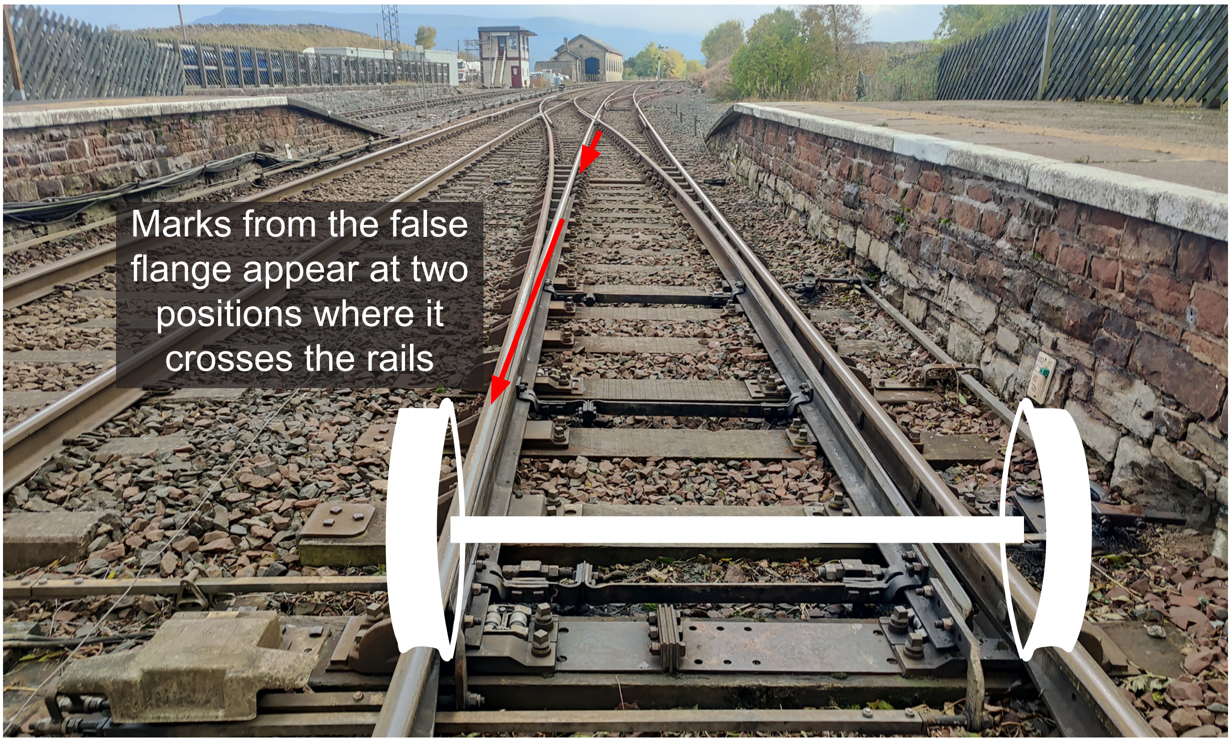

Figure 28: Illustration of locations where false flange marks will be visible at points.

Figure 29: False flange marks at Howe & Co's Siding.

Figure 30: False flange marks at Kirkby Stephen.

Figure 31: Illustration of wheel flat depth required to show false flange marks.

Location of wheel slide initiation

81 Given the absence of significant defects on the wagon braking system (paragraphs 34 to 46) and the unlikelihood of the other possible causes (see paragraphs 89 to 97), it is most likely that the wheel slide started during a brake application. Examination of data taken from the locomotive's on-train data recorder (OTDR) showed that there was a number of fairly short, light (4.6 bar brake pipe, or <25% full service) brake applications after the train had passed Ais Gill. These started about 6.2 miles (10 km) before Kirkby Stephen (figure 32), where the first false flange marks were seen. Before that there was a single, longer and harder (4.4 bar brake pipe, or 35% full service) brake application on the approach to Dent station. This brake application was 3.9 miles (6.2 km) before Garsdale and 13.7 miles (22 km) before Kirkby Stephen.

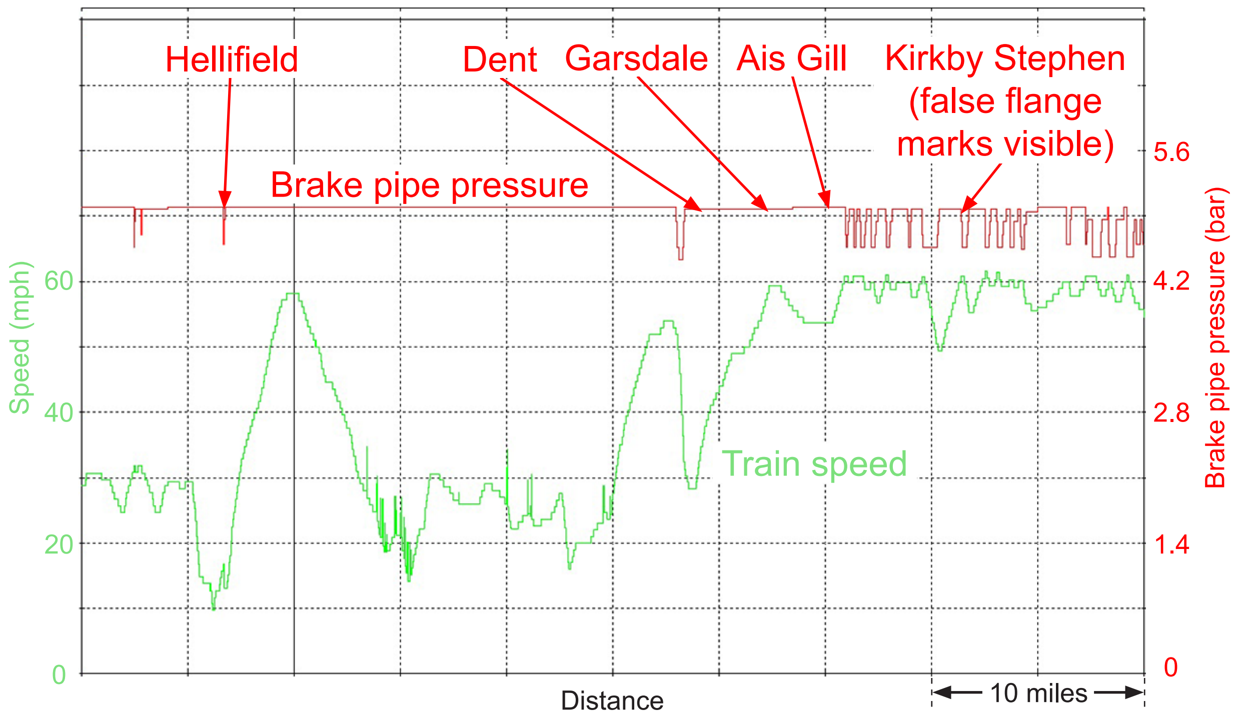

Figure 32: OTDR data showing speed and brake applications.

82 Before that, the previous brake application at Hellifield had been short and light (4.6 bar brake pipe, or <25% full service). This was about 21 miles (33.7 km) earlier. It is very unlikely that the slide started at this point or earlier because a significant wheel flat with a false flange would have been generated in the 25 miles (40 km) between Hellifield and Garsdale and false flange marks would have been visible across the rails at the sets of points there. The webcam footage from Garsdale (paragraph 54) also did not show any sign of sparking from the wheels, which would probably have been visible if the wheelset had slid for the previous 25 miles.

83 It is possible that the slide initiated during one of the short, light brake applications after Ais Gill, as this would still be consistent with there being false flange marks at Kirkby Stephen but not at Garsdale. The initial brake applications after Ais Gill were less than 10 seconds long and light (4.6 bar brake pipe, or <25% full service), while the later brake applications in this area were slightly longer, but still less than 20 seconds, and of similar magnitude. However, the distance from the first brake application after Ais Gill to the first false flange marks at Kirkby Stephen was only about 5.7 miles (9.2 km) and this may not have been long enough to wear enough of the wheel away to make visible false flange marks at Kirkby Stephen.

84 The brake application on the approach to Dent station was prompted by a permanent speed restriction of 30 mph (48 km/h), as described in paragraph 53. The brake application was about 30 seconds long, with the brake pipe pressure dropping to 4.4 bar, equivalent to approximately 35% of full service braking. If the wheel slide had initiated here, the 3.9 miles (6.2 km) to Garsdale would probably not have been enough to develop a false flange big enough to leave rail marks, so this is consistent with the absence of such marks. However, the 13.7 miles (22 km) to Kirkby Stephen would very likely have been enough to develop a false flange large enough to leave the rail marks that were observed there.

85 As a result, RAIB considers that the wheel slide was probably initiated during the brake application on the approach to Dent station, and that it is possible, but much less likely, that it could have been initiated during one of the brake applications just after Ais Gill.

86 RAIB has noted that there was a small wheel flat audible in webcam footage at Horton-in-Ribblesdale (paragraph 52), but not in similar footage at Garsdale (paragraph 54). The absence of significant braking before this location means that it is likely that the Horton-in-Ribblesdale sound is from the pre-existing wheel flat on the eighth wagon (paragraph 31). RAIB does not have a definitive explanation for why this wheel flat is not audible in the footage at Garsdale. However, it is possible that the slight right-hand curvature of the line there has resulted in the wheelsets running slightly further to the left than on the left-hand curve at Horton-in-Ribblesdale, and so with a different part of the wheel tread surface in contact with the rail, avoiding or minimising contact between the small wheel flat (figure 10) and the railhead. It is also possible that the higher speed of the train at Garsdale has made the wheel flat less audible among the other noises made by the train.

87 This causal factor (paragraph 73) arose because:

a. The wheelset stopped rotating, and continued to slide, probably as a result of a normal brake application on a section of track with low wheel/rail adhesion (paragraph 88).

This sub-factor is now considered.

88 The wheelset stopped rotating, and continued to slide, probably as a result of a normal brake application on a section of track with low wheel/rail adhesion.

Possible causes of the wheel slide

89 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 90)
- an uncommanded brake application following a malfunction within the air braking system (paragraph 91)
- an uncommanded brake application following an object becoming caught within the brake rigging (paragraph 94)
- an object becoming jammed between the brake rigging and wheels (paragraph 95)
- one or more seized axle bearings on the wheelset (paragraph 96)
- a brake application made during normal operation, but in conditions of low wheel/rail adhesion (a probable causal factor in the accident, paragraph 97).

These factors and their potential relevance as a cause of the wheels sliding on the ninth wagon are discussed in the following paragraphs.

The handbrake being left on

90 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 referenced in paragraph 71). Detecting handbrakes that have been left on is one of the purposes of the roll-by examination undertaken before departure of a freight train. The ground staff at Clitheroe witnessed three roll-by examinations before the train's departure from Clitheroe, all of which were recorded on body-worn cameras (paragraph 49). All three examinations showed that all the wheels on the train were freely rotating at this time. In addition, after the derailment, the handbrake on the ninth wagon was found to be in its released position. This indicated that a handbrake being left on was not the cause of the wheels sliding.

A malfunction within the air braking system

91 The braking system of the ninth wagon was tested after the derailment (paragraph 35). 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 longer release time than expected (paragraph 37).

92 Both the brake distributor and the BFCB brake cylinders from the ninth wagon were removed for bench testing and disassembly (paragraphs 39 and 43). These tests showed no evidence that either the brake cylinders or the brake distributor were not functioning correctly at the time of the derailment and did not explain why the leading wheelset on the ninth wagon had stopped rotating.

93 RAIB has therefore concluded that it is unlikely that a malfunction within the wagon braking system caused the wheels to slide.

An object caught within the brake rigging

94 RAIB has considered if an object might have become caught between the brake beam and bogie frame. Witness evidence suggests that train 6C00 did not strike any lineside equipment, vegetation or objects that had been left on the track, such as track maintenance tools. If it had done so then this would also have more likely affected the leading vehicles in the train. The post-accident inspection of the ninth wagon did not identify any object that had been struck or become wedged between the brake beam and bogie frame. The inspection of the other wagons in the rake did not identify any missing components that might have affected the brakes on the ninth wagon. This, along with the absence of damage related to a trapped object, leads to the conclusion that this was not a cause of the wheels sliding.

An object jammed between the brake rigging and wheels

95 RAIB's investigation into the accident at Ferryside (see paragraph 176) 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. Before the accident at Petteril Bridge Junction, the roll-by examination carried out before the train departure from Clitheroe (paragraph 49) did not identify anything amiss with the train such as displaced or hanging braking components. Examination of the wagon after the derailment did not identify any evidence, such as brake block damage, that an object had become caught between the brake rigging and the wheels, leading to the conclusion that this was not the cause of the wheels sliding.

Seized bearings

96 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. The leading bogie on the ninth wagon was examined after the derailment and the wheelsets were found 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. RAIB has therefore concluded that a seized bearing was also not a cause of the wheels sliding.

A normal brake application in low adhesion conditions

97 As discussed above, no significant failure conditions could be postulated and supported by evidence which would explain why the wheels slid and caused the generation of the very large wheel flats on the ninth wagon. RAIB has therefore concluded that wheels probably began to slide when the train's brakes were applied in a location where the adhesion available was insufficient to sustain the level of brake retardation demanded.

Low adhesion conditions

98 RAIB has concluded that it is probable that the wheel slide initiated during a brake application on the approach to Dent station (paragraph 53). However, it is also possible, but less likely, that the slide could have initiated at the first of several smaller brake applications at the start of the descent from Ais Gill (paragraph 55).

99 At Dent, the driver made a normal brake application (35% of full service) that was about 30 seconds long, starting just before the advance warning board for the upcoming speed restriction (figure 33). During this brake application, the train passed a group of trees that was outside the railway boundary and surrounding a stream that passed under the railway in a culvert.

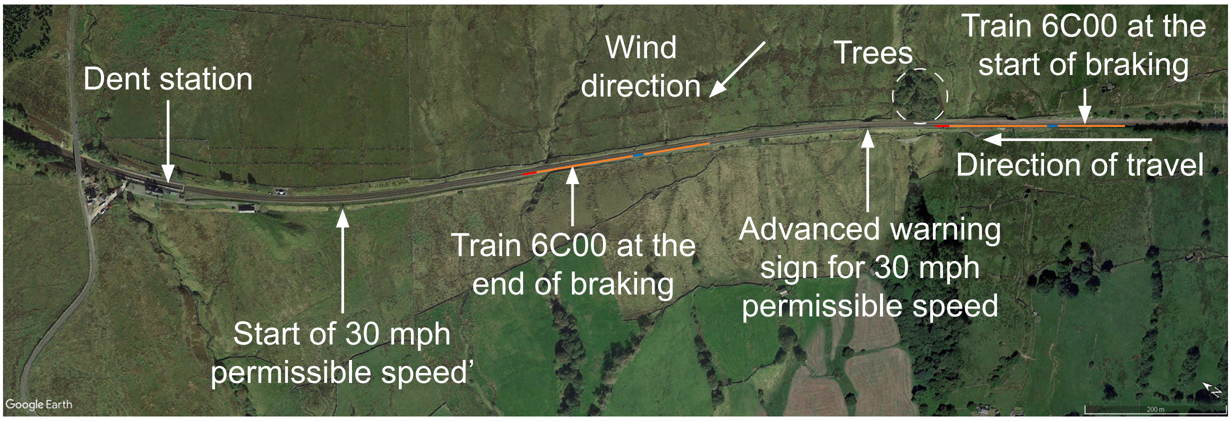

Figure 33: Satellite view of braking location at Dent (ninth wagon shown in blue).

100 As train 6C00 was traversing the Settle to Carlisle line, it was windy, with weather stations recording average wind speeds of around 15 to 20 mph (24 to 32 km/h), with gusting over 25 mph (40 km/h). This location is particularly exposed, being in the Pennine hills and near to the highest altitude mainline station in England at Dent. Given that it was mid-October, this made leaf fall from any trees in the vicinity likely.[7] Weather stations also recorded the air temperature at about 9°C, only about 1°C above the dew point (paragraph 27), making condensation on the railhead a possibility (as noted by signallers further north, paragraph 25). The combination of leaf fall conditions and possible condensation means that it is credible that there were low wheel/rail adhesion conditions at this location.

101 After Ais Gill, the driver made several shorter, lighter brake applications to manage the speed of the train (figure 34). There were more individual scattered trees here than at Dent, but there was no concentrated source of leaf fall until a cutting where the third brake application was made. The same environmental conditions would probably have been present here as at Dent, although the leaf fall source was more spread out. However, low wheel/rail adhesion at this location would also have still been a possibility.

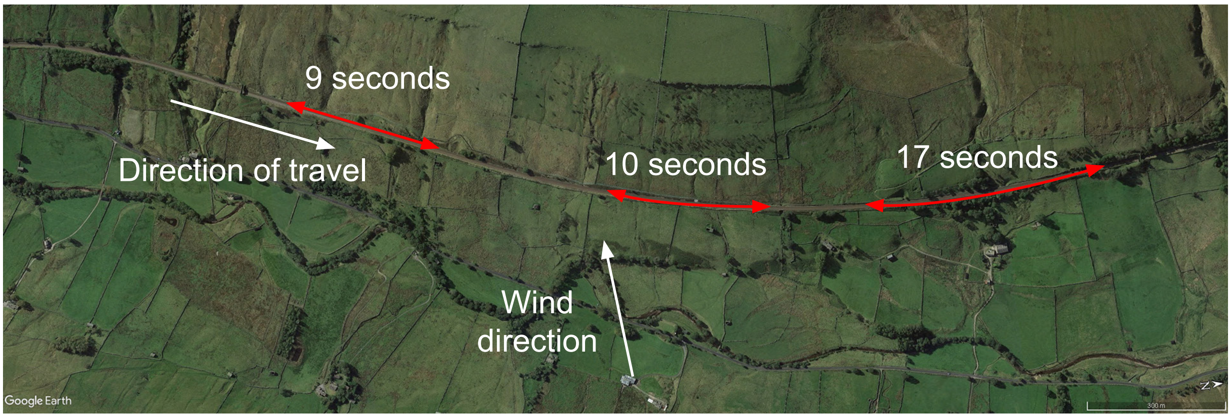

Figure 34: Satellite view of braking location at Ais Gill.

102 RAIB has considered the possibility that low wheel/rail adhesion existed due to forms of contamination other than seasonal leaf fall. Although this possibility cannot be ruled out, RAIB found no evidence of such contamination from, for example, reports from drivers of other trains on the line.

103 Network Rail has a contract with a national weather forecaster to provide twice-daily adhesion forecasts. These predict railhead adhesion levels and damp rail risk for areas within each Network Rail route. The adhesion forecast uses an adhesion risk score which runs between 0 (good) and 10 (very poor). These scores are then categorised into five colour-coded levels, from ‘good adhesion’ (green) progressing through ‘wet railhead’ (light green), ‘moderate adhesion’ (yellow), ‘poor adhesion’ (red) to ‘very poor adhesion’ (black).

[7] For the purposes of managing wheel/rail adhesion, Network Rail considers the autumn leaf fall season to run from 1 October to 13 December each year. While the rate of leaf fall can vary depending on weather conditions throughout the year, the rate of fall normally begins to accelerate in the middle of October with the ‘peak leaf fall’ period occurring from around 22 October through to around 31 October.

104 The adhesion forecast issued at 13:31 hrs on 19 October predicted a moderate average adhesion risk score of 4 (yellow) for the Cumbria area, which includes the Settle to Carlisle line. This did not highlight any expectation of abnormally low adhesions levels for the time of year and did not require any proactive action to alert drivers to such conditions. This was reflected in the absence of reporting of low adhesion conditions from drivers on the Settle to Carlisle line on that day. The driver of train 6C00 also reported after the accident that the conditions on the journey had not been abnormal for the time of year and that the train had not lost any time compared to the timetable for the journey.

105 Examination of the OTDR data from the locomotive showed that its wheels were experiencing wheel slip when traction was being applied by the driver, particularly when the locomotive was at full power on the long climb from Settle to Blea Moor, and when accelerating at Appleby and after Lazonby & Kirkoswald (figure 35). This demonstrates that adhesion levels were low at many places along the route, and the locomotive was managing this by limiting the amount of power that was being applied to the wheels and by depositing sand onto the railhead just ahead of the wheels to improve adhesion conditions.

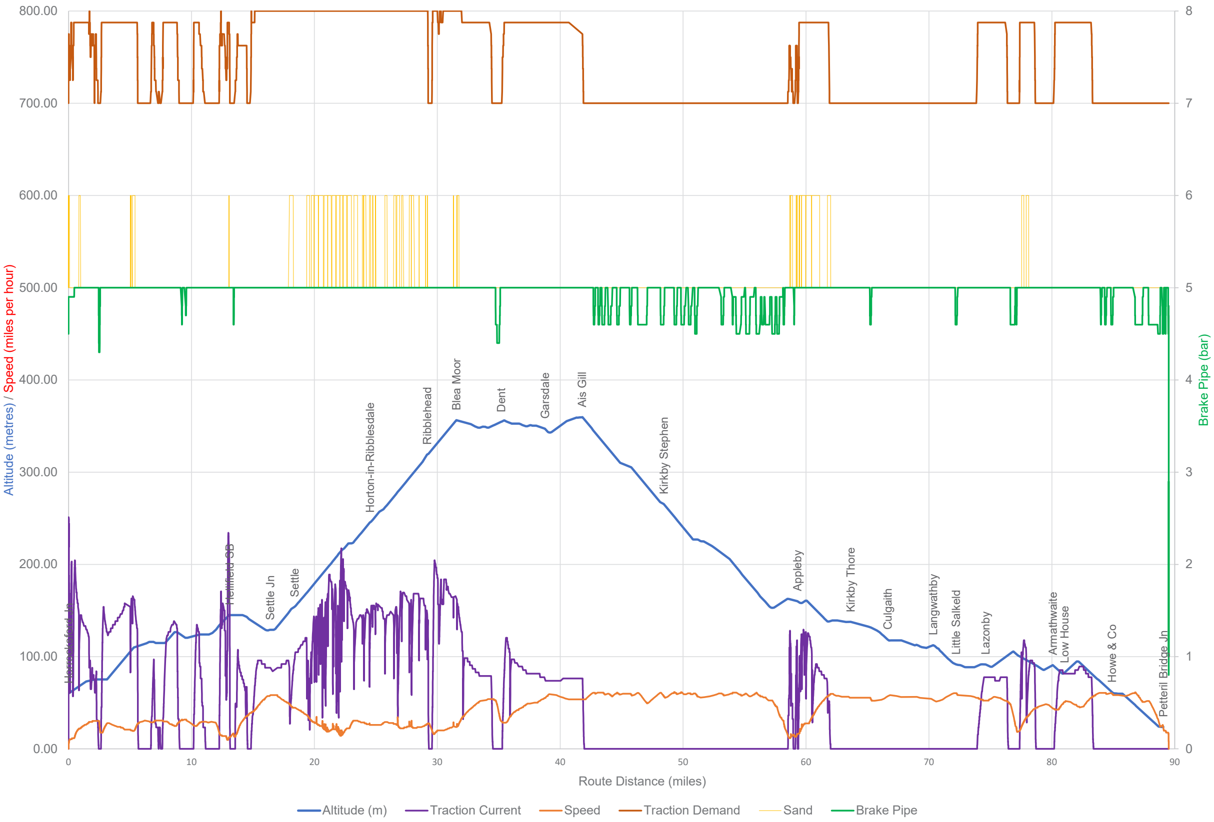

Figure 35: Locomotive data showing low adhesion under traction.

106 Because the locomotive was experiencing wheel slip under traction, it was operating at the limit of the available adhesion in some locations. This meant that it was possible for RAIB to calculate the approximate average available adhesion (coefficient of friction between wheel and rail) using the weights of the locomotive and the train, the speed profile of the train and the gradients. RAIB made this calculation for three varying length sections of the line north of Settle, during which the locomotive was at full power and managing its traction output (table 1). This analysis can only be undertaken when the locomotive is providing traction and exhibiting wheel slip, so no similar analysis was possible in the vicinity of Dent and Ais Gill when the train was braking.

Section of line	**Length (m)**	**Average gradient**	**Speed change (mph)**	**Tractive effort at rail (kN)**	**Calculated average adhesion (coefficient of friction, μ)**
Settle to Ribblehead	17354	1 in 105	-18.0	137	0.110
2.6 km north of Settle	3218	1 in 98	-12.5	128	0.103
5.5 km north of Settle	465	1 in 95	-6.6	83	0.067

Table 1: Calculated adhesion north of Settle.

107 Sand was being deposited by the locomotive, to improve friction, for much of the time in all three of the sections calculated, and for the entirety of the shortest section. Post-accident examination of the locomotive by GBRf confirmed that the sanders were in working order. In addition, there was a working traction gel applicator (TGA, see paragraph 129) near the start of the second section.

108 The calculations show that the locomotive was experiencing effective localised wheel/rail available adhesion conditions of 0.067 in at least one location. Note that this value was in the presence of sand that was being automatically deposited by the locomotive, and that the adhesion level in the absence of sand would have probably been lower still. The adhesion conditions that the wagons experienced later, when the slide initiated, would have been during braking and in the absence of sand. These values compare to a typical adhesion level on clean rail (wet or dry) of at least 0.15.

109 On the day after the derailment, several drivers of trains on the section of line south of Appleby that remained open reported low adhesion conditions at multiple locations. Although drivers were aware of the accident the previous evening, this was probably related to the fact that the rail head treatment train (RHTT) (see paragraph 127) had been unable to treat the line on 19 October due to the line closures caused by the derailment, and that seasonal low adhesion conditions had formed on the untreated sections of track over 19 and 20 October. This gives further support to the likelihood that conditions on 19 October were able to produce low wheel/rail adhesion along the length of the Settle to Carlisle line.

Level of adhesion required to initiate a slide

110 During post-accident testing of the ninth wagon (paragraph 38), the forces between the brake blocks and the wheel treads were measured for several levels of brake application. For a brake application of the magnitude recorded on the approach to Dent station, a force of 13 kN was measured. Using representative data for the friction between the brake blocks and the wheel tread, this was equivalent to a retarding force of about 3.6 kN per wheel at the railhead. For a fully laden wagon, this meant that the adhesion level (coefficient of friction between wheel and rail) would have to be at least 0.03 for the wheel not to slide under that level of braking.

111 Initiation of a wheel slide would suggest an available adhesion level of less than 0.03. This was less than the worst case of 0.067 calculated for the short section north of Settle, although this value was in the presence of sanding and so was likely to have been significantly higher than that available without sanding (paragraph 108).

112 RSSB[8] research project T1107 (Trial of sander configurations and sand laying rate) states that '*the coefficient of adhesion between wheel and rail can be as low as 0.01*' in the presence of leaf contamination and moisture. The railway industry's Adhesion Working Group manual (Managing low adhesion) also states that adhesion on damp leaf '*can be as low as 0.01*'. Data reported in the RAIB investigation into the buffer stop collision at Chester station (RAIB report 26/2014) also identifies multiple instances of adhesion values as low as 0.01. All of those references show that adhesion values of less than 0.03 are credible in the conditions of leaf contamination and moisture which may have been present at Ais Gill and Dent.

Level of adhesion required to maintain a slide

113 The RAIB investigation into track damage between Pencoed and Llanharan (RAIB report 03/2023) referenced an external study that used experimental data to conclude that a wheelset on a 76 tonne wagon, with 19 tonnes axle load, sliding for 20 seconds generates a wheel flat of approximately 60 mm in length, and about 1 mm deep. If the wheel slide was generated at Dent, considered by RAIB to be the most likely location, the brake application was about 30 seconds and the wagon weight was 102 tonnes (25.5 tonnes axle load). It is therefore credible that a wheel flat of up to 70 mm could be generated during such a brake application.

114 Once a wheel flat has been generated, the centre of gravity of the wagon at that point will have lowered. In order for the sliding wheelset to start rotating again, there needs to be sufficient friction between the wheel and the rail to generate enough force to lift the wagon back to its normal position. The same study geometrically calculated the critical adhesion required between the wheel and the rail to allow the wheelset to restart rotating for different lengths of wheel flat (figure 36). For a 70 mm wheel flat, this shows that an adhesion level of above 0.082 would be required. This is considerably higher than the 0.03 required to initiate a wheel slide under the braking experienced at Dent (paragraph 110).

[8] A not-for-profit body whose members are the companies making up the railway industry. The company is registered as Rail Safety and Standards Board Ltd, but trades as RSSB.

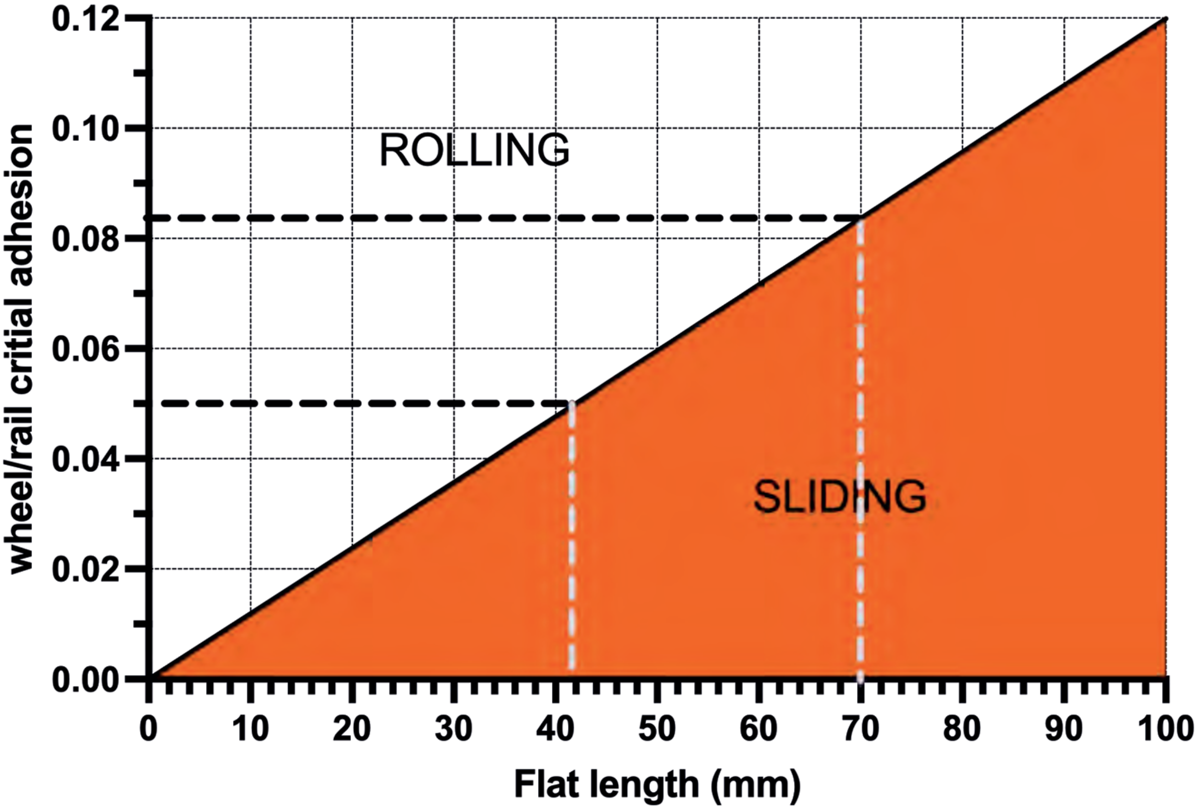

Figure 36: Plot showing the relation between wheel/rail critical adhesion and the flat length.

115 As the slide is maintained, the wheel flat will get larger, and the friction required for the wheel to be able to start rotating again also becomes larger. By the time the flat gets to 100 mm, the adhesion level then required needs to exceed 0.12, which is higher than the average seen (even with sand present) on the climb from Settle to Ribblehead.

116 Caution has to be taken with the predicted and calculated levels of rail adhesion, as these are generally relevant for a rolling wheel on the head of the rail. Once the slide has been initiated, the temperature at the interface rapidly rises, and the surface of the wheel can even start to melt. RAIB has not undertaken any work to understand the effect of such temperatures on the available adhesion between sliding wheels and the rail.

117 Although it is believed that the wheelset did not start rotating again after the slide had been initiated, RAIB observed that there were marks from a false flange on the rail that suggest that it had possibly rotated in the last 20 metres before the derailment. One possible explanation for this is that the train had slowed to less than 20 mph (32 km/h) for the approach to Petteril Bridge Junction, thus allowing the wheel slide surface to start to cool down a little, potentially affecting the coefficient of friction. In addition, the track curvature at that location was tighter than anywhere earlier during the slide, possibly allowing the wheelset flanges to contact the rail during curving and providing more friction to restart rotation. An alternative possible explanation is that another vehicle with an undetected large false flange has passed through Petteril Bridge Junction on some unknown previous occasion. However, the wheelset on the ninth wagon of train 6C00 was sliding before it reached the point of derailment (paragraph 69).

Reason for only one wheelset being affected

118 RAIB has not been able to find any definitive evidence to explain why only the leading wheelset on the ninth wagon stopped rotating, and why only one wagon experienced a significant wheelslide in the adhesion conditions present. However, it has identified a possible reason why this was the case.

119 The adhesion (friction) and braking conditions at each wheel during the brake application will not have been identical, or even constant, for a number of reasons:

- Before the train's arrival the adhesion conditions through the site of wheel slide initiation would not have been constant.
- As the train's wheels ran over the site, the adhesion conditions would have been changing as a result of the contamination being disturbed or compressed by the wheels.
- The brake force along the train would have been increasing as the brake application was increased, with that increase being delayed at each wagon as the changing brake pipe pressure propagated along the train's brake pipe.
- The train was moving as all of this was happening.

120 If at any point in the train's passage the brake force applied by the brakes on the wheels is greater than the available adhesion at rail level, then one of the wheelsets will experience that first and that wheelset will enter a slide. The act of that wheelset sliding along the railhead will alter the coefficient of friction experienced by subsequent wheelsets, and probably increasing the available adhesion, meaning that they would be less vulnerable to entering a slide.

121 RAIB considers it credible that the leading wheelset of the ninth wagon was the first to experience a level of adhesion at the railhead that was insufficient to sustain the brake retardation force being applied at that moment, resulting in the slide. Subsequent wheelsets are very likely to have seen greater adhesion levels, and so did not slide.

Evidence of wheel slide damage on different JPA wagon fleets

122 The JPA cement tank wagons owned by VTG are operationally split into a number of sub-fleets, although all use the same type of bogies with the same braking system. Two of the sub-fleets operate from Clitheroe cement terminal. When loaded, one of these operates to Glasgow, over the steeply graded route via the Settle to Carlisle line and Beattock summit.[9] The second takes loaded wagons to Avonmouth, on the Bristol Channel, in the downhill direction on the steeply graded Lickey incline[10] and Filton to Avonmouth lines. A third sub-fleet operates from Hope cement works, in Derbyshire, to terminals in the south-east of England, such as Dagenham and Theale, over routes with less demanding gradients. A fourth sub-fleet operates over less graded routes from Dunbar cement terminal, in East Lothian, to destinations in Scotland and the north-east of England.

[9] Beattock summit is located between Carlisle and Glasgow.

[10] The Lickey incline (gradient 1 in 37) is between Birmingham and Cheltenham Spa.

123 VTG collated data from a limited sample of three wagons from each of the Clitheroe to Glasgow and the Hope sub-fleets. This data included the dates and mileages of the brake block changes over the previous three years, and the dates and mileages of the last wheelset changes.

124 The data showed that the ninth wagon was not wearing out brake blocks or wheelsets at a greater rate than the other wagons sampled in the same sub-fleet. Both the sampled sub-fleets showed very similar results for the typical mileage that wagons ran between brake block changes, despite the different gradient profiles that they ran over.

125 A noticeable difference between the sub-fleets was that the wagons operating from Hope appeared to achieve about a third more miles between wheelset changes than those operating over the Settle to Carlisle line. It also showed that the Clitheroe wagons appeared to have their wheelsets replaced individually as a result of damage to the wheel tread, which would include wheel flats and other wheel slide-induced damage. The Hope sub-fleet, in contrast, appeared to have all four wheelsets changed at the same time, suggesting that this was a result of them being changed due to them approaching wear limits rather than as a result of physical damage. This was consistent with the Hope sub-fleet achieving a significantly greater mileage from wheelsets than the Clitheroe sub-fleet.

126 RAIB acknowledges that this observation is based on a very small sample size and that maintenance practice differences between Clitheroe and Hope terminals might also influence when and why wheelsets are changed out. RAIB has not undertaken any further work to explore this possible relationship, but the available data suggests that wagons operating on steeply graded routes, which would require harder braking, appear to experience wheels sliding at a greater frequency than those operating on flatter routes. This is possibly further supported by the presence of two pre-existing flats on the eighth and eleventh wagons in train 6C00 (paragraph 31).

Management of adhesion on the Settle to Carlisle line

127 Network Rail managed low adhesion conditions on the entirety of the Settle to Carlisle line using an RHTT that jetted the surface of the rails with high pressure water (figure 37). This treatment was primarily undertaken at 60 mph (96 km/h), but defined sections of line, that required more intense treatment, were passed at speeds down to 30 mph (48 km/h).

128 The last RHTT to traverse the down line (towards Carlisle) was 22.5 hours before the passage of train 6C00. The next RHTT was due about 1.5 hours after train 6C00. Although the RHTT travelled over the line from Blackburn to Hellifield, via Horrocksford Junction, the primarily freight-only section from Horrocksford Junction to Hellifield was not treated.

129 Network Rail deploys traction gel applicators (TGA), which apply an adhesion modifying gel to the railhead, to locations in the autumn season where the risk of low adhesion is known to be particularly high. Many of these are associated with stations where there is a history of trains overrunning the platforms or slipping while starting away from them. However, some TGAs are located to assist trains with traction on steep gradients, such as on the climb north of Settle.

Figure 37: The RHTT on the Settle to Carlisle line on the day before the derailment (courtesy of Aidan Fort).

130 Network Rail deploys leaf fall teams to undertake proactive inspections of locations known to be at risk of railhead contamination in the autumn. These teams also undertake proactive or reactive cleaning of the rails at such locations. The focus of these inspections is on locations where track circuits, which detect the absence of trains, are vulnerable to contamination-related failures.

131 Every January, the seasons delivery specialist[11] for Network Rail's North West route, which includes the Settle to Carlisle line, convenes a review meeting with representatives from the seasonal delivery team, operations teams, control teams and the passenger train operating companies, although the freight operating companies are not directly represented. This meeting reviews how well the adhesion management regime had operated during the autumn season that had just ended, including the types and numbers of incidents that had occurred during the season. It also looks at how many of the planned runs of the RHTTs had operated as intended, as well as the numbers of incidents like station overruns, signals passed at danger, track circuit failures and driver reports of abnormally low adhesion. This information is then used to inform any changes that need to be made to the plans for the management of adhesion in the next autumn season, including changes to the RHTT plan and any additional proactive treatment.

[11] The seasons delivery specialist is responsible for planning, implementing and reviewing the arrangements on their route for seasonal or weather related issues.

132 Network Rail also undertakes leaf fall risk assessments at least every five years. For these, the railway is split up into sections of one eighth of a mile (approximately 200 metres), with each section being assessed separately and allocated a risk score. These scores are based on the quantity and locations of different types of trees, and the general terrain in the vicinity. If the leaf fall risk assessment score reaches 16, Network Rail then raises a work order for vegetation management to be undertaken within three years. A score of 26, or above, requires this work to be undertaken within 12 months, and the location to be flagged to the seasonal delivery specialist for consideration as a high risk site for low adhesion that might require additional mitigation to be put in place. Scores below 16 do not require any consequential work to be initiated.

133 The leaf fall risk assessments in the vicinity of Dent and Ais Gill were undertaken in August 2021 and February 2022. At the location where the wheel slide is likely to have started, near Dent (paragraph 84), the closest track sections were given scores of 3 and 5, which were well below both the action threshold of 16 and the high risk threshold of 26. In addition, neither the locations at Dent nor Ais Gill had any record of abnormal adhesion-related problems. As a result, neither location was recorded by Network Rail as being a potential location for leaf fall adhesion risk. RAIB observed that there was no definitive guidance on how the leaf fall scores were intended to be allocated, and so there was the potential for different assessors to allocate different scores.

134 RAIB has found no evidence that the likely slide initiation location at Dent was at abnormally high risk of leaf fall, nor that the trees there directly contributed to low adhesion. However, it was the leaf fall season, and conditions were commensurate with low adhesion being present, as evidenced by multiple reports from drivers on the Settle to Carlisle route on the day after the derailment in the absence of the overnight run by the RHTT.

Train 6C00 not being stopped

135 Train 6C00 was not stopped before reaching Petteril Bridge Junction, after the wheelset on the ninth wagon had stopped rotating.

136 This causal factor arose due to a combination of the following:

a. None of the signallers along the train's route were aware that one of the wheelsets on train 6C00 was not rotating, and therefore they did not arrange for the train to be stopped and examined (paragraph 137).

b. There was no engineered system in place to detect wheelsets that were not rotating and to either automatically stop the train or to alert the signallers along the route to the issue (paragraph 153).

Each of these factors is now considered in turn.

Signaller awareness

137 None of the signallers along the train's route were aware that one of the wheelsets on train 6C00 was not rotating, and therefore they did not arrange for the train to be stopped and examined.

138 Train 6C00 passed the signal boxes at Kirkby Stephen, Appleby and Kirkby Thore, and probably Garsdale too, with one wheelset on the ninth wagon sliding along the railhead, and none of those signallers observed a problem. When the train passed Culgaith signal box, the signaller did not see or hear a problem with the train as it passed.

139 Section 3.2 of Module TS3[12] of the railway Rule Book states that signallers '*must observe the train as it passes the signal box and make sure it has a tail lamp at the rear.'* In addition, section 19.2 of Module TS1[13] of the railway Rule Book states that if signallers *'become aware of anything unusual or wrong with a train … you must immediately stop the train concerned* ... [and] *arrange for the train to be examined and dealt with as necessary'*. The Rule Book does not require signallers to carry out detailed examinations of trains as they pass, but does require signallers to check that a train is complete (by observing that it has a working tail lamp) and to be alert to any obvious visual or audible signs of a problem.

140 Once the train had reached Lazonby & Kirkoswald, it had left the last of the three axle counter sections controlled by Culgaith signal box (paragraph 59). At that point, the Culgaith signaller recognised that all three sections were still indicated as occupied. The track section occupation indicators had lit one-by-one as the train progressed but the signaller did not identify that the sections were not clearing sequentially as the train progressed until the train reached Lazonby & Kirkoswald. This was because the latter two sections were much shorter than the first and they lit up with little time delay between them (figure 38).

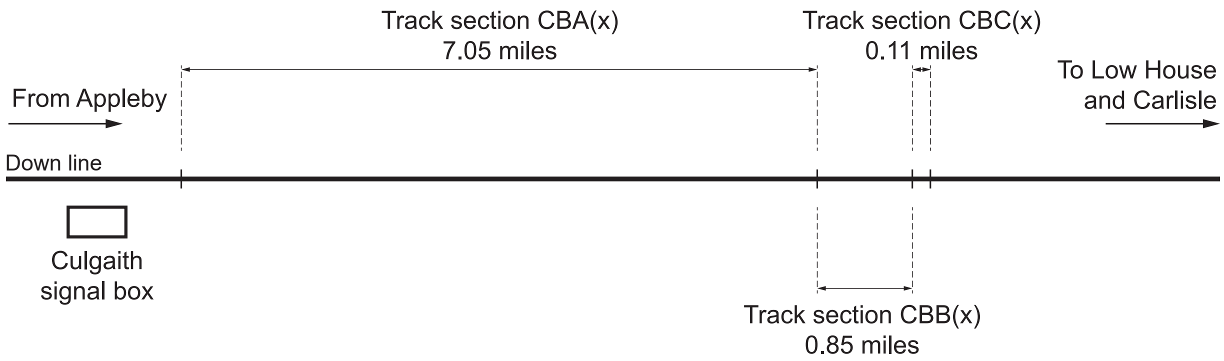

Figure 38: Configuration of the axle counters associated with Culgaith signal box.

[12] GERT8000 Railway Rule Book Module TS3, 'Absolute block regulations', issue 7, September 2021.

[13] GERT8000 Railway Rule Book Module TS1, 'General signalling regulations', issue 15, September 2021.

141 The Culgaith signaller then contacted the next signaller at Low House to check if the train had passed the last Culgaith axle counter and entered the Low House section. The Low House signaller confirmed that it had, and agreed to check that the train was complete when it reached Low House signal box. The two signallers then discussed the likelihood that the axle counters had failed and what steps they needed to take to reset them. The reset procedure required the signallers to caution the next train and arrange for the driver to examine the line, while the axle counter system was put into a reset mode.

142 When the train reached Low House, the signaller there stepped onto the signal box balcony and saw that the rear of the train had a taillight, confirming that it had not divided and left any wagons behind. The signaller did not see any sparking from the train's wheels, even though the CCTV footage at Armathwaite station showed that the leading wheelset on the ninth wagon was visibly sparking one minute earlier (paragraph 60). However, the area around the signal box at Low House is well lit by the floodlights provided for the adjacent road level crossing (figure 39). This external lighting would have made any sparking from the wheels of the passing wagon less visible to the signaller than if it had been dark.

143 After train 6C00 had passed Low House signal box, the two signallers started preparing to reset the axle counters. However, this process was not completed because train 6C00 derailed ten minutes later at Petteril Bridge Junction and the following passenger train was stopped before it reached Culgaith.

Axle counter failures

144 Axle counters use sensors mounted on the rails to detect the passage of wheels, by the distortion of a magnetic field. They are designed to detect wheels with a profile that is compliant with Railway Group Standard GMRT2466 (Railway wheelsets). This standard allows wheels to have a flange profile that is up to 6.5 mm deeper than nominal. Because of the large wheel flat, the leading wheelset on the ninth wagon had a flange profile that was about 20 mm deeper than nominal (figure 21). It is likely that the axle counters on the entry and exit to each of the three axle counter sections detected this non-compliant wheel flange and went into a fault condition. The only indication that the system gives the signaller in a fault condition is for the indicator lamps associated with each section to remain lit, showing the track section as occupied.

145 Section 19.1 of Module TS1 of the railway Rule Book requires signallers to arrange for a train to be stopped and examined if they '*become aware of anything unusual or wrong* …' and that they '*must also look for damage to the infrastructure which might have been caused by the train including multiple or sequential track circuit failures*'.

146 The term 'track circuit' is defined in a separate glossary document[14] as:

> *'A method of detecting the presence of a train or vehicle on a line. An electrical device, using the rails as an electrical circuit, detects the absence of a train or vehicle. If these rules refer to track circuits, this also includes detection by axle counters unless specially excluded.'*

[14] GERT8000-Gloss, 'Glossary of railway terminology', issue 5, September 2018.

Figure 39: Low House signal box, with floodlights circled (top image courtesy of Network Rail, bottom image courtesy of GB Railfreight).

147 While ‘track circuits’ and ‘axle counter sections’ are two distinct and different forms of technology, this definition makes it clear that the term ‘track circuits’ is used in the Rule Book to mean both systems for detecting the absence of trains. However, the definition was in the separate glossary to the Rule Book and is not made explicit in the ‘stop and examine’ rule itself.

148 Both the Culgaith and the Low House signallers recognised that the Rule Book required them to stop and examine a train in the event of multiple or sequential track circuit failures. However, neither recognised that this rule also applied in the case of multiple or sequential axle counter failures.

149 Both signallers had been trained in the early 2000s, before the axle counter equipment was fitted, and the associated indications provided in the signal boxes, in about 2008. As a result, their initial training did not explicitly cover axle counters. Subsequent refresher training also did not explicitly link axle counter sections to the 'stop and examine' rule.

150 When the axle counters were installed, Network Rail undertook briefings of the signallers, explaining what the system did, how to operate it and what actions needed to be carried out in the event of failures. A specific set of instructions for the axle counters on the Settle to Carlisle line was issued to the signallers, and these were being used by the signaller at Culgaith.

151 These instructions stated '*if a section shows occupied during normal operation, you must make sure no trains or vehicles have been left in section. You can then go into failed mode*'. The signaller at Culgaith followed these instructions by asking the Low House signaller to confirm that the train was complete and then starting the process to reset the axle counters. However, the Culgaith signaller did not recognise that the stop and examine rule (paragraph 145) should also have been initiated, and the Settle and Carlisle line axle counter instructions did not make this clear.

152 The signallers reported that spontaneous axle counter section failures were not uncommon, and often all the sections would fail to clear and indicate occupied because of equipment faults. Network Rail provided data to show that 30 axle counter section failures had been recorded at Culgaith over an 11-year period, with 20 of those being multiple axle counter section failures. The result of this history was that the signallers at Culgaith were used to axle counter sections failing, and to following the associated instructions to reset them. None of the data for the recorded multiple failures suggested that a stop and examine had been initiated for a train, although the data was not always clear on the cause and the actions taken.

Engineered systems

153 There was no engineered system in place to detect wheelsets that were not rotating and to either automatically stop the train or to alert the signallers along the train's route to the issue.

154 Network Rail has several systems for monitoring the condition of trains as they traverse its infrastructure. These are located at discrete locations, and their siting is largely determined by the numbers and types of trains at that location, and consideration of any dangerous goods cargo that might be carried on those trains.

155 One such system is a wheel impact load detector (WILD) site. The current system is called ‘Gotcha’, which replaced an earlier system known as ‘Wheelchex’. A Gotcha site has both rails on a section of straight and level track fitted with force sensors to measure the loads imparted by moving wheels. The primary function of a Gotcha site is to identify vehicles that are generating excessive dynamic loads on the railhead, such as rotating wheels that have flat spots or are otherwise out-of-round, so that these vehicles can be stopped before they damage the track. Gotcha sites can also provide data that indicates the weights of individual wheels on passing trains.

156 There were no Gotcha sites on the route of train 6C00 from Clitheroe to Carlisle, although it was the Gotcha site at Braidwood, south-east of Glasgow, that identified the pre-existing flats on wagons 8 and 11 (paragraph 31). However, because Gotcha is configured to measure vertical impact and load forces on the rail, it is unable to detect a sliding wheelset, as was the case here.

157 Another condition monitoring system is a hot axlebox detector (HABD). These are intended to detect failing axle bearings. Sensors are mounted on the outside of the rails to detect the increased radiated heat emitted by a defective axle bearing. If a temperature above a defined value is detected as a train passes, the HABD will alert the signaller to identify the train concerned and arrange to stop it in a convenient and safe place for examination. Some HABDs also have a sensor mounted between the running rails to detect the temperature of wheels, although this is generally not configured to trigger alarms due to the historic difficulty in filtering out spurious false alarms. The RAIB investigation into the derailment at Llangennech (RAIB report 01/2022) provides detailed information on the operation and configuration of HABD systems. However, there were no HABD sites on the route of train 6C00, and no evidence was found that the ninth wagon had a failing axle bearing (paragraph 96).

158 As described in paragraph 144, axle counters have the potential to alert a signaller when a sliding wheelset passes. However, this is not the design intent. The sliding wheelset would need to have worn significantly large wheel flats before the flange would be detected as abnormal, and so the wagon would already be significantly at risk of derailment before it was detected.

159 Although it is technically possible to fit freight wagons with systems to detect non-rotating wheelsets, this is not routinely done due to the additional cost and potential complexity of such equipment. However, such systems are currently being trialled on different wagon types (see paragraph 188). None of the wagons in train 6C00 were fitted with such equipment at the time of the accident.

Identification of underlying factors

160 The seasonal risk management regime might not fully recognise the risks faced by freight trains during low adhesion conditions, which can be different to those faced by passenger trains. This is a possible underlying factor.

161 Much of Network Rail's autumn season adhesion management regime is driven by the issues faced by passenger trains and is thus tailored to address these. As a result, the routes that are treated by the RHTT are focused on those over which passenger trains operate. This is illustrated by the fact that the freight only section from Horrocksford Junction to Hellifield was the only section of train 6C00's route not to be treated. This is despite that section seeing very few trains per week, and thus being subject to the possibility of the additional adhesion issues associated with rusty rails.

162 Similarly, the locations where more intense treatment is delivered are again focused on passenger train related issues. The more intense water jetting (paragraph 127) and proactive attention by leaf fall teams (paragraph 130) are targeted to locations with a history of track circuit failures, which are more likely to affect shorter, lighter passenger trains than longer, heavier freight trains. However, the seasonal adhesion management regime does take account of specific freight risks where these have been identified. An example of this is between Blackburn and Clitheroe, where more intense proactive mitigations have been implemented due to freight trains struggling under traction on the rising gradients in this area.

163 The provision of TGAs (paragraph 129) is primarily driven by locations where passenger trains have demonstrated difficulty in stopping at, and starting away from, station platforms. However, the provision of TGAs on the steep climb north of Settle provides a benefit to freight trains as well as to passenger trains.

164 The above suggests that the outputs from the assessment of adhesion risk appear to deliver mitigations primarily for passenger trains, with a focus on trains being able to stop at stations and at signals. The wheel slide in this accident was not associated with stopping at a station or a signal but has probably occurred at a location where the train was braking. No specific assessment of adhesion risk appears to have been made for other locations where it is known that all trains will be braking, such as the approach to the permanent speed restriction for Dent station.

165 In the event that a brake application force exceeds the available adhesion, as probably occurred with train 6C00, a passenger train would almost certainly not have experienced the same consequences in terms of wheel flat development. This is because most passenger trains are fitted with some form of wheel slide protection (WSP) system, which detects when a wheel starts to slide under braking and then releases and reapplies the brakes on that wheel to allow the wheel to start rotating again.

166 The creation of wheel flats on freight wagons appears to be more common than on passenger trains because wagons are not fitted with WSP systems. This was illustrated by the presence of the pre-existing wheel flats on two wagons in train 6C00. The maintenance data provided by VTG (paragraph 123) also shows that the creation of wheel flats appears to be more prevalent on loaded freight trains that operate over steeply graded routes.

Observation

167 The Rule Book requirement for the driver to look back along the train when it is safe and possible to do so was not effective in identifying that one of the wheelsets on train 6C00 was not rotating.

168 Section 18 of Module TW1 of the railway Rule Book[15] covers the requirement for drivers to look back along their train. It states that '*when working a freight train, if it is safe and possible to do so, you must look out from time to time to make sure the train is following in a safe and correct way*'. Module B3 of the GBRf General Operating Appendix ('Professional driving skills') also states that '*you must look back down your train at the first opportunity and regularly throughout the journey*'.

169 The driver of train 6C00 considered that it was not safe to lean out of the cab window while the train was travelling at up to 60 mph (96 km/h) in the cold windy conditions on that evening. In addition, the driver did not perceive there to be any problem with the running of the train, as it was able to keep to the scheduled timetable. As a result, after looking back along the train when departing from Clitheroe, the driver did not look back along the train during the rest of the journey.

170 It is possible that if the driver had looked back along the train in the latter part of the journey, when the sliding wheelset was sparking, and when it was dark, the driver might have noticed a problem. However, the sliding wheelset was about 150 metres back along the train from the driver's position, and the sparking was not significant for most of the journey, evidenced by none of the signallers on the route seeing it. This would have limited the driver's opportunity to recognise the problem, even if they had looked back along the train.

171 The safety authority for the mainline railway in Great Britain, the Office of Rail and Road (ORR), has encouraged passenger train operators to make safety improvements that prevent passengers from being able to lean out of train windows while they are moving. Passengers have been injured or killed as a result of such accidents, such as at Balham (RAIB report 09/2017) and Twerton (RAIB report 14/2019). RAIB observes that the Rule Book requirement for freight train drivers to lean out of their window to look back along their train while it is moving is potentially inconsistent with the requirements targeted at preventing passengers from doing so, especially when it is dark and they are unable to see whether it is safe to do so.

Previous occurrences of a similar character

172 RAIB is aware of several accidents where trains have developed very large wheel flats, with some resulting in derailments. Some of these were caused by brake defects, or by handbrakes being left on, and so are not directly relevant to this investigation. However, some might also have involved low adhesion conditions and might have involved a similar mechanism for generating wheel flats to this accident.

[15] GERT8000 Railway Rule Book Module TW1, 'Preparation and movement of trains', issue 17, September 2021

173 On the night of 5 to 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 RAIB investigation (RAIB report 03/2023) 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.

174 On 26 August 2020, an oil tanker train derailed near to Llangennech, in Carmarthenshire. The derailment and the consequent damage to the wagons resulted in a significant spillage of fuel and a major fire. The RAIB investigation (RAIB report 01/2022) identified that one set of wheels on a wagon within the train stopped rotating during the journey, resulting in a large false flange, probably due to a defect in the braking system on that wagon.

175 On the evening of 29 October 2018, an RHTT derailed at a set of trailing points at Dunkeld and Birnam station because of large wheel flats on one wheelset of one wagon. RAIB published a safety digest describing the circumstances of the derailment (RAIB safety digest 01/2019). Although the digest stated that it was possible that a handbrake could have been partially applied, it did observe that the adhesion conditions routinely experienced by the vehicles which form the RHTT were abnormally poor, and that the train was very prone to wheel flat related damage.

176 On 30 October 2017, an oil tanker train caused extensive damage to the railway infrastructure over approximately 25 miles (40 km) of the line to the east of Carmarthen, in South Wales. This was because of severe wheel flats caused by one of the wheelsets on a wagon locking up and sliding before starting to rotate again. The RAIB investigation (RAIB report 17/2018) 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. But the investigation also identified a brake application in low adhesion conditions as a possible cause of the wheel slide. It also identified that loaded oil trains were regularly experiencing low adhesion conditions in the leaf fall season and the wagons that formed these trains were also regularly developing wheel flats during the same period.

Summary of conclusions

Immediate cause

177 Train 6C00 derailed, while travelling through 679A points in the trailing direction, due to a large false flange that had developed on the leading wheelset of the ninth wagon (paragraph 67).

Causal factors

178 The causal factors were:

a. The ninth wagon developed very large wheel flats, and consequent false flanges, on its leading wheelset as a result of that wheelset sliding along the railhead for between 48 and 55 miles (paragraph 73). This causal factor arose due to the following:

   i. The wheelset stopped rotating, and continued to slide, probably as a result of a normal brake application on a section of track with low wheel/rail adhesion (paragraph 88, **Recommendation 1**).

b. Train 6C00 was not stopped before reaching Petteril Bridge Junction, after the wheelset on the ninth wagon had stopped rotating (paragraph 135). This causal factor arose due to a combination of the following:

   i. None of the signallers along the train's route were aware that one of the wheelsets on train 6C00 was not rotating, and therefore they did not arrange for the train to be stopped and examined (paragraph 137, **Recommendation 2 and Learning point 1**).

   ii. There was no engineered system in place to detect wheelsets that were not rotating and to either automatically stop the train or to alert the signallers along the route to the issue (paragraph 153, no new recommendation).

Underlying factor

179 A possible underlying factor was that:

a. The seasonal risk management regime might not fully recognise the risks faced by freight trains during low adhesion conditions, which can be different to those faced by passenger trains (paragraph 160, **Recommendation 1**).

Observation

180 RAIB has observed that:

a. The Rule Book requirement for the driver to look back along the train when it is safe and possible to do so was not effective in identifying that one of the wheelsets on train 6C00 was not rotating (paragraph 167, **Recommendation 3**).

Previous RAIB recommendations relevant to this investigation

181 The following recommendations, which were made by RAIB as a result of its previous investigations, have relevance to this investigation.

Recommendations that are currently being implemented

Accident at Llangennech, Carmarthenshire, 26 August 2020, RAIB report 01/2022, Recommendation 7

182 The above recommendation addressed one of the factors identified in this investigation relating to the availability of engineered systems to detect non-rotating wheelsets (paragraph 153). To avoid duplication, it is not remade in this report. However, shown below is a recap of its wording and an account of its current status.

Recommendation 7

The intent of this recommendation is to reduce the risk that wagons will continue to run with undetected dragging brakes or locked wheelsets.

Network Rail in conjunction with RSSB and the National Freight Safety Group should review the technology and systems currently being used in the UK and other European countries to identify how improvements can be made to the railway's ability to alert a train driver, signaller or control room to a wagon defect that may lead to a derailment, such as dragging brakes or an axle bearing failure. This review should include consideration of:

- *the use of existing or new trackside equipment that is designed to detect overheated wheels and transmit an alarm; and*
- *equipment installed on wagons that is capable of detecting a safety critical fault and transmitting an alarm.*

A risk-based plan should be formulated for the introduction of such improved systems, that accounts for the likelihood and consequences of a dangerous goods train derailment.

183 Implementation of this recommendation was still in progress at the time of writing this report. ORR has reported that RSSB has a proposed action plan and timescale for delivery to be taken in response to the recommendation. Since this recommendation addresses the same issue that was subsequently identified at Carlisle, RAIB has decided not to make a further recommendation.

Track damage between Pencoed and Llanharan, South Wales, 6 March 2021, RAIB report 03/2023, Recommendation 1

184 The above recommendation addressed one of the factors identified in this investigation relating to the management of railhead adhesion (paragraph 88). To avoid duplication, it is not remade in this report. However, shown below is a recap of its wording and an account of its current status.

Recommendation 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.

185 Implementation of this recommendation was still in progress and ORR had not reported what progress had been made at the time of writing. Since this addresses issues relating to adhesion management that overlap with issues subsequently identified at Carlisle, RAIB has decided not to make a further recommendation.

Actions reported as already taken or in progress relevant to this report

186 Network Rail has briefed its signallers nationally about the relevance of multiple or sequential axle counter section failures to the Rule Book requirement to stop and examine trains. It has also updated Unit 39 (Axle counters) of its National Operating Instructions (NR/OPS/NOI issue 10) to include a clause explicitly relating sequential failures to the Rule Book requirement to stop and examine trains. NR/OPS/NOI is intended to provide Network Rail staff with additional instruction and guidance relating to the requirements of the Rule Book.

187 VTG is undertaking work to better understand any correlation between incidences of wheel flat related damage on wagons identified during maintenance, and the operational characteristics of the routes over which those wagons operate. This work has identified some routes where wagons experience higher than average rates of wheel flat damage, and this is being fed into the wider industry ‘Locked wheelset working group’. VTG is also engaging with train operators and Network Rail to review railhead treatment on the affected routes.

188 VTG is trialling several novel systems capable of monitoring wheel rotation and implementing wheel slide protection on a number of its wagons in fleets that are known to be affected by wheel flat damage. The intention of these trials is to understand the benefits and practicability of such technology. The data collected will be used to further inform the industry of locations and conditions in which wheel slides are occurring. These trials were initiated before this accident but have relevance to its causes.

Recommendations and learning point

Recommendations

189 The following recommendations are made:[16]

1 *The intent of this recommendation is to understand and manage the risks associated with the operation of freight trains in low adhesion conditions.*

Network Rail and the freight operating companies should work in collaboration with RSSB to review the risks faced by freight wagons during normal brake applications in foreseeably low adhesion conditions. This work should include a detailed assessment of the risk of individual wheelsets sliding sufficiently so that they generate self-sustaining wheel flats that can ultimately lead to derailment. It should also identify what mitigations may be necessary to ensure that these risks are adequately controlled.

Network Rail, the freight operating companies and RSSB should use the findings from this review to evaluate the processes, standards and guidance documents relating to the management of rail adhesion and the operation of freight trains in low adhesion conditions. Network Rail, the freight operating companies and RSSB should produce a time-bound plan to implement any changes found to be necessary from this process (paragraphs 178a.i and 179a).

2 *The intent of this recommendation is to ensure that the rules relating to sequential axle counter failures are clear.*

RSSB, working in consultation with Network Rail, should review the sections of GERT8000 (the Rule Book) relevant to sequential axle counter failures. This review should consider the type of operating incidents that such failures may indicate and identify what mitigations may be necessary to ensure that these risks are adequately controlled. RSSB should update the Rule Book as required following this review. Network Rail should ensure that relevant staff working for them are appropriately briefed and trained on any new or amended rules which result from this update (paragraph 178b.i).

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[16] Those identified in the recommendations have a general and ongoing obligation to comply with health and safety legislation and need to take these recommendations 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, these recommendations are 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.

3 *The intent of this recommendation is to understand and review the effectiveness and safety of the Rule Book requirement for freight train drivers to regularly look back along their train.*

Freight operating companies, represented through the Rail Freight Operations Group, working in conjunction with RSSB, should work to understand the purpose and effectiveness of the Rule Book and other operating requirements for drivers to look back along a freight train while it is moving. This work should consider the risks that looking back is seeking to mitigate, the effectiveness of this measure as a mitigation, and the additional risks that are introduced as a result of the activity. It should also consider what alternative mitigations could be used to appropriately address these risks, and implement any changes to standards, processes and rules identified as necessary (paragraph 180a).

Learning point

190 RAIB has identified the following learning point:[17]

1 The importance of signallers being aware that the current Rule Book requirement to stop and examine trains applies equally to multiple or sequential failures of axle counter sections as well as to such failures of track circuits (paragraph 178b.i).

[17] ‘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
GBRf	GB Railfreight
HABD	Hot axlebox detector
ORR	Office of Rail and Road
OTDR	On-train data recorder
PPM	Planned preventative maintenance
RHTT	Rail head treatment train
TGA	Traction gel applicator
VIBT	Vehicle inspection and brake test
WSP	Wheel slide protection

Appendix B - Investigation details

RAIB used the following sources of evidence in this investigation:

- information provided by witnesses
- information taken from the OTDR of train 6C00 and other services
- CCTV recordings taken from on-train, station and staff cameras
- CCTV recordings from public webcams (operated by Railcam UK in conjunction with the Friends of the Settle to Carlisle Line)
- site photographs and measurements
- inspection and testing of the wagons
- external, expert metallurgical examination of the failed spring from the brake cylinder
- maintenance and design documentation for the JPA wagons
- a review of operational standards, procedures and guidance relating to the operation and maintenance of the train and the railway infrastructure
- a review of previous RAIB investigations that had relevance to this accident.

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